SHORT WAVES

Printed and bound in the U. S. A.

PREFACE

It is believed that this is the first book devoted exclusively to high frequency currents as related to radio communication and associated fields. The authors have been interested in short-wave developments for many years. Recently it was decided to make a survey covering the latest short-wave achievements throughout the world. Inquiries were directed to over 150 leading radio engineers. It was indeed surprising that many of these engineers while intensely interested in short-wave research, had not conducted any original investigations. In other words the present developments attained, have been the result of work by a relatively small number of organizations and individuals.

Another interesting angle, is the fact that the practical progress made to date, has been in advance of the theoretical explanations. The advantages of short waves for radio communication were quickly realized and systems put into actual operation which have many superiorities over the low frequency equipment. During this rapid progress, the desire to obtain practical results was the first consideration and the technical explanations are following. Naturally under these circumstances the theories will be subjected to decided revisions from time to time.

No doubt, in due course, short wave communication will be a means to bring a much closer international relationship with the various foreign countries of the world. The near future need of an international language is instantly apparent. There are many thrills left for the broadcast listener, instead of trying for Los Angeles from the eastern United States, they are now trying for Sydney, Bombay, Paris, Berlin, etc. It does not take much imagination to picture the future, after broadcasting has developed in the foreign countries, equal to the present systems in the United States. Important events in the United States are broadcast world wide and of great interest to our foreign friends. This will be followed by foreign broadcasts of the similar important events of the leading cities of the world, which will be available for reception in the United States. For example instead of watching the well known newsreels, in a theater, we will eventually have the entire audible description available in our homes and later with the visual accompaniment, and practically the same instant it occurs.

The most interesting details of present short-wave developments have been gathered together and compiled in this text and special acknowledgment is due Dr. Charles Grimminger, for his efforts in translating contributions received in various foreign languages.

C. R. L. R. B. G.

New York Control Position.
Bell Radiophone System from North America to South America and Europe.

See Chapter III.

SHORT WAVES

BY

CHARLES R. LEUTZ

FELLOW, THE ROYAL SOCIETY; MEMBER, INSTITUTE OF RADIO ENGINEERS; ASSOC. MEMBER, SOCIETY OF AUTOMOTIVE ENGINEERS; FORMERLY PRESIDENT, EXPERIMENTERS INFORMATION SERVICE; E-I-S INC.; GOLDEN-LEUTZ INC.; PRESIDENT C. R. LEUTZ INC.; AUTHOR, "SUPER-HETERODYNE RECEIVERS", "MODERN RADIO RECEPTION", ETC.

AND

ROBERT B. GABLE

MEMBER, INSTITUTE OF RADIO ENGINEERS; OWNER, BROADCAST STATION WFBG; PRESIDENT, THE WM. F. GABLE CO.; VICE PRESIDENT AND DIRECTOR, C. R. LEUTZ INC.; MEMBER, AAA CONTEST BOARD; DIRECTOR, SYNDICATE TRADING CO.; DIRECTOR, POMEROY'S INC., READING; DIRECTOR, FIRST NATIONAL BANK ALTOONA, ETC.

PUBLISHED BY

C. R. LEUTZ, Inc.

ALTOONA, PA., U. S. A.

"Just as every medieval cathedral had a soul—a part of the soul of its designer and of the souls of the pious men who built it—so every modern machine has a soul; it is a part of the soul of its inventor and of the patient souls of the men who developed it."

PROF. MICHAEL I. PUPIN.

CONTENTS

ACKNOWLEDGMENTS

The authors are indebted to many individuals and radio firms for their kind assistance and close cooperation in preparing this new text. In some cases their contributions have been reproduced verbatim, appreciating their accurate discussions. Appreciation is extended to:

Commander C. P. Edwards, Dept. Marines & Fisheries, Ottawa
C. L. Farrand, formerly President, Farrand Manufacturing Co.
John V. L. Hogan, Consulting Engineer
Paul F. Godley, formerly Receiver Designer, Marconi Wireless Tel. Co. of Am.
H. B. Richmond and Melville Eastman, General Radio Co.
F. W. Dunmore and the Bureau of Standards
N. V. Philips Radio, Eindhoven
Radio Frequency Laboratories Inc.
Western Electric Co.
Deutche Betriebsgesellschaft fur Drahtlose Telegrafie m.b.H.
Transradio A. G. Fur Drahtlosen ubersee-verkehr.
G. H. Nash, Executive Vice-President, Int. Tel. & Tel. Lab. Inc.
C. H. Gray, Engineering Dept., Int. Tel. & Tel. Corp.
N. K. Fairbanks, Engineering Dept., Int. Tel. & Tel. Corp.
E. M. Deloraine, Int. Tel. & Tel. Lab. Inc.
C. E. Strong, Int. Tel. & Tel. Lab. Inc.
E. H. Ullrich, Int. Tel. & Tel. Lab. Inc.
R. E. Gray, Int. Tel. & Tel. Lab. Inc.
H. H. Buttner, Asst. Vice-President, Int. Tel. & Tel. Corp.
Marconi Wireless Telegraph Co. Ltd. London
"Electrical Communication"
"Bell System Technical Journal"
"Radio Craft"
"Short Wave Craft"
Lt. Wm. H. Wenstrom
K. Kruger & H. Plendl, German Exp. Inst. for Aeronautics
General Electric Co.
Westinghouse Electric & Mfg. Co.
O. B. Hanson, Eng.-in-Charge, Plants & Engineering, Nat. Broadcasting Co.
A. A. Oswald, A. T. & T. Co.
W. J. Brown, Uxbridge, England
"Electronics"
"Radio News"
"Q—S—T"
"Telefunken Co., Berlin
"World Almanac"
Jenkins Television Co.
"Citizens Radio Call Book"
Institute of Radio Engineers
C. Lorenz Aktiengesellschaft
Abraham Esau
Walter M. Hahnemann
William Wilson
Lloyd Espenschied
A. G. Lee, Engineering Dept., General Post Office, London

SHORT WAVES

CHAPTER I

Historical Review

The records of civilized history describe many remarkable pasts. From the old manuscripts we read about the early discoveries relating to necessities, art, astronomy, mathematics which even at that time had reached very high standards. Some of the early discoveries have not yet been duplicated in these modern times and others only comparatively recently.

These historical records also describe the centuries of ruthless passions, continued wars, oppressed peoples, during which time the progress of science was naturally retarded and the principal scientific work confined to a few individuals and within some monasteries. It is agreed that the invention of the art of printing was the start of the new scientific age. The "steam age" terminated in the last century and we are now in the "electrical age", the richest period in the entire history of the world. One outstanding discovery is now being presented after another and in rapid succession. A decided achievement is the ability of radio communication engineers to electrically bridge all distances. The day is gradually approaching when telephone subscribers in most any part of the world will be able to communicate with telephone subscribers in any other part of the world. The study of short waves in radio transmission is responsible for this decided advance in international communication and this text describes the present achievements and also the results obtained in allied fields of research.

In 1865 James C. Maxwell, an expert in mathematical physics, believed and stated that visible light consisted of waves in the ether and that electromagnetic waves of other frequencies not visible as light also existed. Heinrich Hertz in 1887 gave an actual demonstration proving that these latter waves existed. Guglielmo Marconi in 1894 started experiments with a coherer, a device which would respond to these waves, the coherer being invented by Branley. Marconi improved upon Hertz's method by connecting one side of the spark gap to ground and the other to an elevated conductor, the first antenna. By 1898 Marconi had been successful in transmitting telegraphic radio messages 14½ miles and in 1901 covered 200 miles, Cornwall to the Isle of Wright. The same year he was successful in transmitting signals across the Atlantic and in 1903 a complete message was received over this same distance.

Sir Oliver Lodge invented inductive coupling, still extensively used today. Pickard and Dunwoody introduced the crystal detector in 1906.

Poulsen, by using an electric arc in a hydrogen gas chamber and in a strong magnetic field, was able to produce electromagnetic waves of a continuous amplitude instead of damped as obtained from spark transmitters. The frequencies obtained from the arc at that time were approximately 20,000 to 30,000 cycles corresponding to relatively long waves. Fessenden, Alexanderson and Goldschmidt developed high frequency alternators, in reality an alternating current generator of high frequency current. Due to the mechanical and electrical limitations, they were only suitable for long waves.

Probably the most outstanding development in the history of the radio art is the vacuum tube. In common form, the construction consists of a glass tube having an internal filament, a plate electrode spaced some distance from the filament and a grid electrode placed between the filament and the plate. The glass tube is pumped out to leave the internal elements in a vacuum.

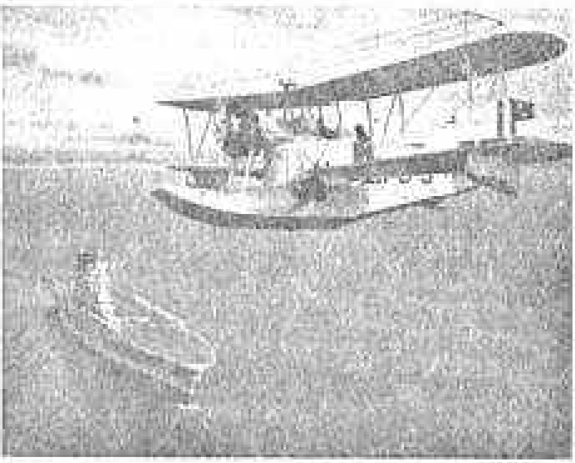


Fig. 1

Short-Wave Radiophone Communication Flying Boat to Aircraft Carrier.

The filament when heated, gives off electrons which are attracted to the plate and passing through the grid. Even extremely small values of electrical energy applied to the grid have a marked effect on the current flowing from the plate to filament and the tube has a decided amplifying effect. Fleming invented the first vacuum tube having only the filament and plate, used principally as a rectifier or detector. DeForest is credited with introducing the grid or third element in 1906. At that time the tubes were subject to irregular operation in actual practice, due to lack of methods to secure a high vacuum in the tubes. Without high vacuum, a small amount of residual gas remained and effected the tubes characteristics. In 1912 the General Electric Co. and Bell Telephone System started their research departments on the development of vacuum tubes. In addition to the radio applications, simultaneous progress was made with tubes for X-Ray work and current rectification, due to the improvements in obtaining very high vacuums. A new tube was developed suitable for telephone repeating stations on long distance lines and led to the development of larger tubes for radio telephony.

In 1915 the largest tube available for radio work was rated at 25 watts. That same year a bank of these tubes were used to successfully span the Atlantic Ocean with radio telephony in an experimental manner. Incidentally, the same vacuum tubes were used as modulators for these experiments, modifying the radio frequency currents so that they embodied the characteristic of speech. This was a great improvement over placing a bank of microphones directly in the antenna circuit of a transmitter. In recent years, water cooled tubes were developed and are now standard equipment in ratings as high as 10 and 20 kilowatts. Experimental tubes of much higher rating are also used regularly.

Even much earlier than the transmitting developments, the vacuum tubes were used to greatly improve the results obtained by radio receivers. The tubes can be used as detectors, oscillators and amplifiers and the sensitivity to which a receiver can be constructed is only limited by the interfering noise which, of course, is amplified with the signal. This has led to the development of directional aerial systems which eliminate noise interference from two or three directions. New types of filaments have been discovered in recent years, reducing the power necessary to operate the tubes without any reduction in efficiency. Early as 1914 amateurs were using a one-tube receiver and with spark transmitters covered distances up to 3000 miles with radio-telegraphic signals under favorable conditions, the wavelength being 200 meters. This was accomplished by adapting the regenerative feature to the vacuum tube, the output of the tube being coupled back to the grid again for further amplification.

Even during the last war, most receivers, of the vacuum tube type had one tube, the detector. Some audio amplifiers were available and the amplifying transformers used did not have an iron core, simply air. The loop, having the directional qualities of transmitting and receiving most efficiently in the direction of its own plane, came into prominent use during the war. This form of antenna is the basis of the present radio compass direction finding systems and for devices to guide and navigate aeroplanes. The multiple tuned antenna was developed for large transmitting stations to raise the radiation efficiency. A typical antenna of this type is suspended on steel towers 400 feet high and having a total of twenty towers over a straight line several miles long. American amateurs were heard in Scotland by Godley in 1921 through the use of a wave antenna and super-heterodyne receiver at the receiving end. A wave antenna consists of a single straight wire, approximately as long as the wavelength desired to be received. It is supported throughout its length by short poles. This form of antenna is highly directional, being highly sensitive to signals from the head on direc-

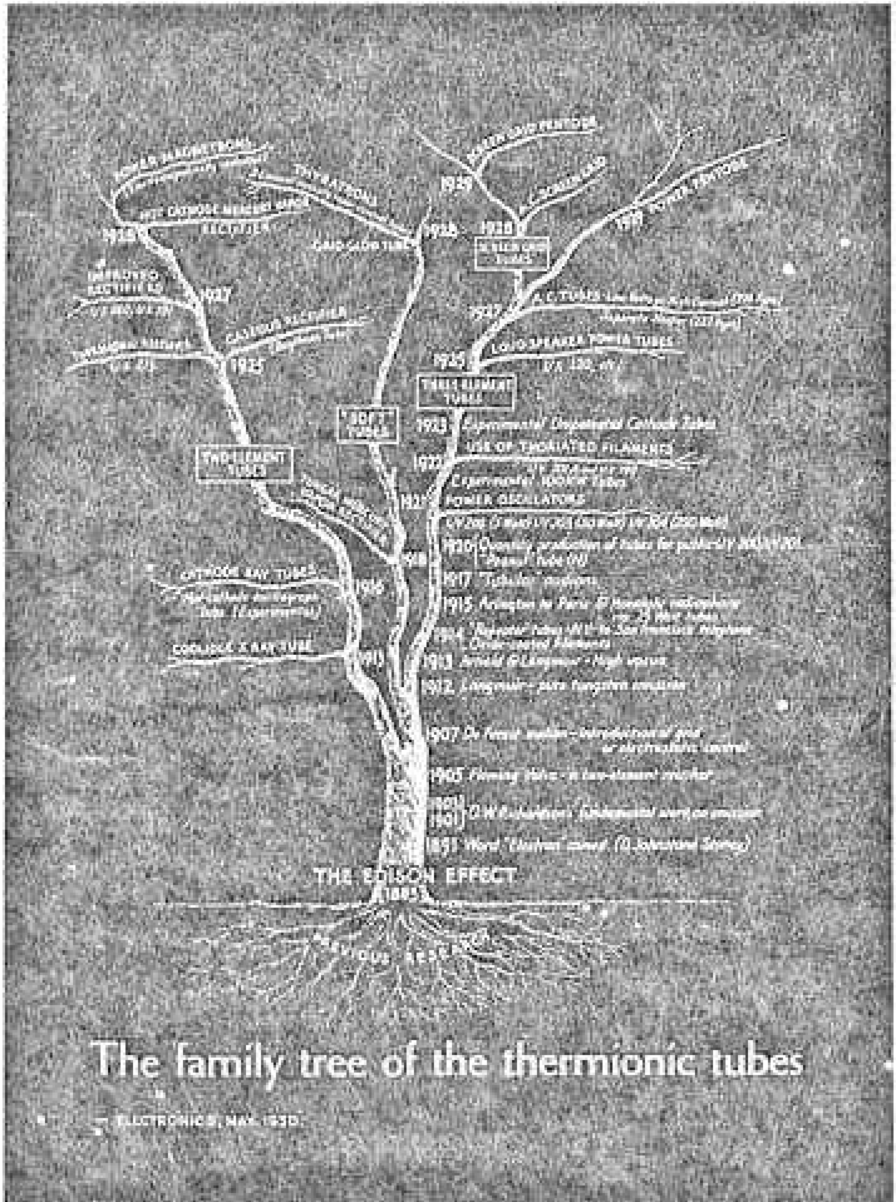


Fig. 2
Development of Thermionic Tubes.

tion and greatly attenuating signals from the other directions including that opposite to the head-on direction. By using this form of antenna and in some cases in connection with two or more similar antennae forming an array, great progress has been made in reducing static interference.

With the event of short waves, it has been possible to design and use antennae of a still higher order of directional qualities. This new type antenna is used for both receiving and transmitting. In the case of transmitting it has sometimes been called a Beam transmitting antenna, as the transmitted energy is concentrated in one narrow direction. By concentrating the energy in this manner, the necessary power to cover long distances has been reduced. In a like manner the use of these highly directional receiving arrays has enabled reducing static or other electrical interferences from all directions except that from which the signal is being received.

The vacuum tube was responsible for the rapid progress made with radio telephony due to the fact that these tubes provided a convenient method of generating high frequency oscillations and also enabled modulating them for telephony. Bell Telephone experiments in 1915 included radio telephony from Arlington, Virginia to Paris, Canal Zone, California and Hawaii, in the latter case the distance being over 5000 miles. During the war radiophone conversations were carried on between airplanes and ground stations and between airplanes. The recent increased interest in the aviation industry is the cause of further developments of radio equipment for aircraft.

Between 1920 and 1922, radio broadcasting became established as a means of entertainment for the American public. The use of high power water cooled tubes at the transmitters has increased their reliable service range. The use of Quartz crystal oscillators enables having the stations maintain their assigned frequencies, preventing interference between stations. Improvements in the broadcast receivers, particularly in regard to the fidelity of reproduction have been steadily made. In the last few years battery operated receivers have been discarded except in rural districts, in favor of apparatus which secures all the necessary power from the home electric lighting circuit. The controls for the receiver have been simplified and in most cases reduced to simply a wavechange or station selector, volume control and switch. The dynamic speaker, although known for many years, is now regarded as ideal for the best quality of reproduction. This type speaker brought out the low notes that were entirely lost in the earlier magnetic horn speakers, and probably the reason for its instant acceptance. The dynamic type speaker can now be used to secure excellent musical reproduction as the large power tubes available supply the proper output for this purpose.

In 1922 the broadcast services were extended from the stations studios to remote points such as churches, concert halls, athletic events, etc., by means of suitable connecting telephone lines. Following the same system, telephone lines were provided which enabled several stations in different parts of the country to transmit the same program simultaneously. Special engineering attention had to be given to the connecting telephone lines in order to faithfully transmit all the low, medium and high notes corresponding at that time from about 100 to 5000 cycles.

From 1921 to 1924, initial experiments were made to extend the regular Bell Telephone system at ships at sea. In 1929 this service was first opened, the initial ship installation being placed upon the Leviathan. Since then it has been extended to other ships.

New developments in water cooled tubes and antenna designs has resulted in the discovery of an improved method of modulation known as "side band" transmission. Experiments also were made indicating that for the region of 60 kilocycles, atmospheric disturbances in northern latitudes were at a minimum. These two factors enabled opening the transatlantic telephone service in 1927. The 60 kilocycle channels now employed include an outbound station at Rocky Point, Long Island and a receiving station at Cupar, Scotland. The return channel is from Rugby, England to Houlton, Maine. This low frequency telephone system was supplemented in 1929 by a high frequency system, Lawrenceville, N. J. to Baldock, England and from Rugby, England to Netcong, N. J. Terminal points were established in New York and London where the land line connections are made to the telephone subscribers throughout North America and Europe. Other radio telephone services have been opened between Madrid and Buenos Aires, Amsterdam and Java, Paris and Algiers, Berlin and Buenos Aires and between Berlin and Bangkok.

The use of high frequencies is now commanding considerable attention. Even in 1917, 150 meters was considered a short wave. Recent experiments have been conducted with wavelengths of 5 meters and even less. The use of higher frequencies as compared with low frequencies has many advantages. A moderate sized antenna can be used for the higher frequencies and much less power for a given range. Certain frequencies are especially suitabl for daylight transmission where the lower frequencies would require tremendous sized transmitters to cover the same distances. The higher frequencies also seem to have greater freedom from atmospheric disturbances. On the other hand the higher frequencies have some disadvantages, the received signal often varying considerably in strength over different periods. The wave propagation is erratic in some instances the signal can be heard with great strength several thousand miles from the transmitter while reception a few hundred miles from the transmitter is impossible, this phenomenon being termed "skip effect." This is in direct contrast to low frequency signals which usually diminish rapidly with increased distance

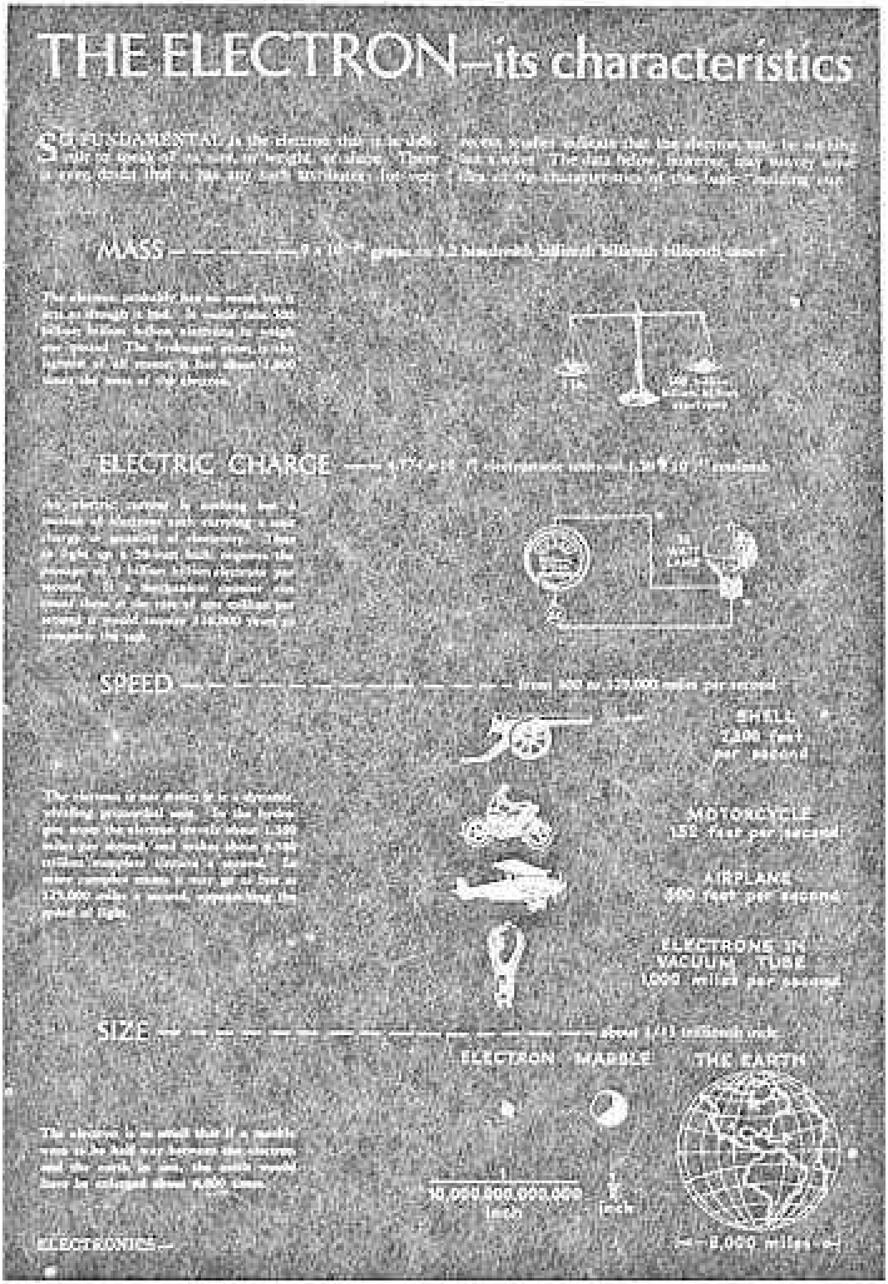


Fig. 3
Electron Characteristics.

covered. The distance carrying properties of the higher frequency waves vary greatly, day and night and in different seasons of the year. In actual practice communication between two points can only be carried reliably by varying the frequency day or night or for the distance to be covered. The earth's magnetic disturbances during some periods has rendered all high frequency reception inoperative. Until further improvements have been made the high frequency system of communication cannot be considered to compare favorably with wire communication.

High frequencies have been used chiefly for long distance radio telegraphy between fixed points by the radio communication companies, government and amateurs. It is not unusual for an amateur in one part of the world to communicate with other amateurs in ten or more different foreign countries in one twenty-four-hour period. Due to the time difference and ability of high frequencies to travel great distances in the daytime, international communication is obtained over the 24-hour period. Short wave equipment has been installed on ships and aircraft and this application is being rapidly extended.

Quartz crystals have provided a means to accurately control these high frequencies.* These crystals have the piezoelectric property of slightly altering their shape upon the application of an electric field and conversely producing an electrical potential difference when a mechanical strain is applied. As a result of these characteristics, one of the natural frequencies of the crystal can be reproduced electrically by proper connections to a vacuum tube. This current furnishes an accurate means of maintaining the frequency of transmission. The natural frequency of the crystal is increased with a decrease in mechanical dimensions. For extremely high frequencies, the crystal would be mechanically weak due to being ground very thin. This obstacle is overcome by using a heavier crystal of lower natural frequency and then doubling or multiplying the frequency through vacuum tube frequency doubler circuits.

Signals for the transmission of pictures or television can be sent over radio transmitters in a similar manner to that employed over regular wire lines, RCA have a "photoradio" service for facsimile transmission in operation between New York and London; San Francisco and Honolulu and New York and San Francisco. Initially, it required about one-half hour to transmit a picture 7 by 9 inches. A rapid system of this type would enable transmitting whole pages of newspaper copy probably faster and more accurately than high speed radio telegraphic equipment.

Rapid strides in television development have been made in the past three years. The Bell system gave a practical demonstration between Washington and New York in April, 1929, over land lines. The performers and speakers at Washington were readily recognized on the receiving screen at New York and their voices were reproduced through loud speakers at that point. At the same time a radio television demonstration was given over a smaller distance, Whippany, N. J., to New York, 22 miles. Crystal systems for controlling the frequencies at both the receiver and transmitter eliminated the necessity of transmitting synchronized currents, this feature being added in 1928. Other improvements made possible the transmission of television scenes from the open air with ordinary sunlight and the transmission and reception of television in colors. The General Electric Co. has been active in this field and gave a demonstration of television the full size of a moving picture screen. C. Francis Jenkins, of Washington, has also been active in this field. European scientists have also made great progress along these lines. Baird, in England, has used both visible and infra-red light and has been reported to have demonstrated the reproduction of television in colors. Karolus in Germany has perfected a cell through which light passes in variable amounts under the control of an electric field. This furnishes a rapid means of varying an intense beam of light. Belin, in France, has been experimenting with optical transmission using a cathode ray oscillograph and Zworykin, of the Westinghouse Co., has made improvements along this same method.

The progress made so far has been rapid, but the actual reproduction so far does not approach the fineness of detail of the regular motion picture.

The outstanding popular development in radio is the broadcasting of news, music and other material from radio telephone stations. Normally,

Fig. 4

Modern Broadcast Installation. Dynamic Speaker in patio disguised as a chimney (upper left), residence Philip K. Wrigley, Catalina Island, Calif.

the radio waves from a transmitter travel in all directions and spread over a considerable area, making it an ideal method for one way communication service to reach a large audience. Station KDKA of Pittsburgh started the first regular published broadcasting schedules in 1920. Immediately thereafter the number of broadcasting stations increased rapidly with a corresponding increase in the number of receiving sets installed to use this service. By transmitting the same program through a number of stations strategically located over the country, it is possible to reach a larger audience than by any other method. This makes it economically feasible to prepare elaborate programs and employ the highest grade talent and artists. The program time or lease of the facilities is sold to national advertisers, which contributes to supporting the broadcast stations. This is a favorable method of bringing the advertiser's name or the name of his product before the public, especially with the use of original programs and not "over advertising."

The National Broadcasting Co. has three chains of stations totaling 67 transmitters. The Columbia Chain serves 58 permanent connections. Other stations are sometimes connected in for special features. Altogether over 150 stations are available for chain transmission, the land line circuits making all these connections total over 34,000 miles.

Broadcasting service in other countries has followed the lead of the United States. In many of these countries, the receiving stations are required to be licensed and a fee paid their government. Part of these proceeds are used to finance the broadcasting stations. Outside the United States there are approximately 500 broadcasting stations as compared with 614 in the United States in November, 1929.

The Radio Corporation of America now has radio-telegraph transmitting stations in the east at Rocky Point, L. I. Marion, Mass.; New Brunswick, N. J. and Tuckerton, N. J., used for the exchange of messages with about 15 countries in Europe, Africa, North and South America. Australia is reached via Montreal. The control point of all these stations is located in New York City and known as "Radio Central". The transmitting is all done by machine senders. Handling the messages from this point makes it convenient for their distribution in the New York City district. On the Pacific Coast, the same company has stations at Bolinas, Calif., Kahuku, Hawaii and Manila. Associated receiving stations are located at Marshall, Calif., Koko Head, Hawaii and Manila. These stations transact business with Hawaii, four points in Asia and the Philippine Islands.

The Tropical Radio Co. transmit from Miami or New Orleans to 13 different points in Central and South America. During 1929 the English radio and cable interests were merged. A similar merger has been under discussion for the American interests.

Additional extensions have been made to the transoceanic radio-telephone service, principally due to improvements in short wave transmission and reception. In September, 1929, the transatlantic telephone service was placed on a 24-hour basis. A telephone subscriber in the United States can now reach anyone of more than 28,500,000 telephones in the United States,

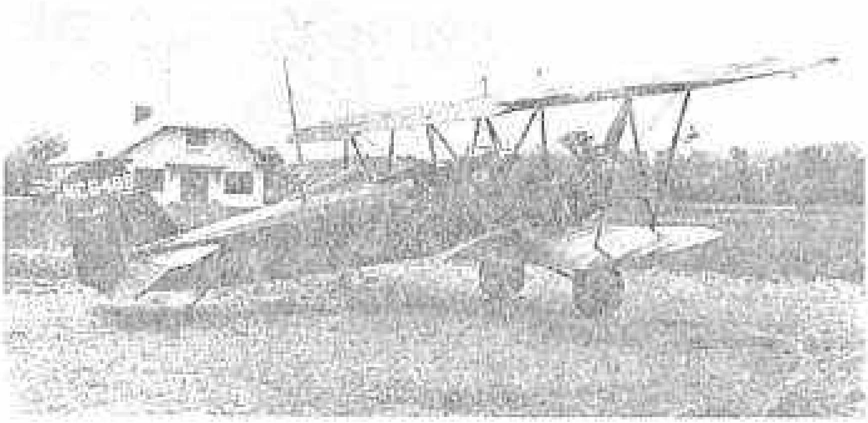


Fig. 5

Airplane equipped with rigid vertical antenna for short wave reception. *

Canada, Cuba, Mexico, twenty European countries and Ceuta, Africa. The new extension to Argentina, South America is to be opened in 1930.

Extensive radio-telegraphic service between ships and shore stations and between ships is maintained by the Radiomarine Corporation of America, Mackay Radio & Telegraph Co. and others. Transmitting stations are located along the Atlantic and Pacific Coasts, Gulf Coast and Great Lakes. The most powerful station of this type is located at Chatham, Mass. This station can communicate with ships on their entire trip across the Atlantic. Approximately 12,000 ships are equipped. The obsolete spark transmitters are being rapidly replaced by vacuum tube transmitters, resulting in more reliable service, greater service ranges and freedom from interfering with broadcast programs. Radio compass stations are in continual operation, enabling ships to obtain their exact position while located up to a few hundred miles from shore.

The U. S. Navy system furnishes locations to ships as requested but can only handle one request at a time along a given section of the coast. The Lighthouse Bureau system is different, having radio beacon transmitters on land and requiring radio compasses aboard the ships, can handle unlimited traffic. The number of such beacons along the American coast is approximately 65 and throughout the rest of the world there are 57 others. In the middle of 1929 over 1,903 ships were equipped with radio compasses, and it should be mentioned that this feature is not required by law. This device is extremely helpful in locating ships in distress and several notable rescues have been effected in this manner. The trend is to equip all ships with radio apparatus and the larger boats also with radio compasses.

On the American Airways, radio beacon transmitters are being erected rapidly to guide the pilots. The associated receiving apparatus on the plane includes an electrical indicator showing when the plane is following the exact course or showing the deviation either side of the course. Some airway transport companies are equipping their planes with radio-telephone apparatus enabling communication between planes and between the planes and the airports. The Department of Commerce in addition to maintaining the beacon stations also has a complete service for supplying weather information to the plane pilots. Continuous wave telegraphy is being used for long distance communication over the airway water routes.

The latest achievement of short wave transmission (fall, 1930) was the international broadcast originating from three widely separated points, United States, Great Britain and Japan. President Hoover spoke from Washington, Prime Minister MacDonald from London and Premier Hamaguchi from Tokio. In each case the principal speaker was also provided with a receiving equipment so that he could hear the other speakers after he had finished. They all spoke on the London Naval Treaty, and the radio programs were made available throughout the United States, Great Britain, Japan and any other country equipped for short wave reception, as the transmission in addition to being sent over the regular broadcasting chains was also forwarded through the short wave transmitting stations of these chains.

Almost simultaneously, the A. T. & T. Co. announced the opening of the extension of telephone service from subscribers in the North American Continent to Australia, via England.

Reviewing the present status of short-wave transmission as related to broadcasting we find there is a definite trend toward the use of these higher frequencies, especially for long distance communication. It is believed broadcasting will be supported by the revenue from the advertisers. In any event, economically, the broadcasting stations must reach the largest possible audience and during the daytime as well as at night. Under present circumstances, the large cities are given the best service and a fairly large area around each of these cities is covered in an effective manner. Some of the medium-sized communities have some of the advantages of metropolitan broadcasting through the adaption of "chain programs." Electrical reproductions, using phonograph records are broadcast by the stations, in smaller cities, a substitute for practical talent.

It is estimated that a high-power broadcasting station such as WEAF and WJZ (New York) using a power of 50 kilowatts, could be depended upon

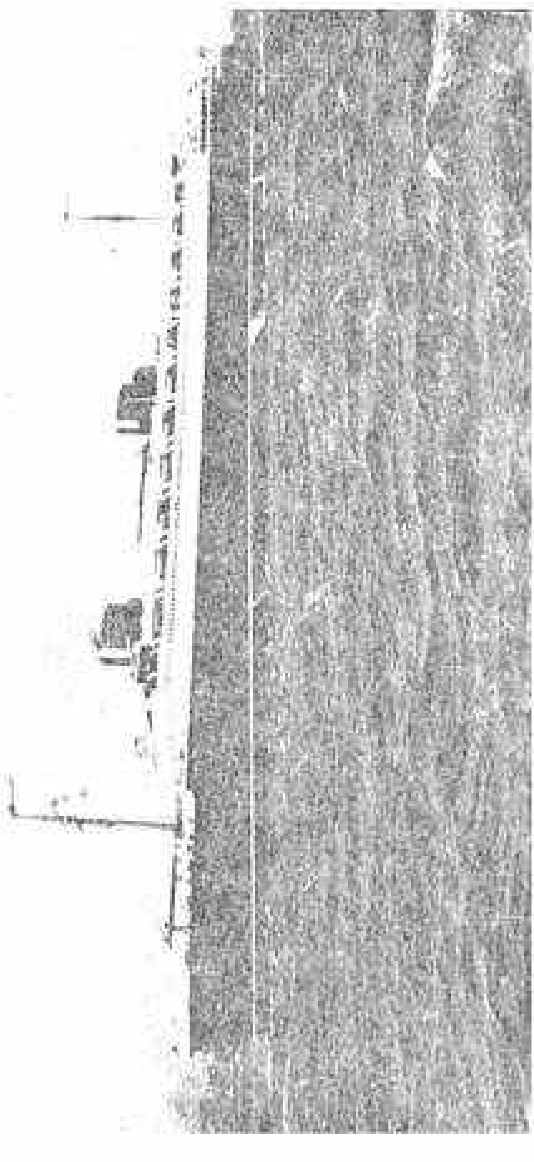


Fig. 5(a)
S.S. *Bremen*, completely equipped with short-wave transmitting and receiving apparatus for radio telephony and telegraphy. (See Chapter IV.)

to serve the Metropolitan district or Greater New York only. Even under these circumstances, there are certain locations within the city, which due to shielding from the high steel buildings, bridges, etc., are not served satisfactorily. Station KDKA (Pittsburgh) with a view to extending the service range, has installed a new type of transmitting antenna designed to provide sufficient power for good local reception and at the same time to divert a good percentage of the power from the areial at a higher angle that will enable it to reach a greater distance satisfactorily.

The daylight range of high-power broadcasting stations varies greatly and different results are noted from observation points throughout the country. For example from New York City it is difficult to obtain satisfactory daylight reception from any distant stations except possibly from Philadelphia or Schenectady. However at Philadelphia or Schenectady good reception can be obtained from the New York stations during favorable radio weather. Down through the southern states, even as far as Miami, WEAF and WJZ can be received in the afternoon, providing weather conditions are favorable and during the winter months.

Observations made from an experimental laboratory at Altoona give some interesting data. This city is at an altitude of approximately 1,000 feet and partially surrounded by mountains that raise to approximately 3,000 feet. It is usually quite cold during the winter and at that time coast reception is commonly expected. The daylight range varies greatly, however during the winter and on cold days a range of 500 miles can be covered satisfactorily, using a sensitive receiver. During the summer, daylight reception of broadcasting stations over any distance is uncertain and invariably unsatisfactory due to static interference, that is as far as the regular broadcast band is concerned.

Now on the short-wave bands we find an entirely different situation. Even during the hotest summer days, when static interference is unbearable on the regular broadcast band, the short-wave stations such as WJZ and WABC in New York and WENR in Chicago, the first named about 300 miles distant and the latter about 500 miles, away are received very satisfactorily, on about 47 meters. Under exactly the same circumstances, the identical programs from the same stations being sent out on their regular broadcast wavelengths could not be received. Now the most interesting point of this comparison is the fact that the power used on the short wavelengths was only a small fraction of that used on the broadcast band wavelength. Short waves can therefore be used as a medium to extend the daylight range of broadcasting stations and to an area which is practically without limit.

In the tropical countries static interference on the regular broadcast band is of very serious proportions and the radio season for any distant reception is extremely short, in most of these countries not over four months, corresponding to their winter season. After that period their source of enter-

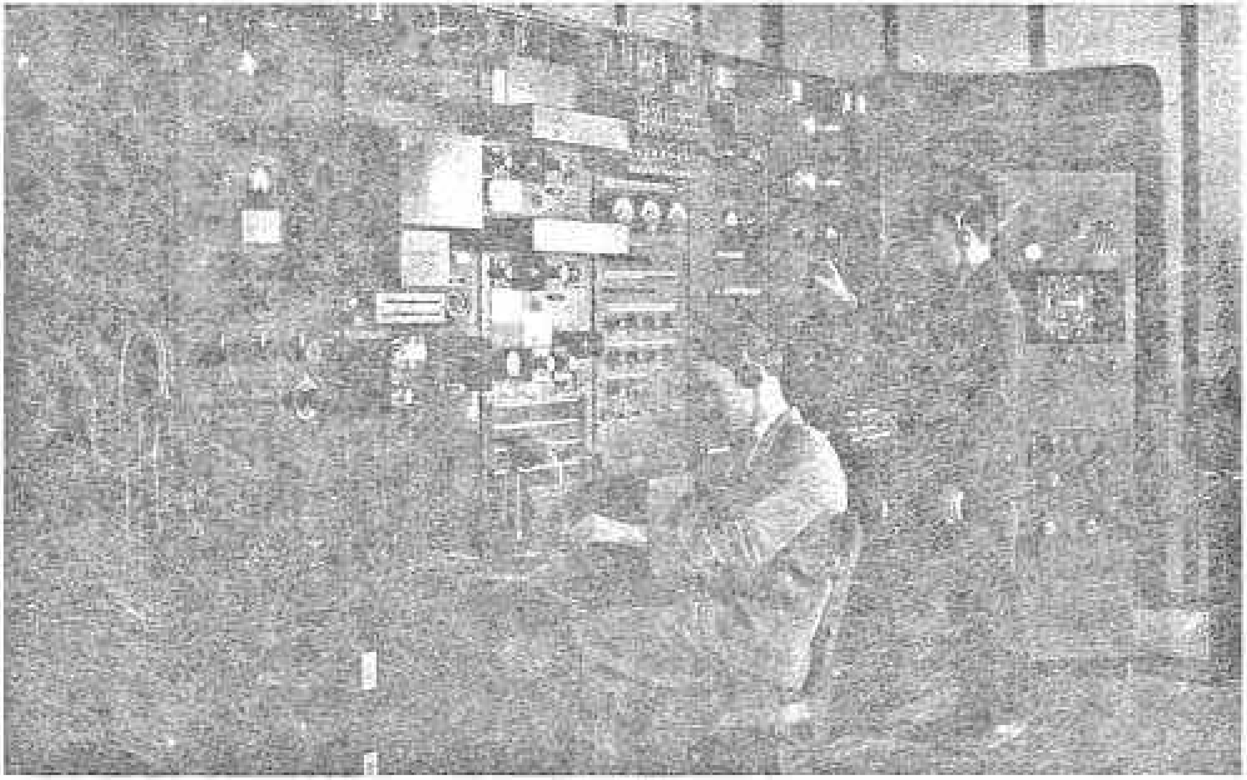


Fig. 5(b)

Receiving Station at Houlton, Maine, for transatlantic radio telephone communication between the United States and England. This system works on long wave lengths and is supplementary to the three associated links which work between these two countries on short wavelengths. The communications received at this point are sent over land telephone lines to the main Central Control Position in New York.

tainment is limited to the local stations or short-wave transmission from distant stations, and there is a greatly increasing interest in the latter. A good short-wave receiver in Havana, Mexico City or similar tropical locations will give satisfactory reception from New York on short waves and with service day or night. The service is of course not limited to the reception from New York, as their are many other European and other foreign stations to choose from.

In the United States, the most well known short-wave transmitters are KDKA (Pittsburgh), WGY (Schenectady), WJZ (New York) and WENR (Chicago). There are numerous others, all of high quality and becoming more popular each day. In Continental Europe, PCJ at Eindhoven, Holland, due to its pioneer work is probably the most internationally popular short-wave broadcast station; confirmed reports on its transmission have been received from practically every part of the world.

Japan's leading broadcasting station JOCK (Tokio) which has been heard occassionally in California and the west coast on the regular band, has now added supplementary short-wave transmitting apparatus. The initial results were very satisfactory and the signals on these wavelengths were picked up in California and Nebraska with sufficient strength to enable re-broadcasting.

In its efforts to establish radio-telephone service between the United States and England, the American Telephone and Telegraph Co. first installed apparatus of high power and to work on a comparatively long wavelength. The supplementary link, on the other hand, was constructed to have lower power but to work on a short wavelength. When additional links were required these were also constructed for short-wave work.

Short wave equipment is absolutely essential for aircraft installations, due to the weight limitations. For example on a transatlantic flight a radio transmitter weighing 100 pounds and designed for 600-meter transmission would have a maximum range of not over 100 miles, not sufficient to be interesting. A similar transmitter, same weight, but designed for short-wave work would under favorable conditions enable communication from the time the plane left one shore until it reached the other.

Short-wave equipment is equally essential for exploration work. The Byrd South Pole expedition was in daily communication with the New York *Times* station in New York City and a daily story of the expedition's progress was printed in the *Times* and associated papers. Likewise the Byrd planes on their flight were in constant communication with the base via short-wave radio. The Byrd expedition had capable short-wave receivers which enabled the reception of short-wave broadcast entertainments, including special programs sponsored for their benefit, these usually being sent through station KDKA. It is of course not difficult to see the many advantages of such a communication system and what it would have meant to some of the early

Fig. 6

Edward Startz, five language announcer, at short-wave station PCJ, Eindhoven, Holland.

explorers who ran into difficulties and had no means of summoning assistance.

The Police telegraph and telephone systems in the large cities are quite complicated. They have been effective although there has always been the disadvantage of lack of direct communication between headquarters and the mobile units. Short-wave radio equipment is now in use in over a dozen cities of the United States for direct communication between headquarters and the mobile units such as Chief's automobile, Squad Cars, Riot Cars, etc. For this class of communication within city limits, the use of a short-wave channel is not essential. Wavelengths above the broadcast band are not available for this purpose and accordingly a frequency had to be selected which fell below the broadcast band. The transmitting station is supposed to have sufficient power to reach any of the mobile stations regardless of where they may be located in the city. The automobile receivers used are of rugged construction and not capable of any fine adjustment and for that reason the power requirements at the transmitting end are higher than actually necessary. From New York, it is not unusual to hear the Detroit Police transmitting station. So far the police radio systems have the decided disadvantage of not having any secrecy feature and the communications or instructions are open to anyone with the same type short-wave receiving set.

Recently a complete radio-telephone installation was made upon one of the New York City Fire Boats. The demonstration given was to show how constant communication could be had between Fire Headquarters and the boat under all conditions. The apparatus used was of special design and construction so that a skilled operator was not necessary at either end. Previously, once the boat was dispatched, it was impossible to recall it until it had reached its destination, a decided disadvantage.

In 1932 there will be an international radio conference at Madrid which promises to prove very interesting. Undoubtedly the regular broadcast band

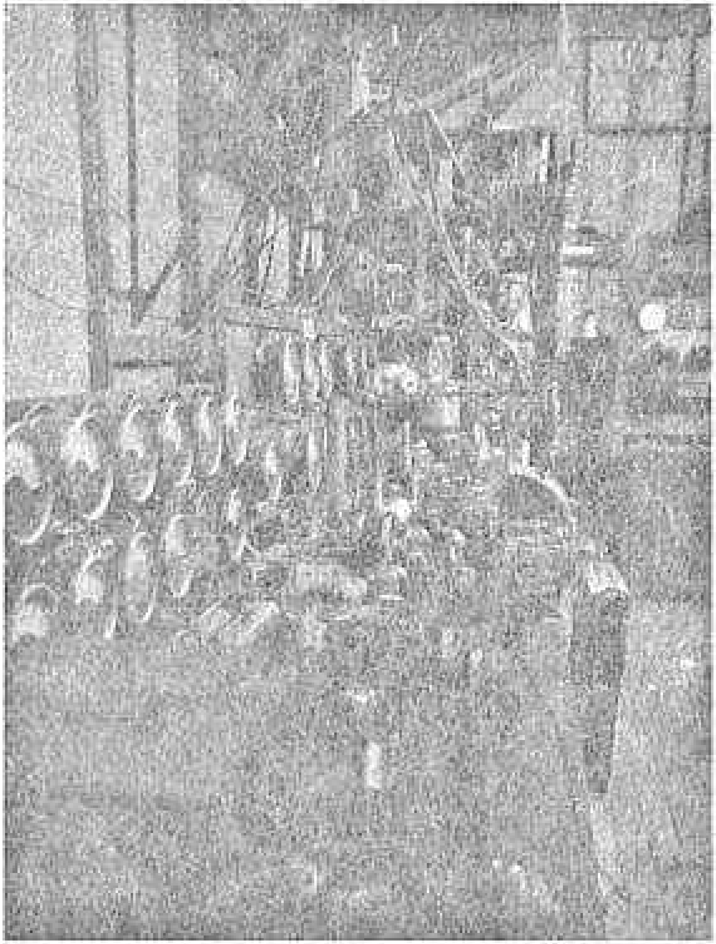


Fig. 7

PCJ Transmitter, Eindhoven.

The Eindhoven station is one of the pioneer short-wave transmitters of the world. The frequency used is maintained by a quartz crystal oscillator, in a combination with frequency doubling stages. The final power tubes are of the water-cooled type. Individual indicating meters are placed at all essential points to check the operating condition. PCJ has a daily program and a summary of all reports received indicates that the station has a world-wide range, during favorable radio conditions.

will be extended beyond the limits of 200 to 560 meters. Canada has already announced its intention to place some of its stations on wavelengths between 560 and 600 meters which is higher than most receivers at present in use can tune to. This coming conference will probably influence the design of new broadcast receivers during the coming year or two. Without any doubt these new receivers for broadcast reception should be suitable to use with a short-wave super-heterodyne adapter and in addition the receiver should preferably cover a wavelength range of approximately 150 meters to 650 meters and provision made to extend the range still higher if required at a later date.

It is of course difficult to design one radio receiver which will cover an extremely wide wavelength band. The tuning condensers most suitable for the regular broadcast band are unsuitable for the shorter waves, likewise the small tuning condensers required for short-wave work are not satisfactory on the broadcast band. Furthermore below 20 meters, the receiver design problem becomes still more complicated. It is believed the average experimenter will prefer, as a matter of convenience, a radio receiver that will cover the broadcast band and still give good results on the shorter waves at least down to 20 meters. This can be accomplished in at least two satisfactory manners. In one system the regular broadcast band is covered by a high-grade tuned radio frequency receiver; the short-wave band covered with a super-heterodyne adapter using the tuned radio frequency receiver as the intermediate radio frequency amplifier, second detector, audio amplifier. The efficiency of this arrangement is only limited by the performance of the tuned radio frequency receiver. With this system, the adapter can be designed to work at a very high degree of efficiency. Furthermore if the tuned radio frequency receiver has interchangeable radio frequency transformers the tuning range can be extended above the broadcast band as may be required.

The second possible system would consist of a super-heterodyne receiver designed for the broadcast band, but having interchangeable coils to extend the range down to the short-wave bands. To secure good results, the tuning condensers should be in two sections, the entire condenser being used to tune the broadcast bands and only part of the condenser for the short waves. This would be a complicated design if single dial tuning was specified and undoubtedly result in low efficiency. The super-heterodyne to be selective should have tuned filter circuits preceeding the first detector for operation on the broadcast band. It would be difficult to continue to use these on the short-wave bands and they would have to be switched out of the circuit.

At the present time, the short-wave receivers generally available for experimental purposes do not compare with the apparatus used for commercial purposes as described in this text. The main reason being that they are built to a price which of course immediately limits the performance of the apparatus. At a later date when the advantages of short wave are more gen-

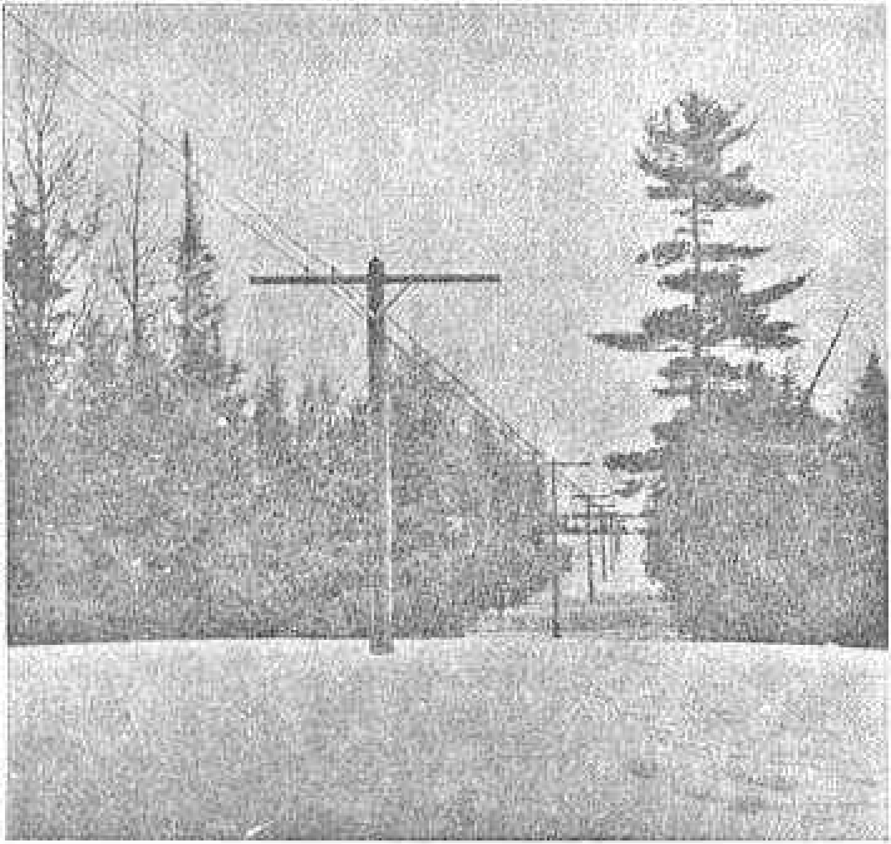


Fig. 7(a)
Wave Aerial at Houlton, Maine, Used for Transatlantic Radio Telephone Reception From England (on the Long-Wave Link).

erally appreciated it is expected that much higher-grade receivers for this purpose will become available.

At the present time the broadcast transmitters, as far as meeting the scientific requirements are concerned, are far superior to the regular run of broadcast receivers. There is a definite reason for this and it is a matter of price considerations. At the transmitting end, the owners have gone to almost unlimited expense to have the best equipment possible. In the first place preliminary investigations are made to find a suitable location for the transmitting apparatus, removed from the city limits and at a point which will give efficient wave propagation. At this location it is necessary to erect costly steel towers for the antenna system and to either construct an elaborate ground or counterpoise system. Then there is the construction of the main building and service buildings. The transmitting apparatus in the main building and the associated power equipment alone could cost one hundred thousand dollars.

The studios must be located in the city at a prominent location and a leading station must have five to seven different studios, the proper construction of which is an expert's work. Associated with the studio are the monitoring rooms, main control room with the amplifying apparatus for each of the studios. Provision must be made for studio, telephone and signal lines between the studio control room and the transmitter located outside of the city. Similar facilities must also be installed to communicate and connect with other stations throughout the country when the station is operating as a unit of a chain. The main offices of the operating company are usually housed

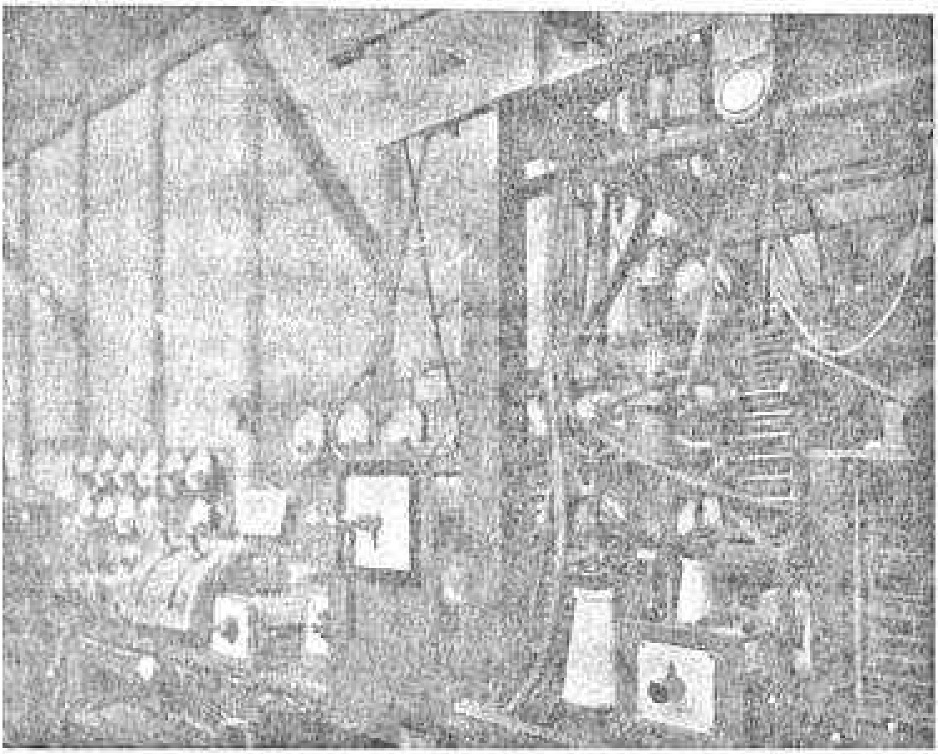


Fig. 8

PCJ Transmitter, Eindhoven.

In this view the water-cooled power tubes are shown with the associated tuning inductances and other instruments. Note that the retaining frame of the transmitter is built of wood to prevent electrical absorption which would occur with metallic structures. In order to continue new experiments the apparatus has not been assembled in a permanent shape.

in the same building as the studios and this requires still more valuable space. Figuring on full service, it is readily seen that a force of 200 to 300 employees would be kept busy to run a high-powered broadcasting station of this type.

The transmitting stations are made practically in an individual manner. Each new instrument manufactured has the new improvements that have been made due to continuous research. These new improvements are often added to older transmitters although they have only been in service a short time.

On the other hand take the situation with the radio broadcast receivers, the tendency during past years has been toward lower prices and yearly models. There is no doubt but what the leading manufacturers have all the necessary data which would enable them to build radio receivers that would have the ability to meet all the scientific requirements. However, this cannot be accomplished if there are price limitations. An example of this which ordinarily would not seem important, is the console cabinet. Unless in designing the cabinet, there is sufficient distance around the cabinet between the front of the dynamic speaker and the back of the same speaker, it is impossible for the speaker to reproduce low musical notes below certain limits. This factor is entirely neglected in most low-price designs. Considering the dynamic speaker itself, the best type available costs more than a low-priced set. In other sets the low-priced type tubes are selected so that the total cost of the set will appear competitive.

The ideal radio broadcast receiver, built without price limitations should be constructed as a scientific instrument, in which case it would not be suitable for installation in a drawing room. On the other hand, the apparatus could be built properly along the above lines and installed in the basement or attic of the residence and tuned by remote control. Possibly apparatus of this type will be available in the near future.

CHAPTER II

Short Wave Propagation

In presenting this book on short waves no attempt will be made to explain the theories relating to alternating current circuits, vacuum tubes and associated equipment. There are books covering these various subjects indi-

Fig. 9

Sunrise, Eastern United States. Most favorable conditions for low-power communications with New Zealand and Australia. The earth's inclination corresponds to November or February.

vidually, in a complete manner and where there is sufficient space available to explain the theories properly. However, in order to appreciate the modern applications of short waves as described in the following chapters, this can best be accomplished by reviewing the subject of short wave propagation.

Prior to the use of short wavelengths the various commercial wavelengths were on the order of as high as 24,000 meters and extending down to 600 meters which was formerly the wavelength for commercial ship to shore traffic. There were also emergency marine wavelengths of 300 and 450 meters, particularly for small boats and a wavelength of 200 meters for the amateurs. On these wavelengths field measurements showed that the strength of the signal diminished gradually with increased distance from the transmitter. It was found that the distance a radio wave of given power would travel over water was about three times that it would travel over land and still be useful for the reception of the signals with the receivers available at that time. In a like manner the same waves travel over a plain surface free from obstructions over a much greater distance than they would travel over a mountainous country. This is illustrated in the accompanying sketch Fig. 12 which shows a relative signal strength as received by a ship in the North Atlantic ship lanes and also the same relative signal strength received from the same station but from points inland from New York and over land. The same illustration shows the shielding effect of a mountain located in between the transmitter and a ship receiving station, in two positions. In the first case the ship located alongside the mountain is unable to receive signals from the transmitter because they are deflected by the mountain and pass completely over the top of the ship's aerial. In the second case

Fig. 10

Over Top of the World. If they follow the shortest (Great Circle) routes, signals from Chicago would shave Greenland to reach Central Europe, cut the Arctic Circle on the way to the Philippine Islands, and cross the North Pole on a direct line to India.

with the ship 500 miles away, the wave signals are again within reach of the ship's aerial. A good idea of the action of the long wave signals is had from the performance of the broadcasting stations in this country in the years 1923 and 1924 prior to great congestion. Operators of broadcast receivers in the East generally found that reception from the Southern stations was much more impressive than reception from the Western stations particularly those west of the Rocky Mountains. 500 watt stations located in the South came in very regularly with very great signal strength a distance of up to approximately 1,000 miles. Stations west of the Rocky Mountains of the same power and approximately the same distance away were received with great difficulty due to the obstruction presented by the mountains in between. It was also found that the daylight range of these stations was very limited and reception from a distance of 500 miles during daylight was obtained only with very sensitive receivers and under favorable conditions. It was found that the night range of the same station was greatly increased and particularly after midnight when there was complete darkness between both the transmitting and receiving points. There were additional obstructions to the progress of the regular wavelengths such as ore deposits in both mountains and along level ground and the masses of steel structures in cities presented an obstacle to the successful reception of signals within congested parts of the city. Prior to the development of receivers having high sensitivity there were certain spots in New York City where it was very difficult to obtain any distant reception at all. The action of short waves as propagated into space is altogether different and there are very many variable factors. The possibilities of long distance short wave transmission with relatively small power was perhaps first demonstrated by the radio amateurs throughout the world. With the event of broadcasting the amateurs operating spark trans-

Fig. 11

Sunrise in Eastern United States. Most favorable conditions for low-power communications with Europe and Africa. The earth's inclination corresponds to November or February.

mitters on 200 meters created considerable interference with the reception of broadcasting signals. New regulations were introduced prohibiting the use of spark transmitters and also appointed lower wavelengths exclusively for their use, down around 80, 40, and 20 meters. This necessitated the development of new equipment and transmitting systems. The amateurs were soon very surprised to find that with this new apparatus using the short wavelengths they were able to establish communication in an irregular manner with similar stations located in other parts of the world. They also found that certain of these wavelengths were entirely unsuitable for night work and other wavelengths were unsuitable for day transmission. Commercial companies also started developments and soon realized that with short-wave transmitters of relatively small power they were able to establish communication between widely separated points in a more effective manner than they had been able to accomplish with much higher power and more expensive equipment. The development of directive antennae which concentrated the transmission in a desired direction and development of directive receiving antennae which were particularly partial to the signal desired and eliminated signals coming from other directions, made it possible to establish communication systems at an expense representing only a small part of that required for the previous long wave systems. Figs. 9, 10 and 11 outline the favorable conditions for transmission around different parts of the globe. The development of short-wave propagation has been so rapid, the desire to secure results has been more important to the engineers than studying and explaining their action in space. Fig. 12 (a) shows the difference between long, medium, short and ultra short waves. The wave length is figured by the number of cycles that occur in a time interval of one second. It will be noted that the greater number of cycles per second, the shorter the wave lengths will be and vice versa. Radio waves are similar to light waves except in size. Accordingly, it is possible to visualize their action by studying the performance of light waves on a small scale. The radio waves leave a simple antenna in practically all directions, see Fig. 13. The ground below cuts off

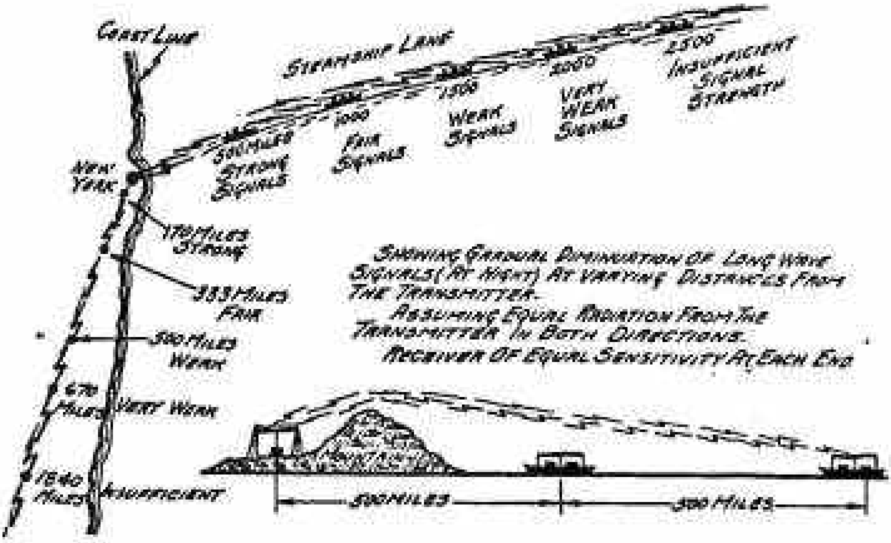
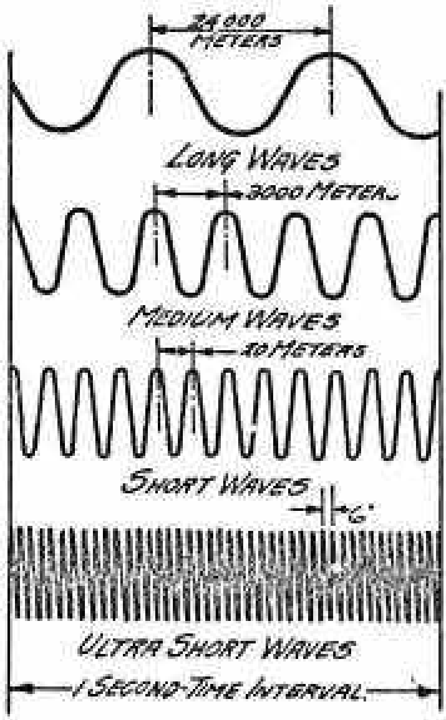


Fig. 12

Relation signal strength to distance, long waves.

transmission below the horizontal absorbing part and reflecting part. An analogy can be made by comparing an electric bulb resting on a dark surface. The glare or radiation from the bulb filament will extend in all directions diminishing as the distance increases from the bulb. The light striking the lowest surface will be partially absorbed and partially reflected, see Fig. 12 (b). If the supporting surface was a light paper in place of a dark paper there would be a large percentage of reflection up again towards the top. If the horizontal surface was a mirror we could see an inverted image of the filament below the actual one. Likewise, in actual operation if the ground below the antenna is a good reflector there is a well defined similar image of the antenna below the ground level. With the ground a good conductor and a good reflector, the radiation is, of course, more efficient. The ideal ground

Fig. 12 (a)
Frequencies.



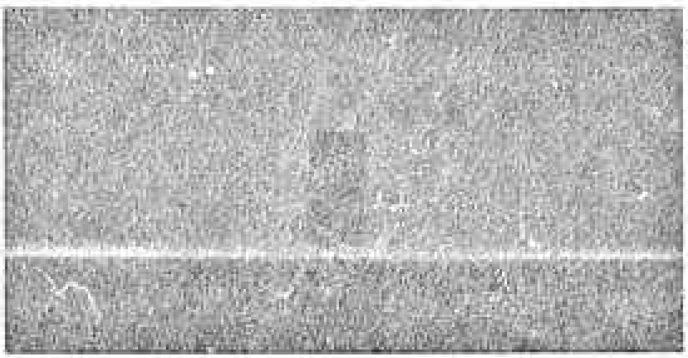
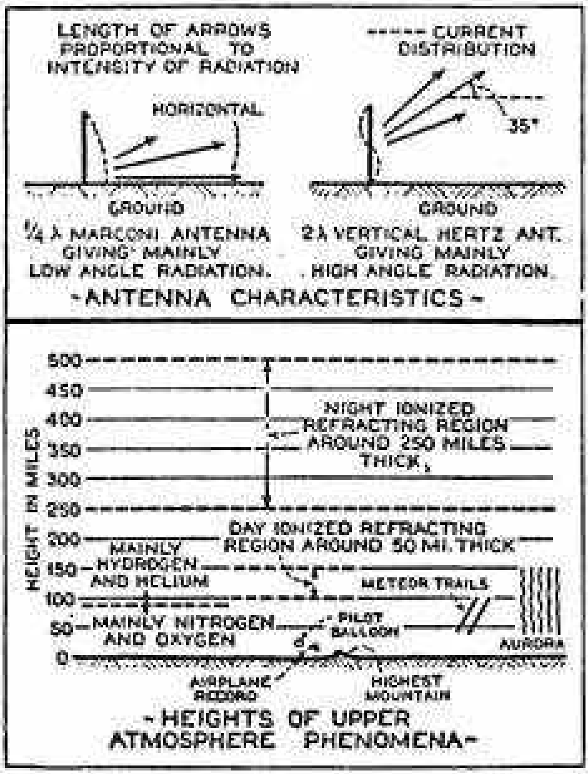


Fig. 12 (b)

Light Filament Analogy of a Transmitting Antenna above conducting ground. The filament behind the screen radiates light in all directions. The "ground" absorbs some of the light, but reflects the rest of it to reinforce that coming directly from the filament.

is, of course, sea water. In some locations a salt water marsh is a similar good reflector. However, there have been cases where the marsh and other damp ground was not suitable in which case it was replaced by a metallic reflector in the form of what was known as a "counter-poise" aerial. This consists essentially of wires elevated above the ground and located directly beneath the antenna. The actual height of the antenna above the ground or "counter-poise" has a definite effect on the radiation quality of the antenna. The above relates to a simple form of antenna. It must be remembered, however, that the antenna can be actually designed to have shapes which will give definite radiation qualities as far as directional effect is concerned. In the illustration of horizontal radiation it will be noted that there is a large percentage of ground absorption although this is less for short waves than for long waves. These effects are further complicated by the fact of moun-



Figs. 13, 14

At the top, Fig. 13 shows the radiation characteristics of two types of antenna, while Fig. 14 (below) indicates the relative heights attained by man and those attained by the night and day ionized regions.

tains or steel structures close to the transmitter which may cause shadows and the effect is sharper for short waves than for long ones. In the transmission of light there is the same effect and it is more pronounced for the red than the violet rays. The same action is true in the transmission of sound. In the transmission of sound an explosion on one side of an obstruction is heard from the other side with greatest intensity at the lower frequencies as these turn more easily around the obstruction than the higher ones. An extreme form of antenna reflector would be an electrical arrangement which gives the same effect as a search-light reflector gives to light. This enables concentrating the transmitted energy in one particular direction practically as a beam and this can be pointed or directed as required. A system of this type is used in a transmitting equipment designed to work between Germany and Argentina, see Fig. 15.

The amount of accurate data on the nature of ionized region above the earth is of meager proportions. Man has only been able to explore the regions up to above eight miles above the earth and then under difficulties which do not enable any extensive observations, see Figs. 13 and 14. It is believed that more useful information will be secured possibly through the use of observation balloons capable of ascending to much greater distance or with rockets. In the early days it was assumed that the earth's upper atmosphere could only absorb radio waves. Two early experimenters, Kennelley and Heaviside, both suggested about the same time that long distance communication must be the result of some reflective or refractory effect in this upper region. This resulted in a rough theory that there was a definite layer or surface located a certain distance above the earth completely around its circumference which acted as a reflecting medium. Others disagree on this point. Inasmuch as the air pressure decreases with altitude as we ascend from the earth's surface some assume that reaching a high enough altitude a vacuum would be encountered. So far the balloon observations carrying meteorological instruments have only ascended to approximately 20 miles. It is obvious then that future investigations at higher altitudes are going to present some very interesting studies. However, there are observations of the action of light waves in the higher altitudes which are quite definite in action, the scattering of short light waves making a blue sky and the transmission of long ones producing the red sunset. There is also a pronounced effect of persistency of twilight after sunset and appearance of dawn. The twilight is, of course, caused by the sun throwing light waves on the air high over head and the fact that it lasts about an hour indicates that the atmosphere up to a height of 40 miles is dense enough to scatter light. This observation is at an altitude approximately twice that obtained with any sounding balloons. Another observation is the action of shooting stars or meteors. It is believed that they are small particles of iron or rock approaching the earth at velocities estimated at from ten to fifty miles per second. It is also believed they originated from the break-up of comets by the sun's radiation pressure and that the comets themselves originated from the Orion nebulous regions when the solar system was passing through them millions of years ago. In passing through the rarefied atmosphere 100 or more miles above the ground frictional heat is developed and the object glows brilliantly and usually burns out before reaching the earth. There have been observations made where the meteor reached the earth in a flaming condition, Fig. 25. In observing the action of these meteors closely, hydrogen and helium lines are indicated in their spectrum leading one to believe that the upper atmosphere is composed of these two gases. From photographs of the actual trail of meteors there are variations in the light intensity of the object itself

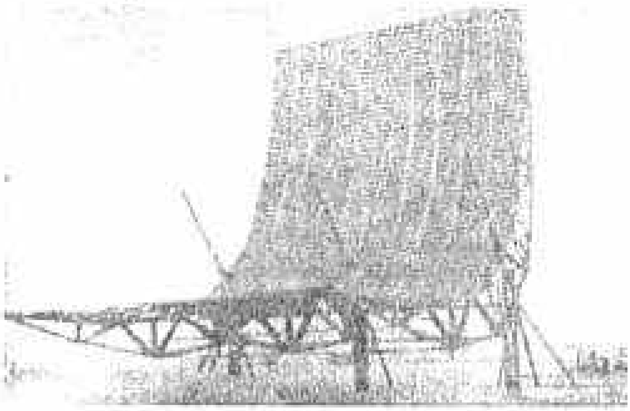


Fig. 15
Reflector Type Transmitting Antenna.

thought to be caused by successive explosion of the surface layers as they are heated, vaporized and worn away. Assuming that an observer was carried to a considerable height above the earth, possibly in a rocket, the following action would take place: in the first place the air pressure diminishes rapidly. The blue sky changes to violet. At between 50 and 80 miles the common nitrogen and oxygen pass and we come to hydrogen and helium. The violet sky fades to blue. Planets and stars appear despite the sun and the sun becomes bluer and more intense. Finally, at 500 miles, the sun shines brilliantly on the rocket and its trail, the sky is completely black and stars are very brilliant and far below appears the dim bulge of the sunlit earth. The foregoing gives a clear picture of the upper atmosphere. We will now consider the behavior of radio waves propagated at high angles. A diffuse gas subjected to certain radiations causes the following actions: electrons are departed from some of their atoms and scatter about by themselves or attach themselves to complete atoms. Three components are therefore contained in the gas: free electrons, positive ions (atoms which have lost electrons) and negative ions (atoms which have picked up extra electrons), and under these conditions it is said to be ionized. It is, therefore, believed that the ionization of the upper air makes it possible for the radio waves propagated at a high angle to be returned to the earth. It is further believed that the ionization begins at about 20 to 30 miles, increases to 100 miles or more and thereafter does not increase and may possibly decrease. The principal cause of this ionization is the ultra-violet light from the sun which strikes only the daylight portion of the hemisphere. This source of energy throws out at inconceivable speeds myriads of actual electrons (β particles) and many ions (α particles). Unlike the ultra-violet, these particles do not continue towards the sunlit part of the earth but many of them follow the lines of force of the earth's field and converge at the magnetic poles. From that point they may migrate towards the equator to some extent. This form of ionization concentrated, has remarkable visual proof in the aurora borealis and aurora australis and colorful displays of diffused light which seems to radiate from the magnetic poles. It is a fact, however, that the green (oxygen) line of the aurora is always present in the night sky even at the equator. This requires a supplementary explanation of night ionization. One theory is that cosmic radiation—electro-magnetic waves about one-ten millionth as long as visible light waves—that appear to originate from the destruction of atoms in the great suns that we call stars. Generally speaking, we can assume that the ionized region is more intense and extends lower in the daytime and is less intense and high at night, also that it is more intense and lower in summer than in winter. It was pointed out before that ionization detects the presence of electrons and two kinds of ions. As far as short-wave transmission is concerned, ions are of little importance the important thing being the number of free electrons per unit of space—the electron density. Increasing the electron density decreases the dielectric consonant of space and as the velocity of the radio wave is inversely proportional to this dielectric consonant to increase velocity above that in empty space. It is seen, there fore, that a radio ray (or beam reduced to negligible thinness for convenience of discussion) is entering a less dense or lighter medium when it enters an electron bank similar to the manner in which light waves enter a less dense medium in passing from water to air or from glass to air. A ray entering a less dense medium at an oblique angle will, of course, be bent out of its straight course or refracted, Fig. 17. A radio ray entering a region of increasing electron density acts in a similar manner and having left the earth's surface on an upward slope is bent down again towards the ground. In addition, any one ray is actually refracted into four different rays or, to simplify the discussion, we will only consider one of them. It seems unreasonable to be so definite about the action of these rays which are invisible so far above the ground. However, the general hypothesis is borne out by experiments under varying methods and the exact evidence is accumulated. In past years a theory was presented that radio waves were reflected from the under surface of a fairly ionized (conducting) layer and this may possibly occur occasionally. In most cases, however, the ray is refracted (bent traversing through mediums) rather than reflected (made to rebound by a surface that will neither absorb nor transmit it). It is more convenient and simple to discuss the phenomena and show the action graphically on a reflection basis. The "refracting layer" indicates the region where the ray begins to bend and where it starts downward. The "equivalent reflecting layer" indicates

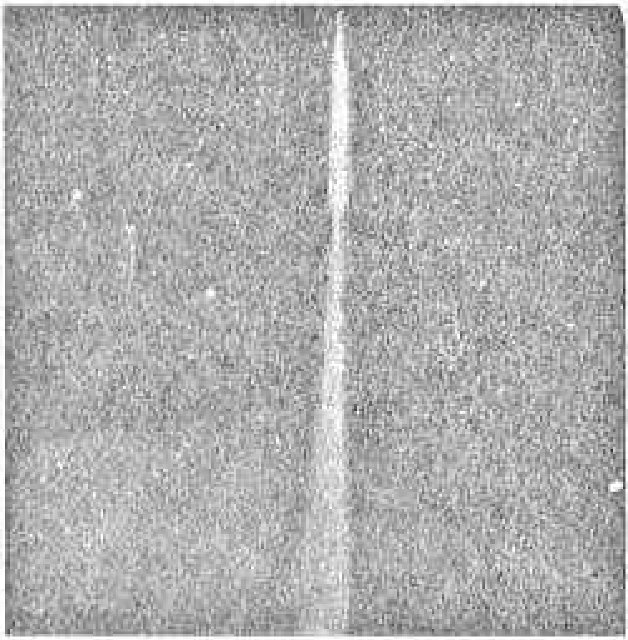


Fig. 16

Probable appearance of things in the ionized layer. The Goddard high-altitude rocket, only man-made contrivance capable of reaching these heights, zooming up from the earth dimly visible hundreds of miles below, gleams in the light of a blue white sun, which blazes against a black sky filled with brilliant stars.

hypothetically the reflecting surface the result of which would be the same downward directing action as a given refracting layer. It should be remembered that the actual summit of a ray in general for short waves is about three-quarters as high as the equivalent reflecting layer. In the illustrations of the light beam analogy, Fig. 21, the light beam slopes up from one of the miniature stations on the ground, strikes the layer and is reflected down to the other ground station. In referring to the layer height and changes in that altitude it does not mean that anything definite or tangible has physically moved. It would rather indicate that changes in the ionized region that may be a particular layer which is refracting certain radio rays, a higher or lower one, actually the effective layer height varies slightly with the inclination of a given ray and varies widely with the wavelength, perhaps twice as high on 20 meters as on 80 meters. However, great variations of layer height are noted according to the season of the year, summer or winter, and day or night. It follows that it is lower in summer, higher in winter; lower in the daytime, higher at night; intermediate for the fall and spring and early morning and late afternoon; lowest on a summer day, highest on a winter night. It is believed that the effective height under these varying conditions is approximately as follows: a summer day 50 to 100 miles; a summer night 150 to 220 miles; fall or spring day 80 to 150 miles; fall or spring night 200 to 300 miles; winter day 100 to 170 miles; winter night 300 to 500 miles. Over the North and South poles the layer is probably very low in summer due to perpetual daylight and very high in winter on account of continued darkness. The actual effect of the height layer Fig. 18 is that the lower layer discriminates against long waves in favor of short and ultra short ones while the high layer favors all the waves that it bends down at all. The exact action is explained later on. Immediately below the refracting layer possibly there is an absorbing layer. Just below the refracting layer there may be an absorbing layer, an important consideration for wavelengths around 214 meters but negligible for waves under 100 meters. In one of the illustrations (Fig. 19) it shows you that a luminous body in water can signal to another point over obstructions by using the reflection over the water surface. At rather large angles from the perpendicular this reflection is possible but of course as the ray increases in elevation it will reach a point where it has no reflection downward at all but instead passes out of the water entirely although possibly somewhat refracted. In addition, there is one outstanding ray which follows a middle course and skirts the water surface which is most useful for communication under these conditions. This might be considered the limiting ray. In the case of water and air this critical angle is 48.5 degrees. Following the laws of reflection the limiting ray descends at the same slope as the ray which ascends although the ray just above it would not ascend at all. Practically the same effect takes place in the downward bend of the radio waves refracting (or equivalent reflecting layer). In the illustration (Fig. 18) given where the angles are complementary or added up to 90 degrees the limiting ray returns to earth at its ascending inclination; the next higher ray does not bend downward at all but skirts the layer; all rays still higher pass off into space useless for any communication upon the earth. The inclination of the limiting angle varies with the limiting ray in general and limiting angles are lower for the short waves and correspondingly low for any wave as the layer rises. The following values of the limiting angle have been given by Taylor: for example—at an equivalent reflecting layer height of 1,000 miles corresponding to a spring day 54 degrees for 40 meters,

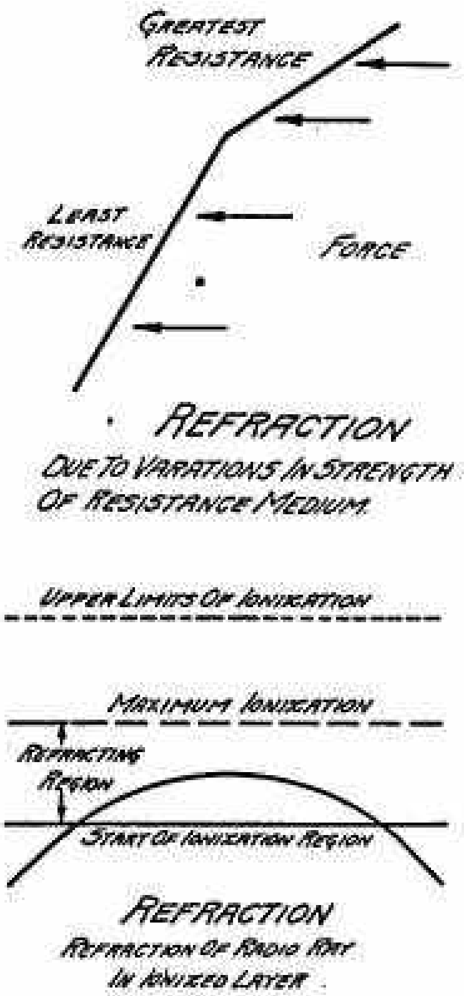


Fig. 17
Refraction, showing action caused by the ionized layer.

18 degrees for 20 meters; at 2 and 20 miles, summer night, 53 degrees for 40 meters, 14 degrees for 20 meters; at 500 miles, winter night, 52 degrees for 40 meters, 0 degrees for 20 meters. The limiting angle of 0 degrees means, of course, that even the tangent or horizontal ray is above the limiting angle and long distance communication is impossible. The critical wavelength is considered as a short wave length which can be used for a given layer height. This approximates 25 meters for 500 mile layer, 11 meters for 100 mile layer. A rare summer day occurrence is a layer as low as 40 miles which would make 5 meter long distance work possible. After defining the limiting angle and the limiting ray we can better explain the "skip distance" which is the distance to where the limiting ray first returns to earth measured sometimes from the transmitter and sometimes from the limit of the ground wave which at high frequencies only extends out 30 to 50 miles. As the wavelength decreases with the same wave layer height the skip distance increases. Therefore, at certain times of day we can communicate between points on 40 meters but not on 36 meters. With a given wavelength skip distance increases as the layer rises; the limiting angle is lower and a given ray can rise farther or bend downward. This is shown in the accompanying diagrams. In actual operation the skip distance may be considered as follows: height of equivalent reflector, 100 miles, no skip on 80 meters, 100 miles on 40 meters, 500 miles on 20 meters and 1,000 to 2,000 miles on 10 meters; a layer height, 225 miles, skip effect hardly noticeable on 80 meters, 200 miles on 40 meters, approximately 1,000 miles on 20 meters and on the 10-meter length it never returns. Considering a layer height of 500 miles there is a very short skip effect on 80 meters, about 400 miles on 40 meters and on the 20 and 10 meters it never returns. In the case of an aeroplane short-wave transmitter there may not be any skip effect noticed if all rays below the horizontal cover all the ground which would normally be skipped. In general it may be considered for any middle range as day brightens we may use shorter waves and as night approaches we should use longer waves. It is not unusual for signals to be heard within the skip distance and is accounted for the ground wave or "throw-back" theory advanced by Taylor and Young. They reported cases of echoes at a Washington transmitter which seemed to come from Labrador and the Southwest and some later throw-backs on 15 meters which came from the ocean. The size of the ground on rough water slopes in relation to wave length makes this theory possible. It will be shown later on that in addition to this one skip distance on very short waves there may be several skips outside the first. Referring to the first discussion of ground absorption within the transmitter and the latter discussion of limiting rays it will be seen that the rays useful for communication will be included between the limiting ray and the lowest ray not absorbed by the ground inasmuch as all these rays return to earth. Higher rays will not return to earth and lower rays will be absorbed. The height of the trans-

mitting aerial and the topography of the surrounding country all have their effect on the lowest useful ray. In actuality this ray is much lower for the shorter wave than for the long or the limiting ray is also lower. In general it may therefore be considered that the lower angle is most useful on short waves and the higher angle on long waves. This means that with only lower refraction it will travel farther along the earth's surface. Furthermore, it may be reflected upwards again and refracted down several times; it is expected that each earth reflection absorbs energy and we may now state the

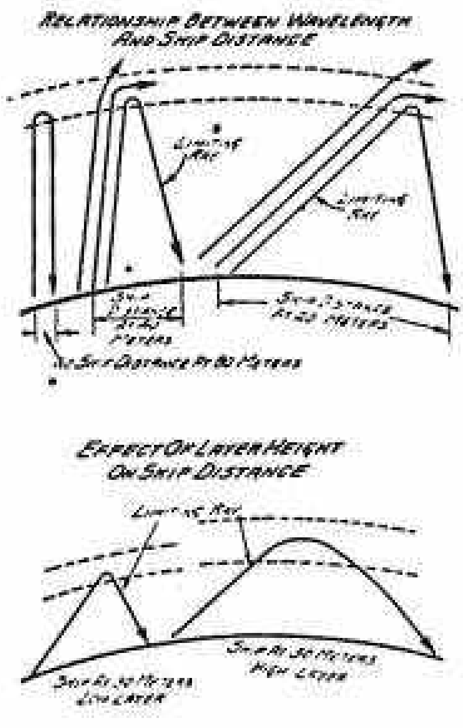


Fig. 18

Skip distance, upper figure showing relation of wavelength and skip distance; lower illustration showing effect of layer height on skip distance.

great advantage of short waves: that being permitted the use of lower useful rays, they traverse farther along the earth's surface on one refraction or on few refractions and reflections with less consequent loss of energy. For long wave communication it is, therefore, desirable to use the shortest possible wave and we find that the strongest signals are always just beyond the first skip distance. Referring to the accompanying diagrams it indicates how the extreme refraction is governed by the layer height. A station desiring to communicate with another separated 2,500 miles on a winter day or at a layer height of 150 miles the lowest useful ray will return to earth far short of that distance. As a matter of fact around 800 miles is the limit for daytime low power work on 40 meters. On the other hand at night the same ray can rise to a 500-mile layer and on its first return to earth will be well within the 2,500-mile range. Furthermore, low power communication from this distance on a winter night is relatively easy. Some considerations have been left out for the matter of simplicity; nevertheless, it illustrates the governing principles. The range may be greatly increased on one sky refraction by one other possible effect. It is believed that the limiting ray or the one just above it does skirt along the layer for a great distance, perhaps half way around the earth, and then encountering somewhat different refracting conditions bend down again towards the earth. This effect may occur quite often even in practice but the scientific opinion and the accumulation of experimental data seems to indicate that it is the exception rather than the

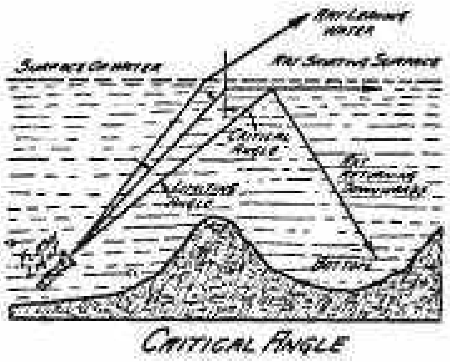


Fig. 19
Critical Angle. An equivalent illustration.

rule and that most extreme distance transmission depends on earth or water reflection. Referring again to a light illustration, suppose that we direct a brilliant and concentrated beam of light obliquely downward on a mirror. We can see in dusty or smoky air that the beam is directed upward in practical form. Substituting a piece of white paper for the mirror the reflecting beam is less intense and spreads out in a wider scope. Substituting gray paper or a rougher surface both the diffusion and absorption increase and continue no further. With black felt the absorption is practically complete. When the downward sloping radio wave strikes the earth's surface the same general effects are possible. Sea water is a fair conductor and if not excessively roughened by storms a good reflector of short waves corresponding possibly to the mirror of our light example. Damp ground fairly level is probably a fair reflector corresponding to rough white paper. On the other hand, ground that is very dry and rough must be a poor reflector absorbing nearly all the energy. Furthermore, the roughness or either water or ground depends on the wavelength. The effectiveness of ground reflection along an accepted theory is a subject of debate. Some scientists maintain that most of the energy is absorbed or scattered. In the case of long distance communication it must be remembered that three-quarters of the earth's surface is covered by sea water. Part of the energy is actually lost and short wave efficiency proves that a few reflections are desirable, but a fair amount of energy is reflected mirror-fashion under average conditions. The downward sloping ray being reflected by the ground skyward and again brought down by an ionized layer refraction at twice the distance of the first ground-strike from the transmitter and we may conceive these continued up and down all the way around the circumference of the earth. In actual practice using high powered transmitters "echoes" which have completed the 24,000-mile circuit some times appear again at the receiver and spoil the signals. There is also the condition where the transmitted signal arriving at a point nearly half around the world arrives

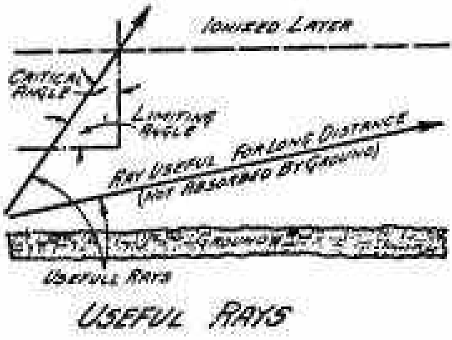


Fig. 20
Useful Rays.

at both directions a short time interval apart. It is obvious that one signal following the other would cause distortion. For this reason it is desirable that the transmitted wave be directed in one direction only. More will be said about this reoccurring signal. Taylor has presented a series of graphs covering this subject, for example: on 40 meters with a layer height of 225 miles (summer night) the first skip extends 200 miles out from the transmitter. At this point the signal comes in strongly and from there on it is continuous with no further skips for the first refracted ground reflection comes down again before the single refractions have extended out to the lowest useful ray. If the 500-mile layer (winter night) is 40 meters the skip extends out to 500 miles with no skips thereafter. On a spring night with the layer at 300 miles we notice the typical ultra short wave pattern the first skip extends out to 2,000 miles at which point the signal is strong and holds out to 3,000 miles. Between 3,000 and 4,250 miles is the second skip, after which the signal holds again until 6,000 miles. The third skip occurs between 6,000 and 6,400 miles and beyond 6,400 miles the signal is continuous. A 10-meter wave has an infinite first skip unless the layers are at 60 miles or lower. With this rather unusual layer the 10-meter pattern would be subject to wide skips and narrow signal bands as far as the Antipodes at least. On longer waves all stations in the signal zones are passed by several waves traversing widely different paths. This is also true of short waves beyond the first or second skip therefore, the patterns are less true in fact than they are in theory.

The causes of fading are all particularly interesting. It has been noted these have been more violent on the shorter wave and this is attributed to the nature of the ionized region and the complicated nature of ray refraction. The major cause is probably due to variations in the height of the refracted layer. Heising has measured the effective layer heights continuously over fairly long periods during the night and has found that it rises and falls in

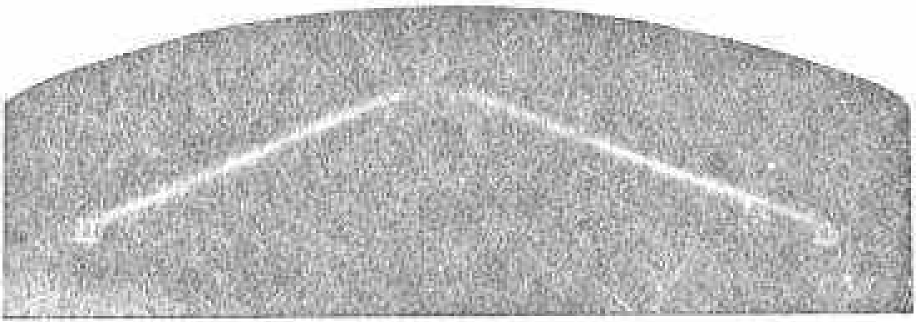


Fig. 21

Light Beam Analogy of Ionized Layer Equivalent Reflection. The light rays represent radio waves leaving the transmitter at high angle, to be "reflected" by the ionized layer down again to a distant receiver.

cycles each of which lasts around 15 minutes. It is calculated that the rising rate is something like 6 miles per minute. The falling speed is thought to be much greater possibly around 20 miles per minute. It may be considered in general that the layer height swings up and down in slow cadence rising gradually and falling rapidly. On the other hand in the daytime under the sun's ultra-violet radiation the layer is much steadier and consequently it is noticed that in the daytime fading is much less pronounced. It is also noticed that the most pronounced short wave fading occurs at the outer edge of the skip distance. At this point the ground-strike of the limiting ray may fluctuate back and forth with the signal varying between the maximum and zero. Further matters must be considered besides layer height. Relative numbers of electrons and ions, upper air absorption, the extent of the ionization height, all play some part in determining the effective layer height. The phase difference between the rays arriving at different paths is quite important and believed to cause a great part of the 50 to 100-mile fading in the broadcast band.

In view of all the varying factors and matters to be given consideration it would seem fortunate that short wave transmission is as steady as it is. In the previous discussion reference has been made to layers of uniform height and it is apparent from long distance work such an ideal condition will hardly exist, for example, if the night layer is much higher than the day layer, and we feel sure it is, there must be more defined slopes at the sunset and sunrise lines. To visualize these slopes as they possibly occur on earth it is only necessary to shine a spot light on a small globe. To illustrate conditions at any particular date, we can refer to the sun's declination in the Nautical Almanac and tilt the globe so that the shadow line is the given number of

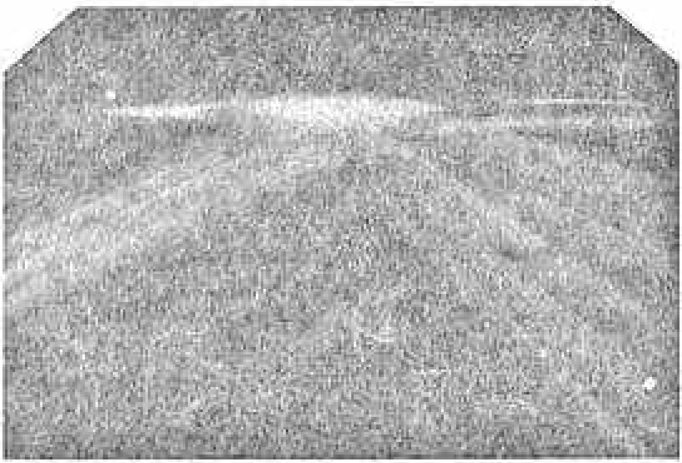


Fig. 22
Ground Reflected Rays.

degrees beyond (for + declination) or short of (for — declination) the North Pole. Considering the percentage of path in darkness and the consequent high layer suited to few reflections, sunrise is probably the best time for amateur work on the 40-meter band with Australasia. This is particularly true in the Western United States in as much as in addition to giving a favorable slope the sunlight in East absorbs interfering signals from most of the American continent. As an actual fact communication has been carried on between Texas and Australia with the sun an hour up in the sky. On the other hand, for communication with Europe and Africa, sunset is preferable. Communication has been handled between New York and Belgium an hour before sunset taking advantage of the darkness over most of the path and minimum of interference from the West and the layer slope. It does not seem impossible that the layer slope may focus several incoming rays the majority of which would normally go to other regions on a single receiver with considerable increase in signal strength. This theory has been advanced by Wenstrom exclusively. He has reported that the 25-meter phone signal from Chemsford, England, received at New York increases very noticeably about one hour before sunset, continues relatively strong through sunset and drops off rapidly with approaching darkness.

Taylor pointed out the daylight-darkness layer slope may have a decided effect on the patterns of ultra-short waves. Toward darkness all skips after the first tend to close up making the signal zone practically continuous. Toward daylight the second skip and possibly other ones tend to open up and create narrow signal zones separated by wide skips. At 20 meters, therefore, it may be possible to transmit from a western station to an eastern station but

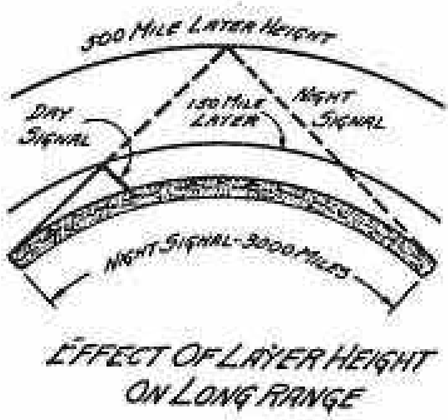


Fig. 23
Effect of Layer Height.

not from an eastern station to a western station. In other words, we can use a shorter wave for a west to east communication than for an east to west.

Actual Results

The Radio Engineering Division of the German Experimental Institute for Aeronautics have made a series of interesting measurements and observations covering the adaptability of short waves for aircraft communication. Messrs. K. Kruger and H. Plendl outlined the results in recent writings. Previous investigations on short-wave propagation have been confined to the matter of covering relatively long distances. These new investigations covered the distances now required by aircraft 500 to 1,000 kilometers and the results obtained present new data.

One of the questions to be decided was whether it would be possible to cover the entire range of distances continuously with one frequency, or whether a series of different frequencies would be necessary. The associated problem was the influence of the power variations during day and night and the propagation of these waves.

The following tabualtion is given describing the apparatus used:

TABLE I

LIST OF EQUIPMENT USED

No.	Designation of equipment	Manufacturer	Type of wiring	Range of wave-lengths in meters	Antenna power of transmitter in watts	Weight without batteries in kg.	Figure No.
1	One-knapsack set SERKT 127 Transmitter:	C. Lorenz A.-G.	quartz-controlled, one stage without intermediary circuit	40-60	2		
	Receiver:		audion, 2 low-frequency stages	30-60	—	5.7	
2	Short-wave transmitter for airplanes (first experimental type)	Telefunken G.m.b.H. in cooperation with Radio Division of DVL	(a) quartz-controlled, one stage with intermediary circuit	40-80	2	2.2	
			(b) quartz-controlled, two stages with duplication of frequency	20-40	2	4.5	
3	Short-wave transmitter for airplanes (improved type)		quartz-controlled, two stages with duplication of frequency	30-70	2	4.0	1 and 2
4	Laboratory transmitter	Radio Division of DVL	quartz-controlled, double duplication of frequency Amplification of capacity	10-60*	10 or 60	14.4	
5	Short-wave receiver for large stations, Gr. 98 special	Telefunken G.m.b.H.	push-pull audion, 3 low-frequency stages	11-80*	—	14.3	
6	Short-wave receiver for airplanes	"	audion, 3 low-frequency stages	30-70	—	5.0	3
7	Short-wave receiver for large stations, E.R.K.127	C. Lorenz A.G.	audion, 2 low-frequency stages	12-100*	—	12.1	
8	Rectifier measuring apparatus	Radio Division of DVL	grid rectification with measuring instrument in anode circuit	—	—	2.2	

* with interchangeable coils

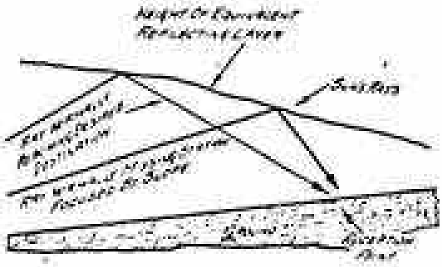


Fig. 24
Sunrise-Sunset Slopes.

The Lorenz set generates its high-frequency energy in a single quartz-controlled stage. The minimum wavelength is approximately 40 meters, the limit of practical quartz oscillator crystals for practical operation in a simple circuit. Telegraph signals are sent by interrupting the plate circuit, so that the oscillation of the quartz must start each time the key is pressed down. This arrangement is not ideal as the sudden application of voltage to the crystal may under certain conditions excite a secondary wave of the quartz, which often occurs in crystals of small size, instead of the primary wave; this causes a change in tone at the receiver or even inaudibility. This is of course annoying to the receiving operator especially in high-speed code reception.

The Transmitter designated No. 2 in the table was developed to eliminate these undesirable features. There are two stages, according to wiring scheme 6 (Table 1). The first stage is quartz crystal controlled and has a wave-

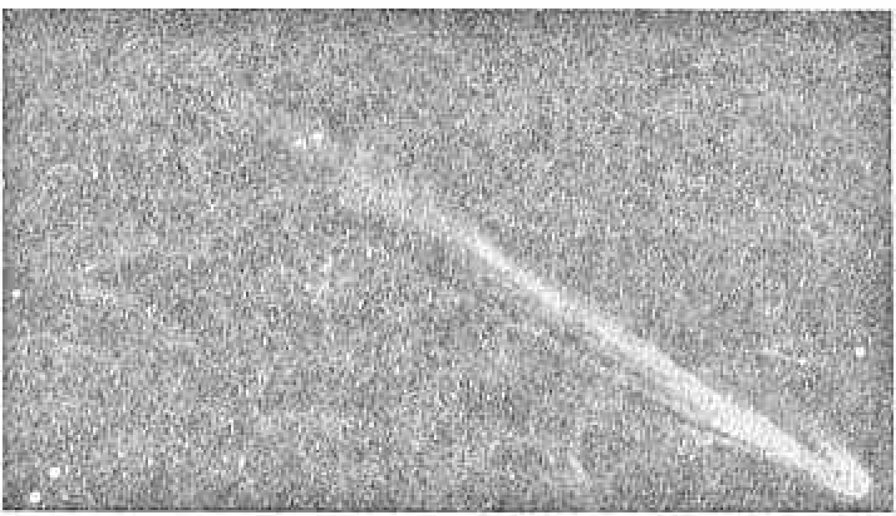


Fig 25
Meteor Trail.

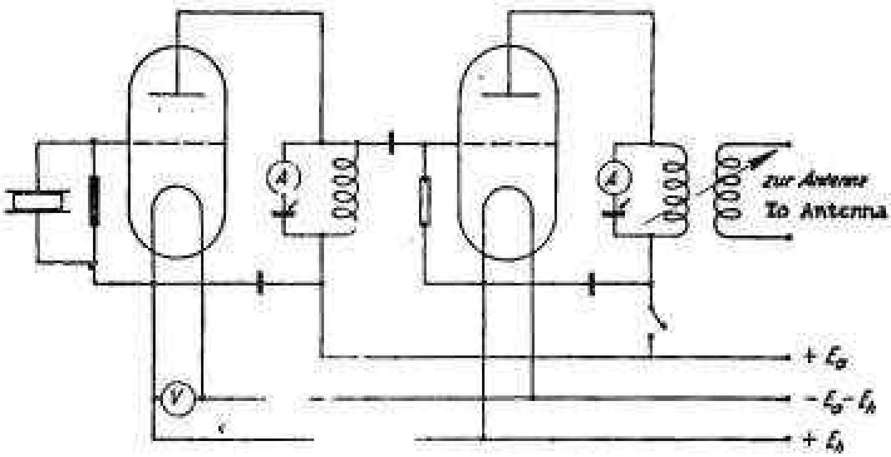


Fig. 26

Basic Wiring Diagram of Short Wave Transmitter for Airplanes, Quartz Controlled Type with Duplication of Frequency. Design DVL—Telefunken.

length range of 40 to 80 meters. The second stage is a frequency doubler, the minimum wavelength of the arrangement thereby being reduced to 20 meters. The signalling is taken care of by breaking the plate circuit of the frequency doubler tube (about 200 volts), the quartz-controlled stage, held constantly in the oscillation condition.

The superposed tone obtained in a receiver from this transmitter is perfectly clear, easily distinguished from disturbing noises and very suitable for high-speed radio telegraphy. The same advantage would be obtained if, in the keyed second stage, a power amplification of the quartz frequency were provided, instead of the doubling of the frequency. However, in this case, because of the amplifier circuits tuned to the quartz wave, the coupling would be too large between the antenna and the quartz stage that continues to oscillate during the intervals of transmission; when the key is released. Operating such a transmitter, the superposed tone in the receiver during these intervals would not completely disappear, but only decrease in intensity. This would impair the legibility of the signals.

The quartz-controlled first stage can be used independently but only with the disadvantages previously mentioned. The additional cost and complications of adding the frequency doubler stages are therefore well spent. Therefore, the quartz control and frequency doubler were combined in a single set as an improved type set for aircraft (No. 3 in Table 1). The wavelength range of the doubling stage is 30 to 70 meters. Fig. 26 shows the basic wiring diagram.

As mentioned under the chapter of aircraft equipment, reception in air aeroplane is made difficult by the motor noises, vibration and ignition electrical disturbances. The short wave receiver for aircraft must have special requirements to insure satisfactory operation, outside of the important consideration of size, weight and associated equipment; it must have high amplification in order to produce signals of a greater intensity than the local disturbances (non-electrical). It must of course be rugged in construction and protected against acoustical influences, in order to prevent the ever present mechanical and acoustic vibrations from exerting a disturbing influence on reception. While ignition noise can be reduced, it is more important to maintain a pure constant tone for the receiving operator which enables receiving messages even through a disturbing background.

Receiver designated as No. 5 was used for most of the observations made in the airplane. This is a special "Telefunken" design for use in large stations and for aircraft work was provided with a third low frequency stage of amplification, instead of the heterodyne. Aluminum was used for the cabinet instead of copper. The results from this receiver were generally satisfactory, but it did not produce a pure superposed note due to vibrations from the air plane. A good many experiments followed and led to the development of the short-wave receiver for airplanes mentioned in Table I as No. 6 and shown in Fig. 27. This receiver had the same sensitivity, but showed considerable saving in weight and space, also, it was much less sensitive to vibrations. The following results outlined not only relate to the short-wave propagation phenomena but also relate to the development and testing of the apparatus involved.

The experiments were subdivided in the following manner:

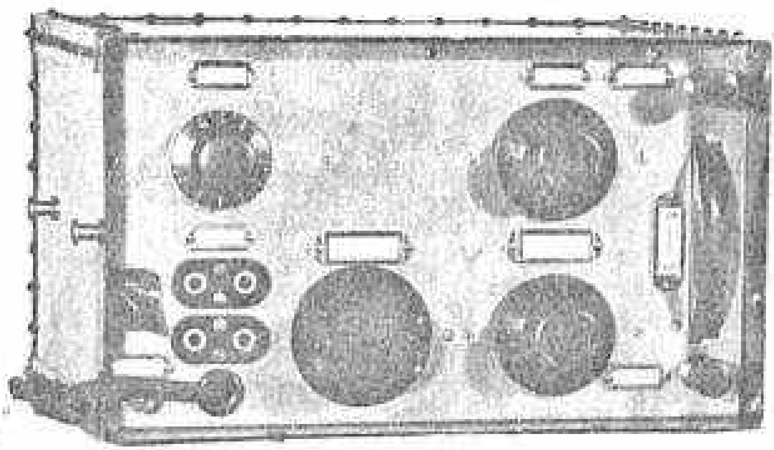


Fig. 27
Short Wave Receiver for Airplanes. Design DVL—Telefunken.

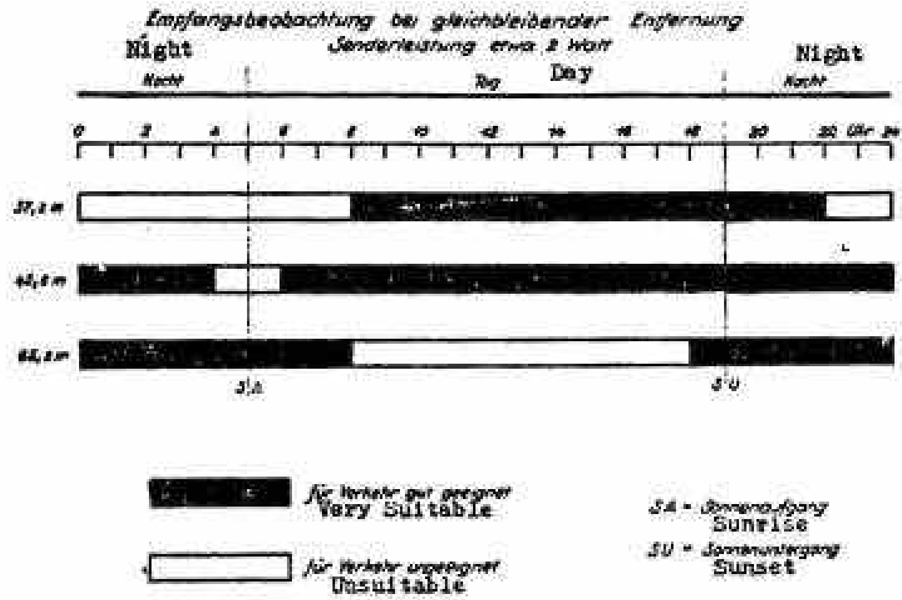


Fig. 28

Graphic Presentation of the Results Obtained with Reception at Constant Distance.

For *constant distance*, the intensity of the signals in relation to the time of day was observed with different wavelengths taken as the parameter.

Different airplane antennae were compared in this respect. The transmitting power was maintained at 2 Watts in most cases.

The influence of *varying distance* on the intensity of the signals was observed with different wavelengths as the parameter. Generally these observations were made exclusively during broad daylight throughout the entire distance, and continued through a whole year. In the experiments, horizontal dipoles were used as an antenna.

(A) Experiments With Constant Distance

The stations participating of major importance, were the land stations at Berlin-Adlershof and Munich. Adlershof conducted the transmitting, Munich, the reception, the distance between these two points being approximately 500 Kilometers. In order to keep the Adlershof station informed on the results, a small two-watt transmitter was installed at Munich, providing a means of intercommunication. In comparing airplane antennae, local flights were made over one of the two stations, while the other station recorded the observations, therefore the distance between the transmitter and receiver remained constant.

At Adlershof the observations were made in a small building, detached from the main Radio Division building to prevent external disturbances as far as possible. Remote control enabled operation of the transmitter in the main building.

In Munich, the apparatus was located in a special small building. The antenna at both locations, consisted of a horizontal dipole with a length of about twice 8 meters and with bifilar conduction of energy.

The primary purpose of these experiments between ground stations was to ascertain the behavior of different wavelengths during different hours of the day, and recording this data. It was also desired to determine if, and by what means suitable communication during the daytime could be established over a distance of 500 Kilometers, with outputs of from one to ten watts. The wavelengths used varied between 30 and 65 meters and undamped radio telegraph signals were used exclusively.

Fig. 28 shows the results of these experiments as relating to the wavelengths of 37.2, 48.6 and 65.2 meters. The black portion of the bars indicate the hours during which it was possible to use these wavelengths for communication, and the white portion of the bars indicate no communication possible, or unsatisfactory signals.

This particular data illustrated was gathered during the middle of April. This is mentioned as there are variations with seasons due to the varying length of the day. This diagrammatic illustration is the condensed result of a number of observations and not claimed to show quantitative values.

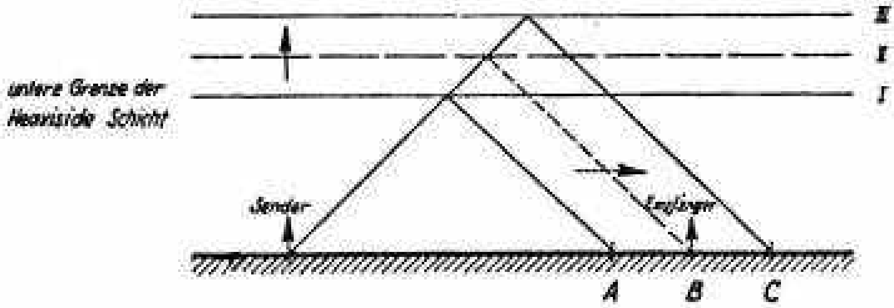


Fig. 29

Diagram of the Boundary Wave of the Fading Zone.

It is interesting to note that the limits of the fading and the reappearance of the short waves as illustrated in the figure are quite distinct. The transition from an extremely loud signal to practical inaudibility generally takes place in a few minutes. At this time reception suddenly wavers greatly, the frequency of fading increases many times, while the amplitude of the signal intensity decreases rapidly. During this critical period, the intensity of the received signal fluctuates in the course of fractions of seconds, in a ratio of 1:1000 or more.

Brief variations in intensity also occur frequently at other hours, especially around noontime, but to a less noticeable degree, about 1:10 and more rarely 1:100 as taken on a measuring device.

Due to the logarithmic sensitivity of the ear, variations in the intensity in the ratio 1:10 have but little influence on the audibility. During the evening and night hours, the intensity of reception varied within comparatively narrow limits, about 1:15 and in a few cases even a perfect constancy of the signal intensity was observed.

Impairment of reception by atmospheric disturbances could not be detected except on occasional events caused by local thunder and lightning storms. The intensity of the signals varied from 2 to 8 m.a. and even in some cases to a maximum of 30 m.a. and this was in general substantially above the noise level, the latter being on the order of 0.05 m.a. Temporary disturbances of local origin such as, commutator sparks, ignition sparks, etc., did cause some annoyance.

A good idea of the wave propagation phenomena can be obtained in the following manner. The failure in reception occurring in some places during the night and in the early morning hours for shorter wavelengths (37.2 and 48.6 meters in Fig. 30) are evidently caused by a shift in the minimum distance required for the return of the space wave to the surface of the earth, this is, by a displacement of the "skip distance" away from the transmitter, during the night. One can imagine the phenomenon as being caused by the fact that during the night the space wave due to the less intensive ionization of the lower layers, is refracted at a greater altitude than during the daytime. Fig. 29 illustrates this phenomenon. The lower boundary of the Heaviside layer during the night gradually shifts up from I to III, so that the innermost wave belonging to the skip distance shifts from A to C. At a certain moment, this limiting wave passes the point B, which is the location of the receiver, the result being a rapid decrease in the intensity of the signal. In the morning the action is reversed, the result being a correspondingly rapid increase in the intensity of the signal received at B.

Contrary to the short wave action so far considered, for which reception is unsatisfactory during the night or early hours of the morning, the corresponding moments when the somewhat longer waves of air (for example those of the 65 meters in Fig. 30) occur around noon. The transition differs here from that occurring in the case of the shorter waves, in that it is gradual. The difference must be due to the fact that with increasing wavelength, the guided wave becomes active at points farther and farther away, while the innermost limit of the space waves shifts toward the transmitter, so that space wave and guided wave overlap. Fading zones, which were the cause of suc-

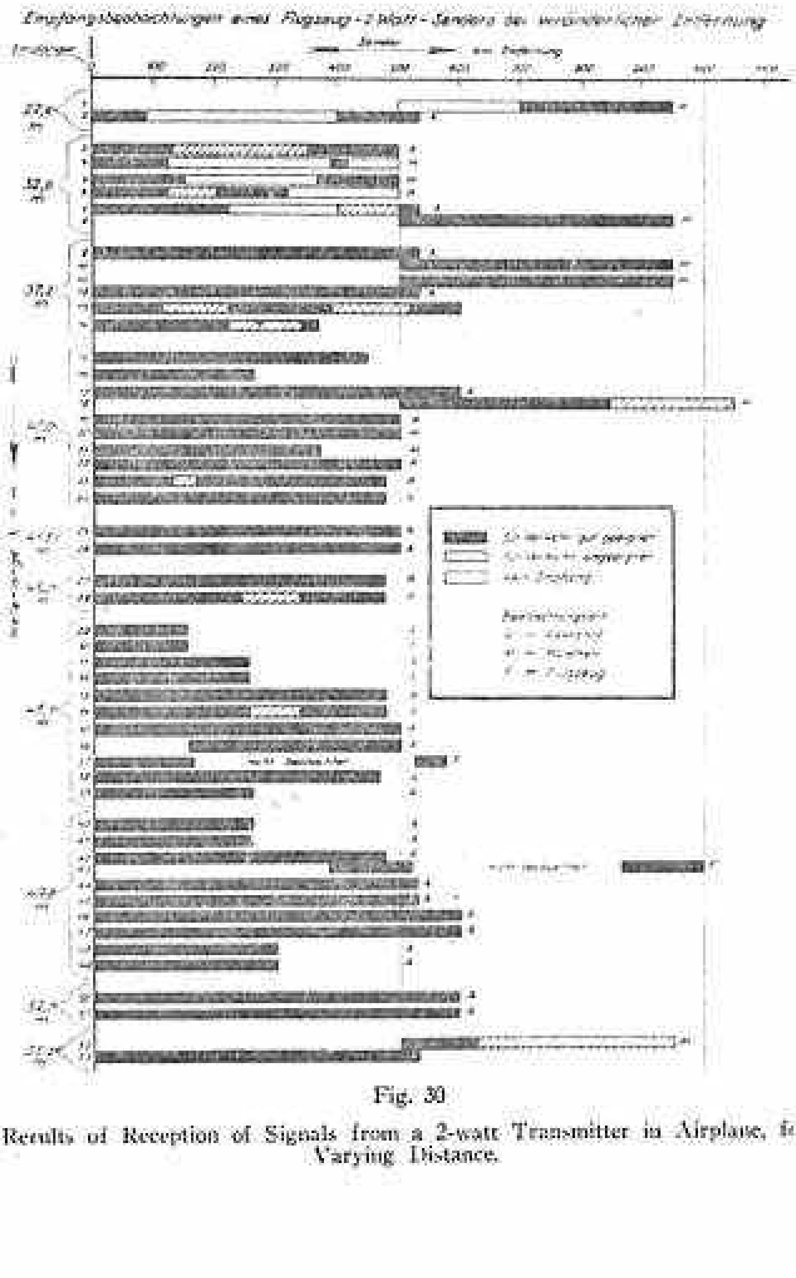


Fig. 30

Results of Reception of Signals from a 2-watt Transmitter in Airplane, for Varying Distance.

den variation in signal intensity, as shown above, therefore do not occur here any longer.

Similar results to those just described above between the two grand stations was also obtained by numerous local flights above Berlin-Adlershof and above Konigsberg in East Prussia, there flights being made during different times of the day and also during the night. In this case, the transmission occurred with different waves from the airplane while the latter was in flight, and the reception was observed in Munich, the distance being about 500 and 1,000 Kilometers respectively. The results obtained by experiments between ground stations proved that they also applied to a great extent to communication between an airplane and ground. Incidently during the numerous ascents and landings there was no perceptible difference in reception when the plane transmitted from the ground or from the air. Furthermore, no essential difference was noticed caused by the altitude at which the plane was flying during its transmission.

During these local flights, comparisons were made between different kinds of transmitting antennae. The dipole always used in other cases was compared with a single wire trailing antenna which was excited in one-quarter or three-quarters of a wavelength respectively. It was demonstrated that the tightly strung dipole was essentially superior, as to constancy of frequency, providing purity of superposed note in the receiver, as compared to the trailing antenna whose position is never completely stable. Considering the signal intensity, the trailing three-quarter wavelength antenna was slightly superior to the dipole, while the one-quarter wavelength trailing antenna was decidedly inferior.

(B) Experiments With Varying Distance

The previous discussion related principally to the propagation of short waves as a function of the time of day, the following experiments are related to the determination of the influence of the distance between the transmitter and receiver on the signal strength at the receiver. Metal airplanes of the F-13 type were available for these experiments and equipped with dipole antenna and corresponding associated interior equipment. Experimental flights were also made in a Dornier-Wal airplane whose wings were covered with fabric.

A series of overland flights were made in different directions with these airplanes within the German frontiers and transmission from the airplane occurred principally with undamped waves and a power of 2 watts in the antenna. Observations were always made at Adlershof and in addition sometimes at Munich. Adlershof being the starting and finishing point of these flights, the longest distance within Germany was confined approximately 600 Kilometers, when the reception was observed at Berlin. To extend the experiments over a greater distance, without having the planes leave the frontiers of Germany, several flights were made to Konigsberg and Tilsit, in which case the reception could be observed from Munich, for a maximum distance of about 1,000 Kilometers. In addition to the 2-watt transmitter, a receiver was always taken on these flights, enabling a check on the transmission and providing a means of communication with the observing land stations. During these flights the transmitter was kept in continuous operation and usually actuated by a clock mechanical sending apparatus. This automatic transmission was supplemented by reports covering the plane's position and weather observations.

Fig. 30 showed the deductions drawn covering the relation to distance, the receiver always being placed at a distance 0, while the airplane transmitter must be considered as moving in the direction of the abscissa. Every observation of an overland flight corresponds to a horizontal bar; these plotted in Adlershof are indicated by an A and those in Munich by an M. These bars are numbered continuously and arranged according to wavelengths. The black portions in the illustration correspond to reception perfectly suitable for radio communications, the cross-hatch portions indicating uncertain wavering reception and the white portions represent the range of distance where reception fails entirely.

Reviewing the diagrams in Fig. 30 it is clearly indicated as to the essential difference between the shorter and longer waves within the range of 27 to 55 meters.

Below 38 meters, these shorter waves show distinct fading zones, contrary to fact that they are suitable over the longer distances. Wavelengths between 40 and 46 meters, have fading zones occur only exceptionally, so that the possibility of good communication increases for the smaller distance. For wavelengths over 50 meters, no fading zones are perceptible. This wave bank (approximately 50 meters) is therefore suitable for constant communication over a range of distances up to about 600 Kilometers.

The favorable results obtained with the 50-meter band was confirmed by a series of overland flights, during which the signal intensity of a transmitter located on the ground was observed by means of a receiver on the airplane. Most of the time this transmitter operated on 48.5 meters (undamped waves) and with an antenna power of about 60 watts. Four of these flights extended over a distance of 600 Kilometers, and an equal number over a distance of 300 to 450 Kilometers. In each of these cases a satisfactory signal strength could be obtained, without fading zones, using receivers with sufficient sensitivity (detector and three audio stages).

According to Fig. 30, the fading zones for the waves of 27 meters and 32 meters occur between 100 and 400 Kilometers. The boundaries of these zones have an entirely different behavior. Whereas for the inner boundary the reception weakens in a gradual manner, there occurs in the case of the outer boundary an abrupt change in the signal intensity, corresponding to the sudden action of the space wave. There is not always a complete extinction of the reception in the fading zone, rather it happens that the transmitter, even with such a low power as 2 watts, remains faintly audible at all times. In principle, it is impossible to indicate accurate and definite boundaries for these zones, as shown by the example of observation No. 6 in Fig. 30. In fact in the middle of the range which had appeared to be, in all other observations of this wave band, a pronounced fading zone, there was obtained good communication over a long distance (about 120 Kilometers).

Accordingly it must be assumed that the zones of pronounced weakening or entire failure of reception observed for a transmitting power of 2 watts would no longer have any disturbing effect if the power were sufficiently increased, in the ratio of about 1:1,000 to 1:10,000; this assumption is based on experience previously gathered with high powers (8 Kilowatts). The experiments made at that time with relatively high powers showed that even with considerable shorter wavelengths (15, 18 and 28 m.) there cannot be located any absolutely dead zones, this being in direct contrast with the results reported by Reinartz, Taylor-Hulbert and Heising. The only result was that zones of pronounced weakening of the reception signal intensity were observed, this being in accordance with the observations reported by Eckersley, published at about the same time, which in addition to similar results obtained by actual observations, contained a theoretical explanation of these phenomena.

For wavelengths greater than 37 m. the results of the observations were decidedly inconsistent. Whereas in the cases of Nos. 9 and 12 the reception was always free from noticeable weakening, cases 13 and 14 showed spots where reception was uncertain. The discrepancies may have been caused by difference in seasons, as the former observations were made at the end of March and the latter in the beginning of July.

In the adjacent wave band of 40 to 46 m. about twenty observed flights indicated weakening zones in only three cases, the longest distance being 90 Kilometers. In this connection it must be remembered that exclusive use was made of horizontal dipoles as antenna at both the transmitting and receiving ends. Still more recent experiments seem to indicate that these weakening zones could be reduced by using vertical or combination antenna at the receiving end.

Excepting the three cases mentioned, where weakening zones were discovered, these waves and especially the 50 m. band gave continuously, a strong signal strength at the receiving end resulting in generally strong and interrupted operation, using a loud speaker. It was always possible to obtain distinct and easily measurable deflections of the rectifier measuring instrument after the low-frequency amplifying stages of the radio receiver.

The general observations in regard to signal intensity were about as follows. When the airplane equipped with the transmitter, moved away from the observing station, the signal intensity decreased in the first 20 Km. from about 15 m. a. to 5 m. a.; thereafter it remained at about this amount during the entire remaining part of the flight up to a certain critical distance. With the tubes used in the measuring apparatus, this deflection corresponded to a great volume in the loud speaker reception, and without being impaired by the outside disturbances. When this distance is exceeded, the signal strength decreases rapidly, but it always remained sufficiently strong for reception by means of a head-set. The critical distance is indicated in Fig. 30 by a vertical line. For the 37 and 40 m. bands it lies at about 800 Km.; for the 53 and 55 m. waves, at about 400 Km.; and for the 50 m. wave at about 600 Km. The critical distance therefore increases with a decrease in wavelength. The width of these critical zones was about 10 to 20 Km. and was covered by the airplane in a few minutes. Both the abrupt decrease in signal intensity with decreasing distance were repeatedly observed. In the case of observations 10 to 11, for example, the critical distance 780 (Km.) for 37.2 meters was observed both on the outward and return flights.

The fading phenomena observed during transmission from the airplane in flight were of the same order of magnitude as those observed for a constant distance under normal circumstances. Within the critical distance, for which the signal intensity was high and practically constant, it was never found that communication was impaired by fading phenomena. Only in the case where this distance was exceeded, the effect of fading occasionally caused a disturbance for a short interval. The critical distance therefore constitutes the maximum range for communication by means of the wave under consideration, for which reliable continuous reception is certain.

These observations just mentioned appeared to be independent of the airplane's altitude. The signal intensity remained the same independent of whether the airplane was in flight or on the ground. In several instances reception was still possible, at a distance of 500 Km. from the observing station, even though the plane and its transmitting equipment was in a closed reinforced steel shed.

In addition to the experiments described above, during which the transmitter was located in an airplane, there were additional experiments covering observations from the airplane. These tests were primarily intended to assist in the development of an airplane short-wave receiver and also to determine the power required for the ground transmitter for suitable communication. The wave band of 46 to 50 m. was selected on account of its previous satisfactory performance. The observations were taken on a series of ten long distance flights, the longest distance lying between 300 and 600 Km.

When the airplane is on the ground, with its motor stopped, the results of the observations mentioned above also apply, without further complication, to the reception inside the cabin. However, with the motor running, we have to consider the disturbances already mentioned, which of course impair the clarity and relative signal strength of reception. Because of these disturbances the 2-watt transmitter is not sufficient in this case; at any rate, the ground transmitters which are intended for communication with airplanes will be provided with higher powers. This will be true in spite of the fact that with the 2-watt transmitter using continuous wave telegraphy, satisfactory reception has been obtained on the airplane up to distances of 45 Km. using the receiver described as No. 5, Table 1. In other cases, the transmission from the ground station occurred with about 60 watts, the reception noted being of good signal intensity on flights up to 600 Km. distant.

In further investigations it is expected to determine the necessary power for the ground transmitters and to eliminate at least part of the fading by proper design of the receiving antenna systems.

CHAPTER III

Transoceanic Short Wave Radio Telephony

For many reasons, the decision of the International Telephone and Telegraph Corporation to establish a short-wave connection between South America and Spain presented problems particularly attractive to those engaged in the provision of such a link. The plans called for connecting subscribers in certain South American telephone operating areas with the great Spanish telephone network and, in addition, through Spain to other European networks. The requirements of the whole project included telephone transmission of a high commercial order for a prescribed number of hours each day, and the provision of equipment capable of connecting at the transmitting end and at the receiving end with two- or four-wire long distance land circuits—the control positions being located at each end of the radio link. Further, it was stipulated that the equipment should be such as to make it difficult for speech to be overheard by those for whom it was not intended. The development was commenced in the Research Laboratories of the International System at a time when little was known regarding short-wave telephony. Consequently, new problems had to be faced in all parts of the equipment, i.e., both in the radio and in the low frequency sections of the undertaking.

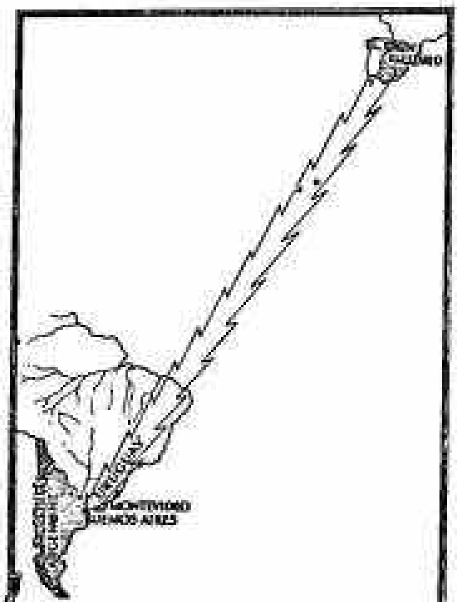


Fig. 31
Spain-South America Radio Telephone Link.

The radio path extends from the vicinity of Madrid to the vicinity of Buenos Aires, the distance between the ends of the radio link being about 6,400 miles. This path cuts the meridian at the equator at about 34 degrees. In following thus an oblique line between the Northern and Southern hemispheres, it passes through zones notorious for atmospheric disturbances, and through the equatorial region where radio transmission is particularly subject to fading. Devices for counteracting the effects of fading are accordingly installed, and in addition echo suppressor circuits for preventing the speech from being reflected at the distant ends form an essential part of the equipment.

When the requirements had been ascertained, the design of the equipment was begun in the Research Laboratories. Owing to the special nature of the problems, the Laboratories not only carried out the research work but, together with the manufacturing organization of the International Telephone and Telegraph Corporation, they were responsible for the construction, installation, and testing of the complete equipment. On the other hand, the operating organizations in Spain and in Argentina undertook the work of designing and constructing the special buildings for the plant and for the attendant staff. They also constructed the directional antenna and the telephone lines for connecting the radio equipment with the telephone networks.

The training of the operating staff—a matter of great importance—was also dealt with by the operating organizations. To provide for commercial service over so vast a stretch of the earth's surface under such novel and exacting conditions, constituted a work of considerable magnitude, and its success is a matter of satisfaction to all who were concerned therewith.

So far as is possible within limited space the particulars contained in this text are intended to impart technical and general details concerning a radio link that in many respects introduces a new era in telephonic communication. It is approximately twice the length of the North Atlantic link.

Madrid-Buenos Aires Radio Link and Its Wire Connections

On October 12, 1929, the communication facilities of the International System were very greatly extended by the opening for service of a short-wave radio-telephone link between Madrid, Spain, and Buenos Aires, Argentina. With the opening of this link it has been possible for the first time for the public to talk from their own telephone sets in South America to the Old World. The importance of this channel can hardly be overestimated, since it renders a "network" to "network" service as distinguished from point-to-point service between special booths, and is capable of connecting any telephone in the principal cities of Europe to any telephone in the principal cities of Argentina, Chile, and Uruguay.

Reference to the map, Fig. 31, shows in part the extensive nature of the telephone systems served by the link. At the South American end, connetion is made to 210,000 telephones in the Argentine Republic and 17,000 in Uruguay. At the European end, there are 155,000 telephones in Spain to which the service is available and there are no technical difficulties which prevent this service being extended to those areas in Europe which at present enjoy European International Communication.

It is of interest to note that the circuit is the second largest area-to-area link in the world, being exceeded in this respect only by the Great Britain-U. S. A. connection. It is, however, by far the longest area-to-area public telephone link in existence, covering approximately 6,400 miles (10,290 Km.) as against the 3,200 miles (5,150 Km.) from England to America, and is provided with a privacy system.

The terminals of the circuit are located at Madrid and Buenos Aires, respectively, and consist, at each end, of a transmitting station and a receiving station situated some distance apart and connected by land lines to the terminal equipment which is situated in the control office. The transmitting station for the Madrid terminal is located at Pozuelo del Rey, about twenty-

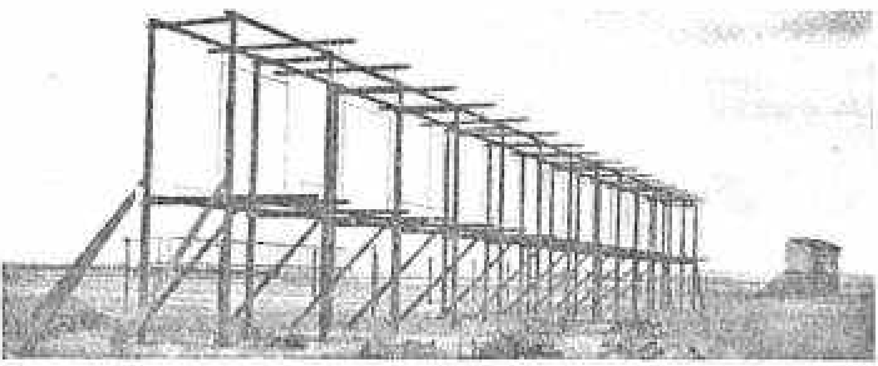


Fig. 32
General View of Madrid Receiving Antennas.

two miles (thirty-five kilometers) to the east of Madrid, and the receiving station at Grinon, about fifteen miles (twenty-four kilometers) to the south of Madrid. The transmitting and receiving stations for the Buenos Aires terminal are located respectively at Hurlingham and Platanos, each being some twelve miles (twenty kilometers) distant from Buenos Aires.

In order to give reliable service over the entire day, three wavelengths are used at each transmitter. Approximately a fifteen meter wavelength (20,000 Kc.) is employed during the day, a thirty meter wave (10,000 Kc.) at night, while a twenty meter wave is required for sunrise and sunset conditions.

A detailed description of the various units comprising the link is given

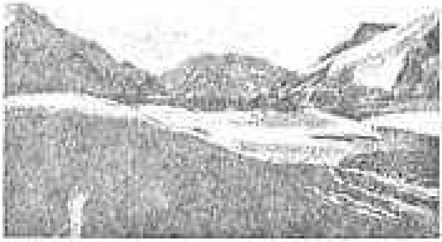


Fig. 33

Andes Mountains, Showing Country Traversed by South American Transcontinental Line.

elsewhere in this book. The accompanying illustrations give general views of the Madrid and Buenos Aires receiving stations.

At the present time traffic on the radio channel is approximately two calls per day and has been as high as nine calls per day.

It is proposed to outline briefly the various wire facilities which are used to connect this radio link to the International Telephone Systems in Spain and South America. This will be considered in two parts, the present and the future.* It may be stated at the outset that, almost without exception, the wire lines which may be connected with the new radio link are high grade, modern circuits well constructed and well maintained and capable of giving first class service.

At present the service from South America is limited to some of the more important cities in Argentina and to Montevideo, Uruguay. In order to reach these cities, however, it has been necessary to meet and solve a number of new and very interesting problems. For example, it has been necessary to place a cable under one of the widest rivers in the world, and to cross one of the highest mountain ranges in the world where, because of snow storms, train service is completely blocked for certain periods each year. Serious insulation difficulties are also encountered, such, for example, as in parts of Argentina where enormous cobwebs are blown into the circuits by the high winds, thus effectively short circuiting the wires.

Present Circuits

In Argentina, service can be given at present to 83 cities. Direct circuits are available to 15 or more of the important cities, these circuits varying from about fifty kilometers in length to approximately seven hundred kilometers. They consist mostly of copper wire about 2.8 mm. in diameter, which is a little larger than No. 12 N. B. S. Several of these circuits are equipped with through line repeaters. Between Buenos Aires and Bahia Blanca (805 kilometers) a three channel carrier current system is installed, while between Buenos Aires and Rosario (410 kilometers) there are two such systems.

The service to Montevideo is given over a subfluvial cable under the Rio de la Plata from Buenos Aires to Colonia, from which point an open wire line takes the circuits into Montevideo. This cable was laid in the early part of 1929 and consists of a twelve quad, sixteen gauge, paper insulated non-loaded cable designed for operation on a four-wire basis. The twelve quad cable will therefore carry twelve simultaneous conversations or eighteen conversations if the phantom circuits are used.

The length of the cable, thirty-seven miles, is so great that it has been necessary to instal repeaters at each end in order to secure satisfactory speech volume. At present the repeater equipment for six circuits is installed, permitting six simultaneous conversations. Plans are under way for increasing the number of circuits in the near future. The cable has been equalized to improve the quality of transmission.

In Spain, connections can be made at Madrid to practically all the more important cities in the country and to many places of lesser importance (2,256 cities in all). The Spanish network consists of upwards of 222,350 kilometers of copper wire, mostly three mm. in diameter (slightly larger than No. 9 A. W. G.); 112 through line repeaters and 45 terminal repeaters are used in connection with this open wire network. Superposed upon these circuits out of Madrid there are 13 three-channel carrier current systems, which add very appreciably to the message carrying capacity of the circuits. In addition, approximately 170 kilometers of toll cable have been placed between Barcelona and Valls. It is expected that this cable will be extended rapidly in the next few years so that Madrid and Barcelona and also Madrid and Irún (near San Sebastián) will be connected by cable.

Circuits are available from Madrid not only to the points mentioned in Spain, but to some other countries as well. For example, there are direct

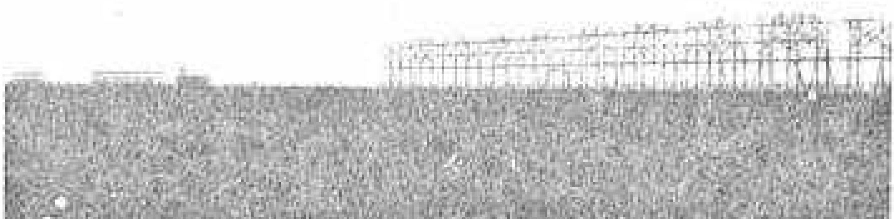


Fig. 34

General View of Buenos Aires Receiving Antennas.

circuits to Lisbon, London, Paris and to other cities in France. At Algeciras, which has a direct circuit from Madrid, conections may be switched over a 24-mile submarine cable to Ceuta, Morocco, thus putting South America into telephonic communication with a third continent.

Future Circuits

Connection to 30,000 telephones in Chile will soon be available by compositing the All America telegraph circuits from Buenos Aires to Santiago, a distance of over 1,300 kilometers. The circuit consists mostly of 2.9 mm. (No. 9 A. W. G.) copper, except where cable has been installed over the highest portion of the Andes. The cable section is about sixteen kilometers in length and consists of a buried three quad, thirteen gauge, paper insulated cable with two quads loaded for carrier current circuits. The other quad is loaded for voice frequency only. In some of the more exposed open wire sections, where extra mechanical strength was required, 4.19 mm. (No. 8 B. W. G.) copper has been used instead of the 2.9 mm. wire. Also throughout long stretches a pole has been set between each two existing poles in order to guard against failure of the poles or wire. Superposed upon this circuit from Buenos Aires to Mendoza (about 1,000 kilometers) there is at present a single channel C-2-F carrier current system with one intermediate repeater. This system will be replaced in the near future, however, by a three channel system with three repeaters.

As the European network grows additional points will, of course, come into communication with Madrid and hence with South America.

Work is also under way on a radio link from Madrid to Tenerife, one of the Canary Islands. This island is being connected by a 35-mile submarine cable with Las Palmas on the island of Gran Canaria. The message carrying capacity of this cable will be increased by the installation of carrier current apparatus.

In South America, connections to thirty additional cities in Argentina will be made in the near future. The extensions which are being made to the toll plant in Chile will also add many other cities in this country to the network in the near future.

It is expected that, within two years, a radio link from Buenos Aires to Bogotá will add Colombia to the list of countries which may use the Buenos Aires-Madrid link, and it is entirely possible that similar arrangements may be made for some of the other countries.

The Use of Short Waves in Radio Communication

The rapid expansion in the interchange of knowledge, both commercial and intellectual, involved by modern civilization, has necessitated an increasingly complete utilization of the means of communication which science affords. The first attempts at the electrical transmission of sounds were directed towards the possibility of sending electrical impulses along conductors, and from these first experiments wire telegraphy and telephony were developed. From a scientific viewpoint the development of telephony constituted a notable advance over that of telegraphy. A further step was the superposition, particularly upon aerial lines, of several signals, which was accomplished by employing carrier currents modulated by the speech frequencies. Carrier frequencies as high as 30,000 cycles per second were so used, the use of higher frequencies being precluded by the excessive attenuation to which they were subject.

The facilities for long distance communication were still further increased by the discovery that electromagnetic waves having very high frequencies may be propagated through space without the necessity for an intervening conducting circuit. At first, frequencies of the order of 100 kilocycles per second (Kc/s.) were used in this way, but the means then available for producing these waves were such as to encourage the use of the lower frequencies lying between 10 and 100 Kc/s., particularly as these were found to be more suitable for long distance communication. Research in recent years has, however, enabled very much higher frequencies to be used commercially. These, comprising the frequency range from 3,000 to 25,000 Kc./s. (wavelengths from 100 to 12 meters), are known as "short waves," and since it has become possible to overcome the inherent difficulties involved in their use, the study of their properties has shown that by their use not only can the number of available channels of communication be increased, but that in certain cases communication can be effected which could only have been carried out at much greater expense had long waves been employed.

It is usual when speaking of radio waves within the above wide limits of 10 to 25,000 Kc/s. to divide them into three categories, namely, long, medium and short waves. It is hardly necessary, however, to point out that the difference between these is not fundamental, but lies rather in the fact that certain fundamental properties become more or less pronounced as the frequency changes. In consequence of this, radio practice varies considerably in accordance with the type of wave employed.

The longest waves, the frequencies of which lie between 10 and 100 Kc/s. are suitable for long range international telegraphy on account of their reliability, and in spite of the fact that they are liable to interference from atmospheric disturbances. Within this range the waves having frequencies greater than 50 Kc/s. may be used for radio telephone transmissions, the London-New York Transatlantic telephone circuit being the best example of this.

Waves having frequencies between 200 and 2,000 Kc/s. are found to be best adapted for shorter distance transmission, and in particular to broadcasting. The lower end of this range possesses properties similar to those of long waves, being characterized by a comparatively large measure of reliability. With the higher frequencies, on the other hand, new characteristics make their appearance; in particular, considerable diurnal variations in the received field strength.

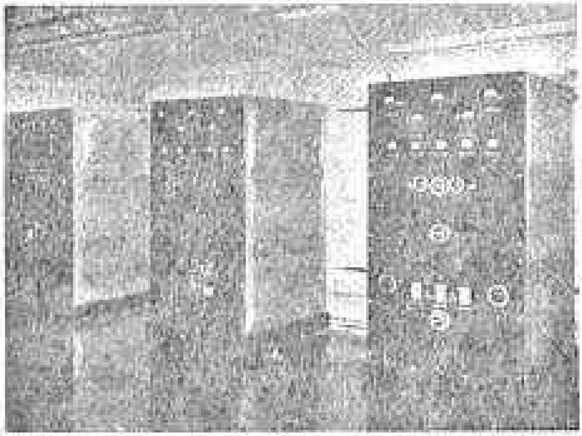


Fig. 35
Type III Short Wave Transmitter—Assembly of Transmitter Units.

Finally "short" waves in the range of from 3,000 to 25,000 Kc/s. become more and more suitable for long distance communication as their frequency is increased, in spite of certain irregularities in transmission, the causes of which will be referred to later.

This rapid survey of the properties of electromagnetic waves shows that for the particular case of long distance radiotelephony, medium waves are not suitable, but that either the upper or lower ends of the frequency spectrum may be employed.

The differences between the propagation characteristics of short and long waves are explained by assuming that while long waves travel directly from the transmitter to the receiver, short waves received at considerable distances from the transmitter have suffered progressive reflection from a more or less well defined ionized layer in the upper atmosphere. Since the rays have not traveled near the surface of the earth, it is not possible to calculate the received field strength from an empirical formula, as can be done from the Austin-Cohen formula in the case of long waves; and in practice, field strengths may be obtained which are greatly in excess of those predicted by this formula.

A disadvantage experienced in the use of short waves lies in the way in which the received field strength varies in accordance with the time of day, the season of the year, and the distribution of light and darkness over the path of the transmission. The effect of such variations may be greatly reduced by the provision in the receiving system of an automatic volume control which adjusts the amplification in accordance with the strength of the received signal. Even when this is done, however, it is necessary when reliable communication over long periods is desired, to employ several frequencies suitably chosen for each particular case.

Owing to the fact that short waves are much less subject to interference from atmospheric disturbances, a very much higher signal noise ratio is obtained from a given signal strength than would be the case with long wave operation, and it is in consequence possible to work with receiving field strengths which would give signals too weak to be heard above atmospheric noise, were long waves employed.

A very great advantage gained by the use of short waves lies in the way they may be propagated in a predetermined direction in space. In order to obtain directive effects with long wave transmission, cumbersome equipment must be installed, of doubtful efficiency and at a very high cost, due to the fact that the size of the antenna necessary is related to the operating wavelength. For example, in order to obtain an effect similar to that given by a concave mirror with light rays, it is necessary for the aperture of the mirror to be at least equal to twice the wavelength and, in consequence, a prohibitively large antenna network would be required when this is of the order of 5,000 meters.

The directive antennas employed in practice for short waves have a length and height of about 10 and 2 wavelengths, respectively. Such proportions, permissible when the wavelength is of the order of 10 meters, are quite impracticable for waves of the order of hundreds of meters in length.

The use of reflectors and directive antennas has become general in modern short wave practice and considerable progress has been made in their design. The systems at present in use give a gain of the order of 15 decibels over a non-directive system, thus considerably increasing the efficiency of radio communication.

Short wave transmission decreases somewhat the transmitter power necessary to secure communication over long distances, this being largely due to increased efficiency of the antenna on the higher operating frequency. The proportion of the power supplied to the antenna, which is actually radiated, lies between 10% and 15% when the longest waves are employed, and increases to about 70% with waves of the order of 15 meters in length.

Thus, when with very long waves, a power of 300 kw. is taken from the mains, 150 kw. may be supplied to the antenna, and of this only 17 kw. is radiated, whereas with very short waves, 30 kw. from the mains may give 10 kw. to the antenna, of which 7 kw. is radiated. When account is taken of the fact that the latter power may be concentrated into a restricted angle by means of a directive antenna, the extent to which the short wave system is more efficient can be seen.

By the use of short waves, an enormously increased number of channels of communication is made available, and this constitutes perhaps the greatest gain that has resulted from their use. If the band of frequencies between 50 and 100 Kc/s. is considered, only 25 channels are available, even though the width of each frequency band is reduced to 2,500 cycles—the minimum required for commercial intelligibility—the carrier and one side

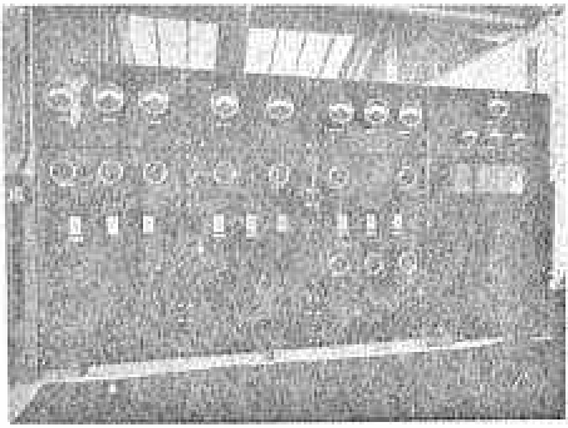


Fig. 36
Type 111 Short Wave Transmitter—View of Power Board.

band suppressed, and no spacing allowed between adjacent bands. Against this, the present state of short wave technique permits the use of 200 telephone channels between 6,000 and 12,000 Kc/s., the spacing between adjacent carrier frequencies being 30 Kc/s. This number would be increased to 600 if the spacing were reduced to 10 Kc/s., a figure which should not be considered impossible of attainment in the light of present progress.

The utilization of the 13-14 meter waveband, the lower limit of wavelengths used commercially, signifies the availability of about 40 new telephone channels, each occupying 40 Kc/s., a figure which may be soon reduced. Thus an additional meter utilized at the high frequency end of the spectrum gives more telephone channels than are available from the whole of the long waves suitable for long distance work.

The use of directive antenna systems previously mentioned must eventually increase still further the number of channels made available by the use of short waves.

In the consideration of this subject, it must, however, be remembered that in order to provide satisfactory operation over considerable periods it is necessary for one station to employ several wavelengths. This not only reduces the number of channels available, but also increases the cost of installation. Thus, since all new channels are likely to be utilized in the very near future, it is not certain if, in the present state of the art, short waves will be employed to the exclusion of long waves on all long distance circuits, or only for exceptionally long distances.

One of the difficulties experienced in short wave operation is the necessity of maintaining the carrier frequency constant to a much higher degree of precision than is otherwise necessary. This is due to the fact that a given absolute frequency variation becomes a much smaller relative variation as the carrier frequency is increased.

Against this, the band of frequencies occupied by a given type of transmission (telephony for example), represents a much smaller fraction of the carrier frequency in the case of short waves, consequently, the problem of transmitting uniformly a band of frequencies is considerably simplified. When long waves are employed, the tuning of the antenna circuit does not permit the uniform transmission of the band of 2,500 cycles width necessary for telephony, whereas very wide bands can be satisfactorily transmitted on short waves. Due to this fact, aided by progress in receiving technique, one can visualize the simultaneous transmission of many different signals, the realization of high speed telegraphic transmission, and finally the transmission of special signals requiring a greater band width than telephony.

The foregoing brief discussion shows the complexity of short wave transmission, where any advantage obtained is attended by some corresponding disadvantage. It also shows, however, the extraordinary fertility of this scientific field, and the considerable possibilities which the important advances already realized indicate to be reserved for the future.

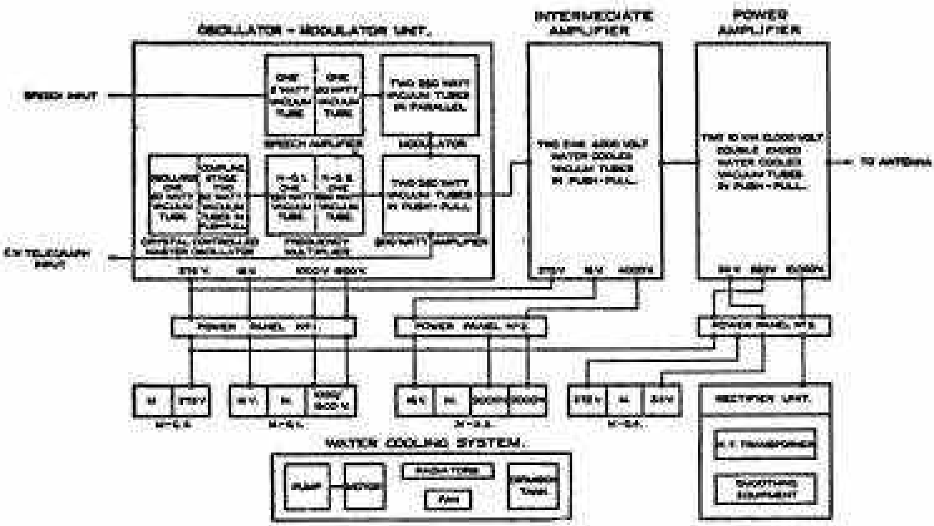


Fig. 37

Type III Short Wave Transmitter—Block Schematic.

The "Standard" Short Wave Radio Transmitters

In no phase of electrical communication has recent progress been more marked than in radiotelephony. The discovery, a few years ago, of the value of short wavelengths for long distance transmission, opened up vastly extended possibilities for linking together the telephone subscribers of different continents. In the realization of a scheme of this kind, the engineer is faced with the problem of attaining in the design and construction of short wave transmitters and receivers the same standards of reliability and grade of service as have become accepted in repeaters and other telephone plants. The trend of modern radio practice in the design of apparatus to fulfill these requirements may be illustrated by a brief description of the short wave transmitting equipment recently developed by the International Telephone and Telegraph Laboratories, Inc.

The transmitter has been designed to include the features for trunk telephone service, inter-continental broadcasting, and high speed telegraphy. It is suitable also for multi-channel telephony, and simultaneous telephony and telegraphy, when used in conjunction with standard types of line carrier telephone and telegraph equipment.

The operating frequencies are of the order for which directional transmission is practicable; and, in general, for point to point service, the equipment is used with a directive antenna concentrating the radiation into a beam pointing in the direction of the receiving station. The power is sufficient to maintain an almost continuous telephone or telegraph service over great distances of the order of ten thousand kilometers.

To maintain continuous service it is necessary to change the operating frequency three or four times in twenty-four hours to suit the transmission conditions corresponding to different states of light and darkness along the trajectory of the waves. The equipment has therefore been designed to be capable of adjustment for operation at any frequency within the band useful for long distance directional transmission, which extends from about 5 to 20 megacycles. A special feature is the rapidity with which it is possible to change from one operating frequency to another. The time required is about five minutes.

As regards operating characteristics, special attention has been paid to securing very great frequency stability, freedom from carrier noise, deep modulation for telephony, and clear-cut signals for telegraphy.

In view of the rapid growth of the technique, the design has been made as flexible as possible by adopting low power modulation and a unit form of construction to permit of progressive extension to incorporate new developments. The general appearance of the set is illustrated in Figs. 35 and 36 showing respectively the radio units and the power control board.

The power delivered to the antenna when working on continuous wave

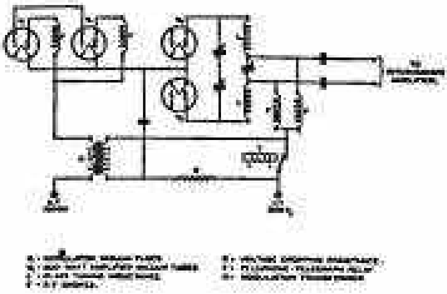


Fig. 38
Simplified Schematic of Modulation Circuit.

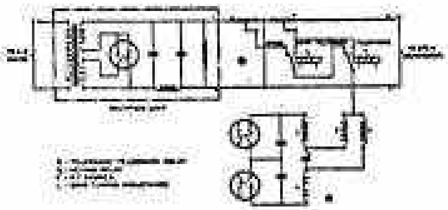


Fig. 39
Simplified Schematic of Keying Circuit

telegraphy at full load is about 12 kw. at 15 megacycles, being slightly less for the higher frequencies and slightly greater for the lower frequencies.

In telephony, the carrier power and the degree of linear modulation are interdependent, being determined by the limitation that the instantaneous peak power must not exceed 12 kw. As is well known, it is preferable to employ a given carrier-power deeply modulated than a higher power less deeply modulated, with the same peak power in each case, since by the former a better signal-noise ratio is obtained, owing to decrease in the background noise caused by the carrier-wave beating with atmospheric disturbances. The modulator circuits have therefore been designed to permit of 90% to 100% linear modulation. The carrier-power must be limited to a quarter of the peak power, that is, to about 3 kw. for 100% linear modulation; but it may be raised to about 4.6 kw. for commercial operation, in which case the slight distortion of the speech peaks when modulating deeper than 60%, can be tolerated. For tone modulated telegraphy, the carrier-wave power is 4.6 kw. and is fully modulated.

The telegraph speed obtainable for continuous wave telegraphy with well shaped signals is at least 200 words per minute. The power drawn from the mains at full load on telegraphy or telephony is approximately 65 kw.

Very severe requirements are imposed on short-wave transmitters with regard to frequency constancy of the carrier-wave, both in respect to dynamic stability, that is, independence of the frequency on keying and modulation, and as regards slow variations caused by changes of temperature or supply voltage, swaying of the antenna, etc. This constancy of frequency is essential, on account of the speech distortion caused by selective fading and interference phenomena which result from an unsteady carrier frequency, and also on account of the close spacing of channels in the short wave band. Stability of frequency during modulation and keying is obtained by the use of a crystal-controlled master oscillator, balanced coupling stage, and frequency multiplication system. Instability due to antenna sway is prevented by the use of successive highly balanced radio frequency amplifiers.

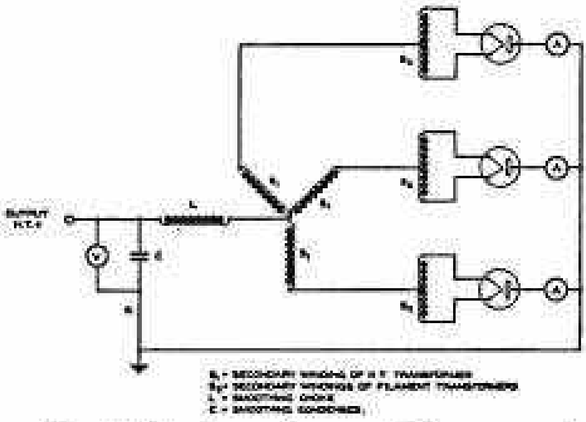


Fig. 40
Simplified Schematic of H. T. Rectifier Circuit.

To obviate slow changes of frequency, the piezo-electric crystal is mounted in a special holder and is kept at a constant temperature by thermostatic control. The general form of the circuit is illustrated in the block diagram Fig. 37.

The master oscillator, operating through a coupling stage, drives a frequency multiplier consisting of two harmonic generators in cascade. The frequency multipliers excite the first of three successive stages of high frequency amplification.

The apparatus for modulation and keying is associated with the first of the three stages of high frequency amplification. Simplified schematics of the modulation and keying circuits are shown in Figs. 38 and 39. The system is one of low power modulation and keying, with subsequent amplification of the modulated or interrupted carrier-wave. The purpose of the frequency multipliers is to lower the frequency of the master oscillator to a value at which quartz crystal control can be satisfactorily applied.

Low power modulation has been adopted as it has the same advantages over high power modulation in a short-wave equipment as have been found in the case of broadcasting transmitters. In addition the low power system seems more promising at present from the point of view of providing for new developments.

The transmitter has four pairs of input lines. Two pairs are for "main line" telegraph and telephone, and the remaining two are for "local test" telegraph and telephone. A key on the set switches over the modulator input and keying relay from the "main line" pairs to "local test" pairs. The change over from telephone to telegraph adjustment is by means of relays controlled by one key.

From Fig. 37 it may be seen that the apparatus divides up into three main sections, i. e., (1) the apparatus for generating the constant frequency carrier at low power and for modulating and keying; (2) the first stage of power amplification; (3) the second stage of power amplification. In the assembly of the apparatus it was found convenient from many points of view to adopt the unit form of construction, each of the three main sections of the system being comprised in one unit. Fig. 35 shows the three radio units. The unit on the left comprises the carrier-generating, modulating, and keying apparatus, and is referred to as the oscillator-modulator unit. The unit in the center is the intermediate amplifier, being the first stage of amplification after the modulated amplifier. The unit on the right is the power amplifier.

Each of the three radio units has its own distinct panel in the power control board, and separate power plant.

For telephone operation, provision is made for monitoring with head phones at the output of each unit, to enable any wrong adjustment causing distortion to be very easily localized.

Among the advantages of the unit form of construction may be cited improved accessibility, flexibility for increase or reduction of power, flexibility for interchange of units in stations comprising more than one equipment, simplification of the problem of symmetrical distribution of apparatus, and certain advantages in circuit design including good shielding between stages and elimination of ground return currents between stages causing instability and carrier noise.

The improvement in accessibility arises from the fact that advantage has been taken of the possibility of separating the amplifying stages some distance from each other and connecting them together by transmission lines so that each amplifier—which must in itself be very compact to keep certain of the connections very short—can be made accessible from all sides.

The flexibility, above referred to, for increasing or decreasing the power renders it possible to work into the antenna either from the oscillator-modulator unit alone (the other two stages being switched off entirely) or from the output of the intermediate amplifier, or lastly in the usual way from the power amplifier. By duplicating the oscillator-modulator, together with its associated power plant, a high degree of security against total failure of the service is obtained.

The units are coupled together by means of short transmission lines. Precautions are taken to obtain series feed current in the lines only, thus avoiding parallel line current returning from one unit to another through earth. The methods adopted have resulted in remarkable freedom from reaction between units, in freedom from stray earth currents, and in equality of the drives and impedance conditions for the valves on opposite sides of the balanced amplifiers.

The units are built on frameworks of duralumin angle and are enclosed at the sides and backs by doors comprising frames of the same material covered by perforated aluminium sheeting. The front panels are of polished slate shielded on the inside by metal sheets. The units are each 6 feet 6 inches high (about 198 cm.), 3 feet 8 inches wide (about 112 cm.), 4 feet deep (about 122 cm.).

The transmission lines forming the connections between units are carried on insulators mounted on the tops of the units, and are insulated from direct current by stopping condensers within the units. The power plant associated with and included in the equipment comprises four motor generator sets, a 10,000 volt rectifier (see Fig. 40), and the power control board. The standard equipment is designed for operation from a 3 phase 50-60 cycle supply at a voltage between phases of either 220 or 415 as required.

The four motor generator sets provide the filament and grid voltages for

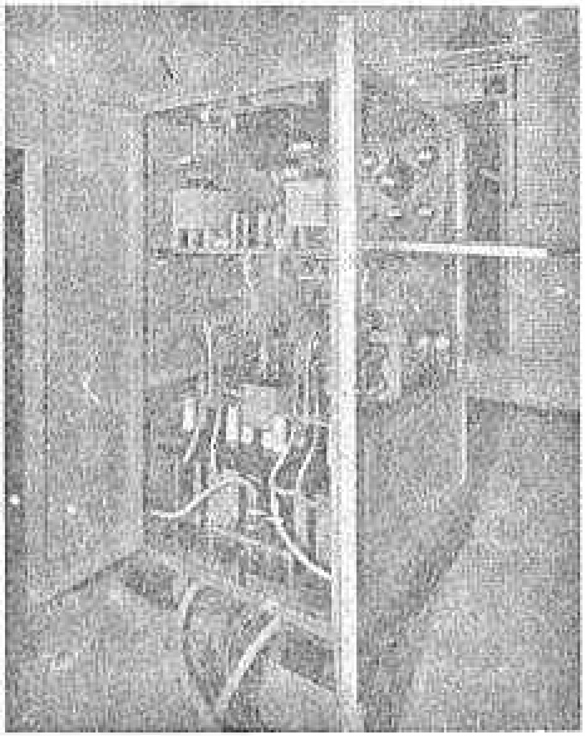


Fig. 41

Rear View of Power Amplifier.

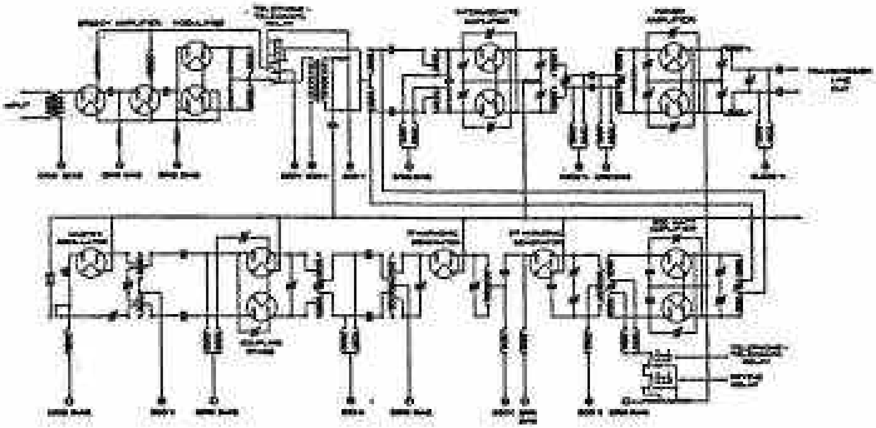


Fig. 42
Type III Short Wave Transmitter, Simplified Circuit Schematic.

all the valves, excitation of control circuits, and high tension plate supplies for the oscillator-modulator and the intermediate amplifier. The 10,000 volt rectifier supplies only the plates of the power amplifier.

A power panel is provided for each transmitter unit, and controls the power plant associated with that unit. The three power panels are lined up with the front panel of the rectifier to form one power board as in Fig. 36. The panels are of polished slate and are mounted on angle iron frameworks. Each power panel is 6 feet 6 inches high (about 198 cm.), and 2 feet 6 inches wide (about 76 cm.). The rectifier panel is 6 feet 6 inches high, and 3 feet 8 inches wide (about 112 cm.). The power board forms the front of an enclosure in which are located the H. T. transformer and the smoothing apparatus of the rectifier system.

The valves used in the Intermediate and Power Amplifiers are water-cooled, and a water-cooling system is included in the equipment. This system consists of a circulating pump, a small expansion tank, and an air blast cooler.

The oscillator-modulator unit with its associated motor-generators and power panel forms a complete low power transmitter known as the Type I transmitter. It delivers about 300 watts to the antenna for continuous wave telegraphy, and 200 watts for telephony. By the addition of the Intermediate Amplifier, with its associated motor-generator and power panel, and the water-cooling system, the Type II transmitter is formed which is capable of delivering to the antenna about 3 kw. for telegraphy and 0.83 kw. for telephony. These telephony powers are based on 100% modulation. Finally the Type III set, herein described, is made up by the addition to the Type II equipment of the Power Amplifier with its associated power panel, machine,

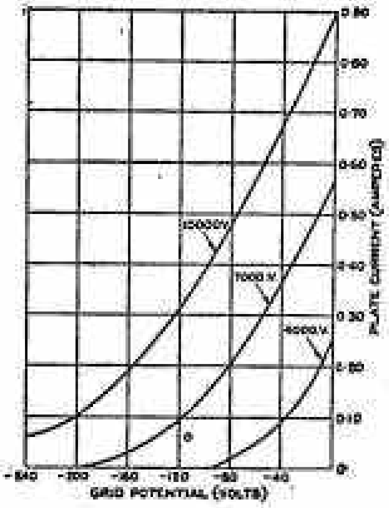


Fig. 43

Anode Current Grid Volts Characteristic—10 K.W. Tubes.

and rectifier. It will be seen that a Type I or Type II equipment may therefore be easily extended if it is desired to raise the power of the installation.

The equipment is started up or stopped, and all potentials are applied by means of push-buttons situated on the Power Board and duplicated on the front panels of the units. Control circuits are arranged in such a manner that it is impossible to start up the transmitter in a way liable to cause damage. No high tension voltages can be applied, for example, until the grid and filament voltages are at their proper levels.

The equipment is adequately protected by fuses, according to standard practices; other security provisions include overload relays in the high tension plate supplies, water flow devices to remove plate and filament voltages in case of failure of the water flow, water temperature alarms, and gate switches on all high tension enclosures, including the radio units themselves.

The mechanical design of the higher powered radio units presented a difficult problem. It was necessary to preserve close symmetry, to keep certain leads short and yet to allow ample spacing to avoid flash over (which occurs very easily on the higher frequencies in the range), to provide for extreme rigidity, and lastly to use insulating-materials sparingly in high frequency fields and only material of low dielectric loss. An idea of the construction adopted may be gathered from Fig. 41.

The general form of the circuit of the transmitter given in the block diagram is shown in greater detail in the simplified circuit of Fig. 42.

The master oscillator employs a special 50-watt valve of high amplification-factor operated with the plate voltage reduced to 300. The oscillator may work as a self-excited oscillator or as a crystal controlled oscillator, according to the position of the switch in the grid circuit.

The crystals for the different operating frequencies are mounted in sealed grass holders contained in a specially designed box fitted with a heating element and thermostat. Four crystal holders for four working frequencies are provided, and a selector switch is incorporated in the box to enable any one of the four to be put into operation. The box contains also four spare crystal holders complete with spare crystals which can be quickly exchanged with the normal holders in case of failure of any of the normal crystals. The spare crystals and holders are maintained dry and at the right temperature by storing them in the temperature controlled compartment and are ready for instant use on their correct frequencies.

The master oscillator is followed by the coupling stage (comprising two 50-watt valves) which amplifies the master oscillator output and acts as a buffer to prevent reaction on the oscillator from the following stages. Such reaction would cause slight instability of the carrier frequency arising from impedance changes during modulation and keying. The coupling stage is a push-pull circuit having two variable balancing condensers which, together with the grid to plate capacities of the valves, form a balanced capacity bridge having the grid input circuit across one pair of opposite corners, and the plate output circuit across the other pair of corners of the bridge. When the capacity balance is correct there can be no reaction between the input and output circuits. The amplifier is therefore stable against self-oscillation, and in addition the master oscillator is completely separated so far as reaction is concerned from the succeeding stage.

The harmonic generators comprise two 250-watt tubes operating as amplifiers arranged for high distortion. For frequencies higher than 10 megacycles, both harmonic generators are used, but for frequencies below that value only one stage is required. The frequency is multiplied in each stage by 2 or 3, according to the frequency required.

The output of the frequency multipliers is a steady carrier at the frequency of transmission.

The next stage is the 500-watt amplifier which is the first of the three stages of high frequency amplification. It comprises two 250-watt valves in push-pull. For telephony this stage is plate modulated, and for continuous wave telegraphy the keying operation is carried out in its grid circuit.

To secure a degree of linear modulation of 90% to 100% it is necessary that the low frequency modulating valves should be capable, without overloading, of impressing—across the plate circuit of the modulated high frequency amplifier—speech frequency voltages having peak values as high as the plate supply voltage of the modulated amplifier. This has been done, without resorting to step-up modulation transformers, by operating the modulating valves on a plate voltage about four times as great as the plate voltage on the modulated amplifier.

For continuous wave telegraphy, to ensure satisfactory operation for short waves, the 500-watt amplifier operates at 800 volts, which is well below the rated voltage of the valves.

For telephony, the plate voltage is reduced to about 400. By this means the carrier-power is cut down to about a quarter of the peak or continuous wave telegraph power, when changing over from telegraphy to telephony.

The method of keying consists in throwing a high negative voltage on to the grids of the 500-watt amplifier from a small rectifier during "spacing."

The intermediate amplifier is of the push-pull type, comprising two single ended, 2 kilowatt water-cooled valves. The valves work at a plate voltage of 4,000.

The power amplifier comprises two 10-kilowatt double ended valves working at 10,000 volts. The anode current grid volts characteristic of these tubes is shown in Fig. 43.

The circuits of the two amplifiers are almost exactly the same, being similar also to the circuits of the 500-watt amplifier and coupling stage. Each amplifier unit comprises essentially a tuned grid circuit terminating the coupling line from the preceding stage, a tuned plate circuit coupled to the outgoing transmission line, and a pair of valves and balancing condensers. The balancing condensers are variable and are accurately adjusted to prevent any reaction from the plate circuit back to the grid circuit.

The grid circuit is loaded with a resistance to swamp the variable grid impedance, and forms the major part of the load on the preceding stage. The resistance also serves as the means of adjusting the drive on the grids when the preceding stage is working into its correct impedance, and has its correct drive.

The grid and plate circuits are coupled to the incoming and outgoing transmission lines by condensers. The condensers are adjusted during the initial testing of the set to secure the correct impedance conditions, the grid condenser being adjusted to present an impedance of about 600 ohms at unity power factor to the incoming line. The plate condenser is adjusted to

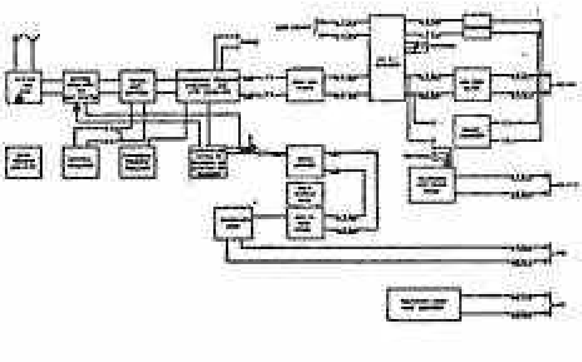


Fig. 44

Block Diagram of Short Wave Radio Telephone and Telegraph Receiver.

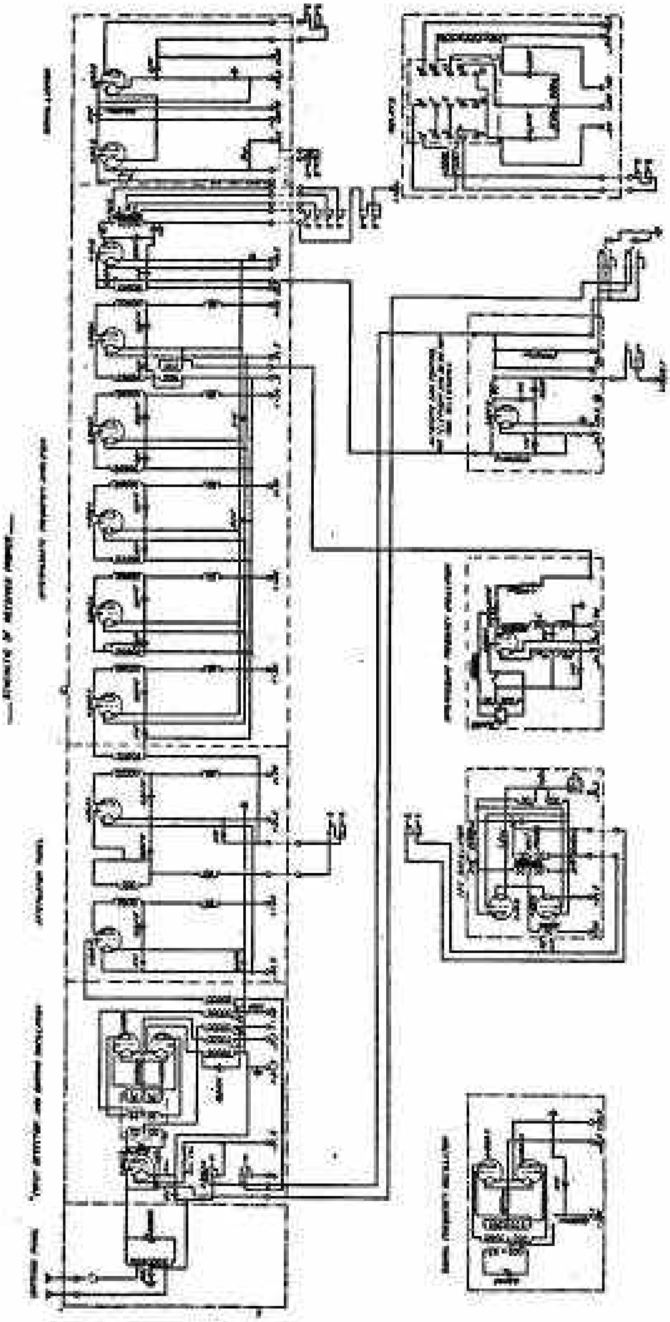


Fig. 45
Circuit Diagram of Short Wave Radio Telephone and Telegraph Receiver.

match the impedance of the output circuit to a 600 ohms antenna transmission line.

As has been pointed out at the beginning, the main object in designing the transmitter was to produce an equipment capable of efficient continuous service in the extension of a telephone or telegraph system. A number of these equipments has been manufactured; some have already entered into commercial service, including the Buenos Aires-Madrid and the British end of the London-New York radio link.

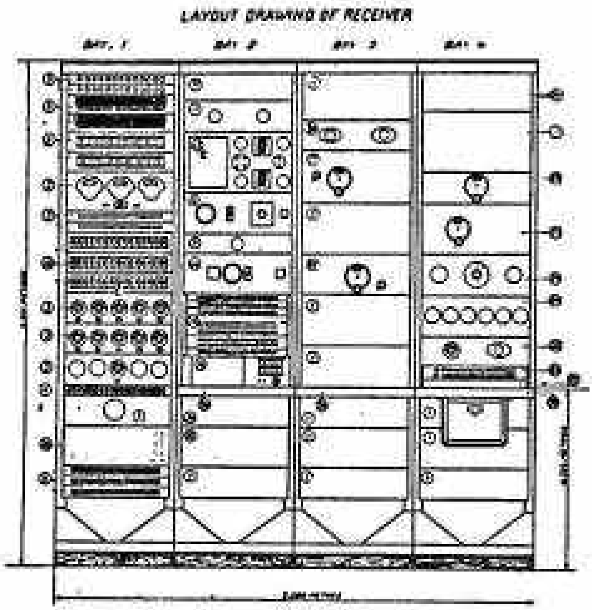


Fig. 46
Layout Drawing of Short Wave Radio Telephone and Telegraph Receiver.

Short Wave Radio Telephone and Telegraph Receivers

Owing to the favorable propagation of radio waves between 30 and 6 megacycles (i. e., of wavelength between 10 and 50 meters) over long distances, there is an ever-increasing demand for commercial receivers covering this range. To turn to advantage the lowness of level of atmospheric interference at these frequencies, such apparatus must be of high sensitivity and reliability. Particular attention has to be given to other points also; tube noise must be kept low despite the high amplification involved, and effective steps have to be taken to render condensers and valves non-microphonic. As it is possible to receive telephony commercially with a radio field strength of the order of one microvolt per meter, and with an antenna consisting of a rod one-half a wavelength in height, an indication is obtained of the minimum telephonic input signal for which provision has to be made. The overall amplification must be sufficiently great to deliver to a con-

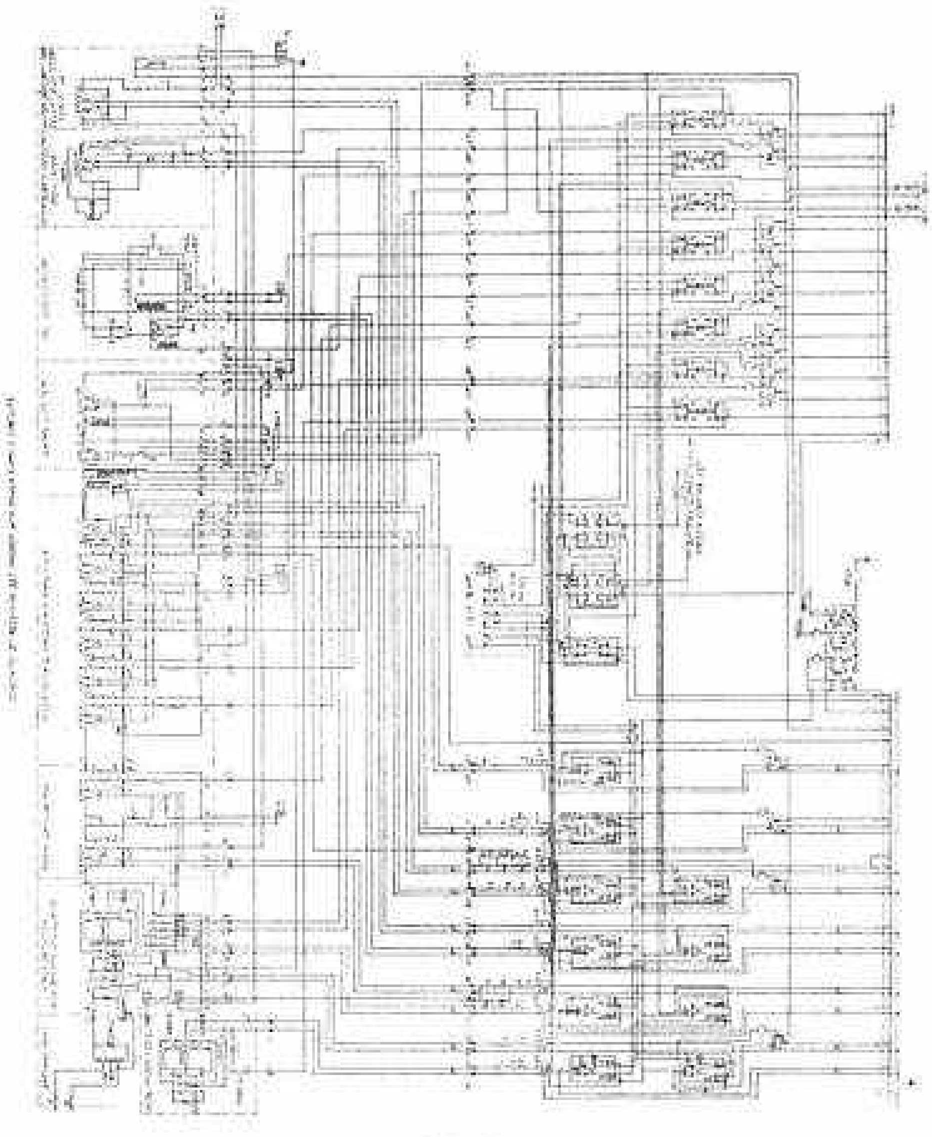


Fig. 47

Diagram of Receiver Circuit Showing Power Supply Circuit.

mercial telephone line a level of +5 decibels, reference volume being taken as six milliwatts. A telegraphic service can be carried on very successfully with still weaker radio field-strengths. The sets here described are, in consequence, made to operate with signals of a fraction of a microvolt per meter.

The equipment is designed for the reception of short wave radio telegraphic or telephonic signals. The telegraphic signals are delivered in the form of tone telegraph impulses for aural reception at low speeds, and in the form of double current impulses for transmission over a telegraph line, in the case of high speed reception. The receiver is capable of operating at speeds up to 300 words per minute with the morse code.

Wavelength Range and Band-width

The operating wavelength of the radio receiver is continuously variable over the range 10 to 100 meters (30,000-3,000 kilocycles). Tuning is effected by means of variable condensers in conjunction with interchangeable coil units. Each coil covers a considerable wavelength band, so that in many cases the desired change of wavelength can be effected by means of the tuning condensers alone. The band-width is from 200 to 5,000 cycles.

Description of Equipment

A block diagram of the whole receiver is given in Fig. 44. The equipment comprises in brief a receiver proper working on the super-heterodyne principle, an automatic gain control for telephony, some auxiliary oscillators, a gain control entitled a "signal limiter" for telegraphy, and certain low frequency measurement and control apparatus. Two aerial connections are shown to the receiver to indicate diagrammatically that a directive antenna system is ordinarily employed. The combination of the signals picked up on a "collector" and on a "reflector" array is effected in the receiver itself, the energies from the two separate parts of the antenna system being brought to the receiver by two single-wire transmission lines so arranged that any high frequency voltages picked up in them both will oppose each other in the grid coil of the first detector, and will balance out.

To render unmodulated C. W. signals audible, a constant frequency 1,000 cycles oscillator is provided, and modulation of the C. W. signals themselves by the 1,000 cycle note is carried out at intermediate frequency. C. W. telegraph signals are, therefore, received in the output 'phones of the set as a keyed note of perfectly steady pitch. The circuit diagram of this oscillator is given in Fig. 45. A variable frequency oscillator that covers the band of the intermediate frequency amplifier is provided. By this means it is possible to employ heterodyne reception of C. W. signals. Although reception by means of the 1,000 cycle modulation has the advantage that a very steady output frequency is obtained, even though the set be subject to violent

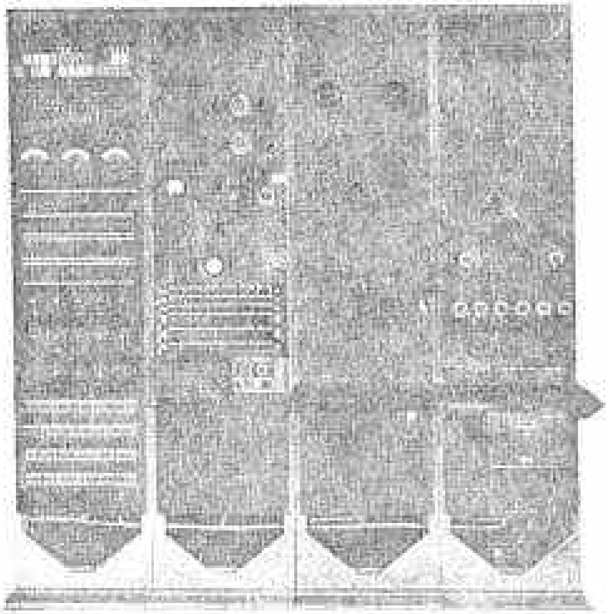


Fig. 48
Front View of Receiver.

mechanical vibration, or to very large variations of H. T. and L. T. supplies, it fails when any loud extraneous noise is produced in the receiver, since the noise itself is modulated by the 1,000-cycle note and acts as a substitute for the C. W. signal.

In ordinary commercial operation, the receiving set must be installed where electromagnetic interference is absent. When, however, the C. W. signal is so weak that it begins to sink into the atmospheric or tube noise, it is more easily readable by heterodyne reception. The Intermediate Frequency Oscillator, moreover, serves another purpose; it is possible to check the band passed by the Intermediate Frequency Amplifier at any time and to adjust the Beating Oscillator so that, especially in the case of telephony, the intermediate frequency corresponding to the carrier of the distant station lies in the middle of the frequency band of the I. F. amplifier. The circuit diagram of this oscillator is given in the schematic diagram, Fig. 45.

In order to facilitate exact tuning of the receiver, an oscillator at signal frequency is provided. If this oscillator is not employed, it is difficult to tune the set when fading is taking place. As the incoming carrier produces, when heterodyned in the Intermediate Frequency Amplifier by the Intermediate Frequency Oscillator, an audible output note, it is easy to adjust the Signal Frequency Oscillator to within a few cycles of the incoming carrier by simply tuning it to give the same audio note. The Signal Frequency Oscillator is strong enough to swamp the incoming waves and, by reason of the presence of a steady local signal, correct tuning of the receiver is facilitated. The circuit diagram of this oscillator is given in Fig. 45.

After traversing the Intermediate Frequency Amplifier, the signal follows one of two different paths according as it represents telegraphy or telephony. In the former case it passes through the "signal limiter," which is described more fully below, to the telegraphist's table, and thence to the line. In the case of telephony, it enters a band-pass filter, which serves to ensure the suppression of frequencies outside the band 200-5,000 cycles. Thence the signal passes into a standard 44-A-1 Repeater, which introduces a gain that may be varied up to 40 decibels. A volume indicator is provided to permit of the adjustment of the gain of the repeater to the proper value.

A layout drawing of the front view of the set is given in Fig. 46.

Bay No. 1 is the battery supply bay and contains the meters, fuses, relays, etc., associated with the application of the various battery supplies to

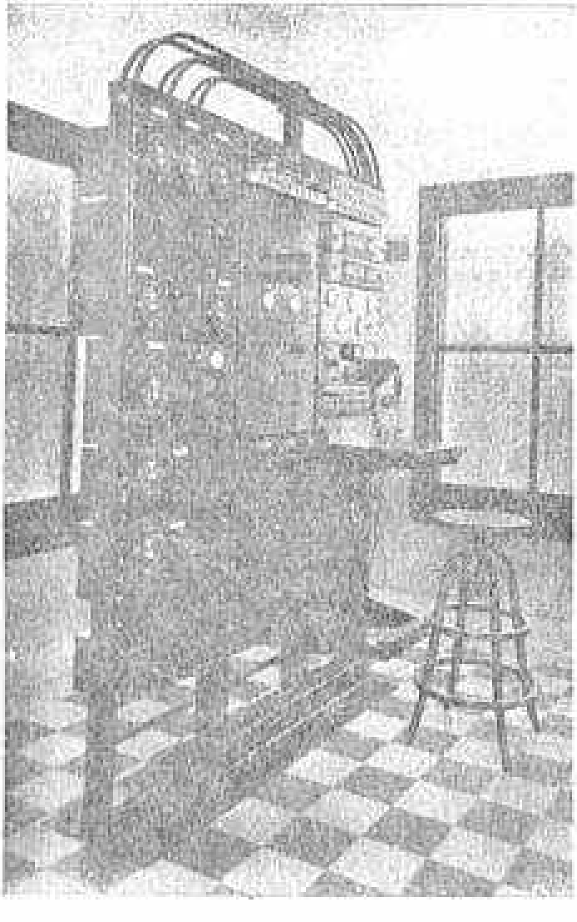


Fig. 49
Receiver at Platanos, Buenos Aires-New York Circuit.

the radio receiver. The second bay contains the speech control apparatus, telegraph relay and order wire circuits. The third bay contains the signal frequency and intermediate frequency testing oscillators and the signal limiter. The last bay mounts all the panels comprising the radio receiver proper, namely, the antenna panel, first detector and beating oscillator, the intermediate frequency amplifier, the automatic gain control and the testing jacks. The key to the numbers shown in Fig. 46 is as follows:

1. Blank panels.
2. Meter panel.
3. Rheostat panels.
4. Condenser panel.
5. Alarm fuse panels.
6. Fuse panels.
7. Alarm lamps.
8. Resistance panels.
9. Relays.
10. Dry batteries panel.
11. 1,000 cycle oscillator.
12. 44-A-1 Repeater.
13. Volume Indicator.
14. Testing panel.
15. Jack Strips.
16. Telephone and Trunk panel.
17. Signal Frequency Oscillator.
18. Keys.
19. Intermediate Frequency Oscillator.
20. Signal Limiter.
21. Relay panel.
22. Antenna tuning panel.
23. Beating oscillator and 1st detector.
24. Intermediate Frequency Amplifier.
25. Jack Strip.
26. Operator's shelf.
27. Blank panel.
28. Shelf with drawer.
29. Manual Gain Control.
30. Filter.
31. Filter.
32. Transformers.
33. Automatic Gain Control and Detector for Telegraphy.
34. Antenna Lead-In panel.

Antenna Panel

This contains the antenna tuning circuit which is designed for connection through a pair of transmission lines to a directive antenna array. The circuit consists of a single coil tuned by a variable condenser, the center point of the inductance coil being grounded through a fixed condenser of 0.01 microfarads. The two transmission lines are connected to variable tapping points on the inductance, whereby the impedance of the line may be matched, and the two lines balanced to earth. The inductance coil is replaceable, enabling the large frequency band to be covered.

The antenna panel is followed by a two-stage transformer coupled amplifier operating at the signal frequency. The coupling transformers are interchangeable and are tuned by variable condensers. This amplifier is not shown in the drawings or photographs of the receiver.

The Beating Oscillator and First Detector

In order that the receiver may be easy to operate, it is necessary that the tunings of the first detector grid circuit, and of the Beating Oscillator should be quite independent—that there should, in other words, be no coupling between these circuits. For this reason, the Beating Oscillator voltage is introduced in the plate circuit and the signal voltage in the grid circuit of the first detector, which operates on the lower bend of the plate current grid voltage characteristic. It is, however, necessary to neutralize the grid-to-plate capacity of the detector tube by means of a small condenser, which is adjusted in the laboratory, but which is made variable so that it can always be readjusted in service. The adjustment can be checked by short circuiting the input from the antenna, when there will be an appreciable change in the plate current of the first detector, if the balancing condenser is out of adjustment.

The principle of symmetry, so important in short wave work, is preserved in the Beating Oscillator, which is "push-pull." This construction facilitates a perfect balance with the neutralizing condenser, that is to say, a balance which is independent of the tuning of the set. As is well known, an arrangement, that is physically unsymmetrical, is usually at short waves electrically unsymmetrical, on account of the low impedance of any small capacity unbalances, and of the relatively high impedances caused by the inductance of the leads. The push-pull oscillator has, in addition, the advantage of added frequency stability—an important point when it is remembered that a variation of 10,000 cycles in 20 million is all that is required to tune to the neighboring channel. The oscillator coil contains three windings, one of

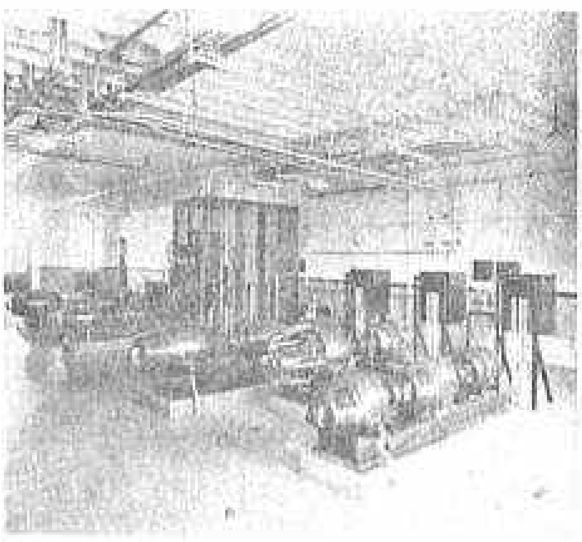


Fig. 50

Motor Generator at Hurlingham, Buenos Aires-New York Circuit.

which is of copper tube, the other two—those conecting to the grids and plates of the tubes—being contained inside the first. By this means, the coupling between the coils is kept close to 100%, so that no coupled circuit effect is noticeable when the oscillator is being tuned. On the other hand, the "skin effect" causes all the high frequency currents to pass onto the outer copper tube, which is made of 5 mm. outer diameter copper, and, therefore, has reduced losses. By this means the decrement of the oscillator circuit is kept low and the frequency stability improved. The 3-winding oscillator coil is assembled as an interchangeable unit, several such coils being used to cover the wavelength range.

Intermediate Frequency Amplifier

The intermediate frequency amplifier operates at a frequency of 500 kilocycles, and has an amplification of about 100 decibels. Seven stages of transformer coupled amplification are provided.

The second detector operates on lower band of the anode current grid voltage characteristic.

The Gain Controls

A manual gain control is provided to permit of a variation of output level of 40 decibels in one decibel steps. In order to overcome the effects of fading, an automatic gain control is provided. It can be thrown in or out of circuit by means of a switch. It contains a single 4102-D (high impedance) tube operating as a third detector with its grid connected to the grid of the second detector located on the intermediate frequency amplifier panel. A resistance of 100,000 ohms is connected in the plate circuit of the gain control tube, and a grid potentiometer is provided whereby the plate current of the tube may be adjusted. This tube fulfills two functions: first it operates as a gain control tube when working on telephony, and secondly as a detector tube when receiving high speed telegraphy. When operating as an automatic gain control tube, the drop in voltage across the 100,000 ohm anode resistance is applied to the grid of the first detector and first amplifying tube. An increase in the strength of the received signal causes an increase in the anode current of the gain control tube, and thus an increase in the negative grid bias applied to the first detector and first amplifying tube. This increase in the negative grid bias reduces the gain of the receiver and thus maintains a constant output level. When operating as a detector for high speed telegraphy, the voltage across the 100,000 ohm anode resistance is applied between grid and filament of the first tube of the signal limiter; the limiter in turn operates a 209 FA relay and the high sped telegraph apparatus.

Signal Limiter

The signal limiter is in effect a two-stage resistance coupled amplifier which may be patched into the output of the telegraph detector when required.

the limiter being provided with input and output jacks for this purpose. The circuit is that of a direct current amplifier thus enabling it to operate on the direct current impulses corresponding to the reception of continuous wave telegraph signals. The limiter employs two 4102-D (high impedance) tubes. The anode current of the second tube is limited to zero during spacing signals, and to 2.7 milliamperes maximum during marking signals.

The limiter is normally patched between the output of the third detector and the receiving relay, and the gain of the receiver is adjusted so that with the lowest received field strength, the marking current in the anode circuit of the second valve is not less than the minimum required to operate the receiving relay (2.3 milliamperes). Any increase in the field strength will then not cause the marking current through the relay to exceed 2.7 milliamperes, and consequently bad operation and chattering of the relay due to an excessive marking current is avoided.

Relay Panel

The relay panel mounts the receiving relay together with the associated circuit elements, designed to deliver current impulses at .. 60 volts to the line. The relay is a standard 209 FA permalloy relay and is capable of operating at speeds up to 120 cycles per second corresponding to 320 words per minute in the Morse Code. The contacts of the relay are suitable for dealing with a current of about 20 milliamperes. The circuit elements associated with the relay include a "kick transformer" for sharpening up the action of the relay.

Battery Supply Circuits

The radio receiver and speech control apparatus require a filament supply at 24 volts with the positive earthed. The total current drawn by the receiver with all tubes switched on is aproximately 10 amperes. In the filament supply circuit to each panel there is an alarm fuse, a rheostat and a three-way key. When the key is in the non-locking position, an ammeter is connected in series with the filament supply to that panel, and when in the locking position the filament supply is cut off.

Alarm relays are connected in series with the filaments of the signal limiter and the three detector tubes, so that failure of the filament supply to any of these tubes causes an alarm lamp to light, and the alarm bell to ring. The voltage of the filament battery may be measured by depressing the 24-volt key and reading the voltage on the meter panel.

The main plate battery supply is at 130 volts with the negative earthed. The total current drain is approximately 0.15 amperes. In addition to the main plate battery, the automatic gain control tube and the first tube of the signal limiter each require a separate dry cell battery of 130 volts. These batteries are mounted on special shelves at the rear of the radio receiver. The current drain from each battery is about 0.5 milliamperes. These two special batteries are insulated from earth.

Alarm fuses are connected in the plate circuit of each tube, and alarm relays are provided in the plate circuits of all tubes except the detectors and the two signal limiter tubes. Failure of the plate current of any of these tubes operates an alarm lamp and the alarm bell. By means of a series of keys, the plate current of any tube may be read on a double range milliammeter provided on the meter panel. By operating the apropriate key, the voltage of each of the three plate batteries may be measured.

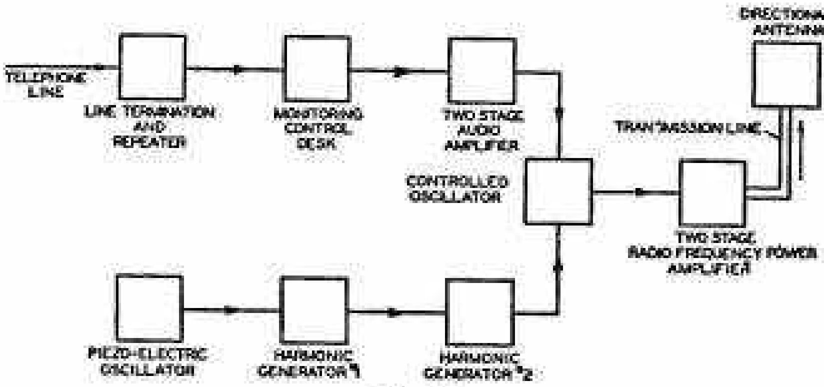


Fig. 51

Block Schematic of Transmitting Station.

For telegraph purposes, a 120-volt battery with the center point earthed, delivering the required value of line current, is supplied. Fuses for this battery are provided on the power supply bay.

A diagram of the whole receiver including power supply circuits and a front view of the receiver are given in Figs. 48 and 49.

The New York-Buenos Aires Radio Circuit

The opening of the radio circuit between New York and Buenos Aires on April 3rd, connecting 277,000 telephones in Argentine, Uruguay, and Chile with 21,600,000 telephones of the United States, Canada, Mexico, and Cuba, marks another step in the world-wide linking of the people of tho earth by means of telephonic communication. By means of the transatlantic radio telephone between New York and London, the Buenos Aires-Madrid radio telephone previously described, and now the New York-Buenos Aires radio telephone, the telephone networks of three continents are in actual or potential communication withone another. The New York-Buenos Aires link is unique in being the first two-way telephone circuit between North and South America. Like the New York-London, and Madrid-Buenos Aires, it is a true radio telephon etrunk link giving service, not to special booths in the cities where the terminals exist but to the entire telephone networks of the countries concerned.

The radio terminals are located near Buenos Aires and New York. At Buenos Aires the transmitting station is at Hurlingham, adjacent to the transmitter for the Buenos Aires-Madrid circuit, while the receiving stations for both the Madrid and New York services are at Platanos. The New York terminal is operated by the American Telephone and Telegraph Company and is located near the short wave transatlantic circuit terminals; the transmitter at Lawrenceville, N. J., and the receiver at Netcong, N. J. The distance between the New York and Buenos Aires terminals is approximately 8,522 kms. (5,290 statute miles).

Transmitter

The transmitter at Hurlingham is located in a building especially designed to house it. On the ground floor and extending the full width of the building is a large room which contains the motor generator sets. Directly above this room is another of the same dimensions containing the power board and radio transmitter proper. On the ground floor adjoining the power room, are a series of vaults containing high voltage transformers and water cooling units. A vacuum tube rectifier for supplying high voltage to the transmitter is located above the transformer vaults in a small room opening into the main transmitter room. The building is designed for an ultimate of two transmitters.

The transmitter is of Western Electric manufacture. It is of the crystal controlled master oscillator type and electrically corresponds closely with the Madrid transmitter. The output stage of the transmitter consists of six water-cooled tubes in push-pull and delivers 15 kw. to the antenna on the highest frequency of approximately twenty-one megacycles (14.3 meters). The installation is especially noteworthy for the precautions taken to insure continuity of service and safety to the operating personnel. Motor generators and power transformers are all supplied in duplicate and so interconnected that in case of failure, any piece of power equipment can be almost instantaneously replaced by spare equipment by throwing a switch. Safety to the personnel is provided by an interlocking system which associates mechanical key operated locks with all switch operating handles and vault inclosure doors. A certain key or series of keys is required to enter any enclosure containing dangerous potentials. The opening of switches, which remove the dangerous voltages from the enclosure in question, releases keys which may be used to open the door. Only when all voltages are shut off and all keys released can the enclosure be entered.

The frequencies used are approximately 21, 15, and 10 megacycles. The

Receiver

The receiver for the New York channel at Buenos Aires is located at Platanos. It is of Western Electric manufacture and is of the superheterodyne type. Two stages of radio frequency amplification are followed by the first detector. An intermediate frequency of 400 kilocycles is employed, the intermediate stage consisting of a band pass filter followed by six stages of amplification, another band pass filter and the second detector. Automatic volume control to minimize the effects of fading is employed. The receiving antennas are of the frame or zigzag type.

Transoceanic Telephone Service—Short-Wave Equipment New York—London Service

Shortly after transatlantic telephone service was opened in January, 1927, the long-wave radio circuit between New York and London was supplemented, first by an experimental short-wave radio link in the west-east direction and later by a short-wave link in the east-west direction. From this beginning, as an auxiliary to the long-wave circuit, the short-wave system has been improved steadily so that its average performance throughout the year now more nearly approaches that of the long-wave system and it has become an important part of the transoceanic facilities. The relative merits of the two systems, their combined usefulness, and their transmission features are the subject of another paper and will not be discussed here. For the present purpose it will be sufficient to note that there are now in operation between New York and London, one long-wave and three short-wave two-way circuits and a short-wave circuit between New York and Buenos Aires.

The radio transmitting units for the New York end of these four circuits are located at the new station which the American Telephone and Telegraph Company has recently established at Lawrenceville, New Jersey. The receiving units are concentrated at Netcong, New Jersey. The factors entering into the selection of these station locations are outlined in another paper and therefore need not be mentioned further. This text is limited in scope to a necessarily brief description of the transmitting and receiving systems and apparatus, a discussion of technical features in the station layouts, and an outline of the major problems encountered in the station design. Comprehensive treatment of individual units is properly left for other entire papers. It will be convenient to deal with the transmitting and receiving stations separately and in each case to consider briefly the system and apparatus of one channel before describing the general station plan.

Transmitting System

The four channels at Lawrenceville are equipped with independent transmitters using certain auxiliary apparatus in common. Each channel involves a radio transmitter with its associated power plant and, wire equipment, and a group of directive antennas designed and adjusted for the specific wave-length assignments of the channel.

The general method of transmission, with the exception of directional sending, is the same as that employed for program broadcasting stations in that the radiated signal contains the carrier and both sidebands. Systems in which one or more of these components are suppressed at the transmitter appear to offer further means of improving short-wave transmission, and the necessary apparatus for the practical application of such systems when operating at frequencies in the order of 20,000 kilocycles is undergoing development. However, throughout the development of the transmitters as now installed at Lawrenceville the possibility of future major modifications in the method of transmission has been kept in mind. For this reason the modulator-amplifier system was adopted. In this system the signal which is to be radiated, is prepared by modulation processes at relatively low power levels and thereafter amplified the requisite amount. The amplifier and its power plant, representing a large proportion of the investment in equipment, can be continued in service with no appreciable alterations, even though the system of transmission and the modulating apparatus undergo radical changes.

The general scheme of transmission is shown in Fig. 51. After passing through the line terminal and control apparatus, which includes standard repeaters, the voice currents are further amplified and employed to modulate the plate voltage of an oscillator consisting of two 250-watt tubes connected in a push-pull circuit and oscillating at the frequency of the carrier which is to be transmitted. The frequency of such an oscillator, if not carefully controlled, will wander outside of the assigned frequency band, thus causing interference with other services and it will also suffer variations during the modulation cycle which contribute to fading phenomena encountered at the distant receiving station. In order to reduce these effects the oscillator is held in step at the desired carrier frequency by means of a second oscillator which is electrically removed from the reactions normally influencing and tending to vary the frequency of the controlled oscillator. Every precaution is taken to maintain accurately the frequency of the second oscillator and among other things it is governed by a piezo-electric quartz crystal whose temperature is regulated closely.

Since it is impractical to use crystals cut sufficiently thin to oscillate directly at frequencies in the range 10,000 to 20,000 kilocycles, thicker crystals of lower frequency are used in combination with harmonic generators which multiply the crystal frequency first by two or three and then by one or two as the case requires. By virtue of the wide differences between the input and output frequencies of the harmonic generators these intermediate steps tend to isolate the crystal oscillator from the other radio circuits and thus aid in stabilizing the frequency.

The modulated radio frequency output of the controlled oscillator is applied to the grids of a two-stage power amplifier employing water-cooled tubes designed for operation at these frequencies. The first stage contains two tubes and the second stage contains six. The tubes are arranged in push-pull circuits, the entire system being carefully balanced to ground. The carrier-output power from the last stage is 15 kw. With 100 per cent modulation this corresponds to 60 kw. at the peaks of the modulation cycle. In other words, a radio telephone amplifier of this type, rated at 15 kw. when provided with a sufficiently large d-c. power source, could be used as a 10,000-kilocycle continuous wave generator of 60 kw. capacity.

The radio signal delivered by the amplifier is conveyed to the antenna by means of a 600-ohm open wire transmission line. The antenna itself is both a very efficient radiator and a highly directive one.

Transmitting Equipment

At the transmitting station the apparatus for each channel comprises, (1) wire terminal equipment and repeaters, (2) a voice frequency control desk, (3) the radio transmitting set containing the oscillators, modulators, and power amplifier, (4) a power control board, (5) rectifying apparatus and filters for supplying direct current at 10,000 volts, (6) motor-generators for providing various circuits with direct current, (7) water circulating pumps, tanks, and cooling units.

The wire terminal equipment and repeaters at the transmitting station are standard units mounted on relay racks beside the voice frequency testing apparatus common for all channels.

The voice frequency control desk provides facilities by which the attendant can monitor the incoming voice currents and the outgoing radio signal. Means are provided for observing the volume of these signals. Oscillators are provided for the purpose of quickly checking the performance of the system during line-up periods and for sending Morse signals over the radio link when required. The control desk is also equipped with apparatus for direct telegraph communication with the technical operator at New York.

The radio transmitter consists of seven independently shielded units mounted on a common sub-base to form a single assembly, 4 ft. by 20 ft. by 7 ft. high. Some of the units are subdivided into several small shielded compartments. Very effective electrical screening or shielding between the various parts of a short-wave transmitter is essential. Otherwise stray fields introduce unwanted feedback couplings which produce distortion effects and spurious oscillations. Beginning at the left there are two units for spech amplification, one for radio frequency generation and modulation, one unit each for the first stage, the interstage circuit and the last stage of radio-amplification, and a double-sized unit for the output circuit. It is interesting to note that the over-all length of this assembly is as much as five-eighths of a wavelength at the highest frequency in its operating range, which is 9,000 to 21,000 kilocycles. Each transmitter is required to operate at several assigned frequencies within this range and to change in a few minutes from one to another. This is done by changing coils and varying condensers in the oscillator and amplifier circuits and switching to different quartz crystals. Except in cases where two assigned frequencies are in harmonic relationship, it necessary to provide a crystal for each of the frequencies. The crystals are mounted in an oven and continuously maintained at 50 deg. ± 0.005 deg. cent., by recording regulators. In order to avoid long interruptions to service in the event of a crystal failure or other circumstance requiring the opening of the oven and the subsequent re-establishment of temperament equilibirium, the ovens and crystals are provided in duplicate.

The electrical problems which are encountered by the engineer designing a power amplifier for these high frequencies arise largely from the inherent stray or distributed capacities and inductances which are far less important at lower radio frequencies. For example, between the anodes of the amplifier circuit there exist capacities, which are composed of capacities within the

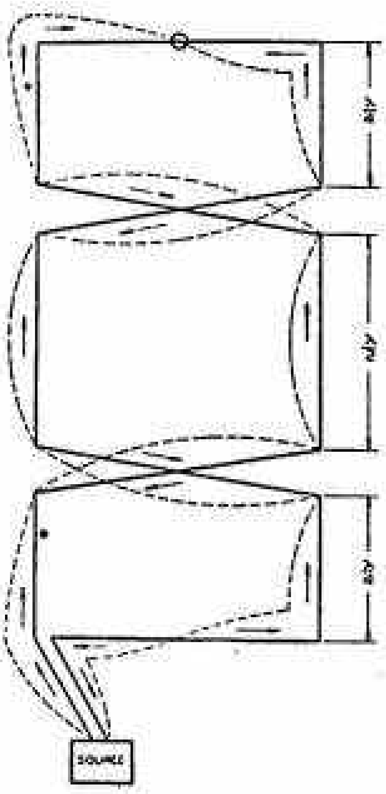


Fig. 52

Conductor Bent to Form One Section of Simple Directive Antenna. The Type Used for Transmitting at Lawrenceville.

tube itself, the direct capacities between the tube water jackets, the mounting plates and the like. The total value of this composite capacity in the last stage is approximately 100 m.m.f. This value cannot be appreciably reduced by any change in design which now seems desirable. The reactance of 100 m.m.f. at 20,000 kilocycles is about 80 ohms. Thus the engineer is confronted at the outset with a generator (the tubes) which has an internal impedance in the order of 2,000 ohms but across whose terminal is shunted inherently an 80-ohm reactance. Fortunately, this obstacle can be surmounted by introducing resonance effects but nevertheless it places very important limitations on the design of the associated circuits. These problems become more difficult with increase of either power or frequency. Increase in power requires higher voltages and currents and thus larger elements, spaced farther apart. The augmented bulk increases both stray capacities and unwanted inductance of leads. Higher frequencies increase the magnitude and therefore the relative importance of these effects.

The power control board has nine panels equipped with the necessary instruments and apparatus for controlling and distributing all power to the transmitter. The motor-generators, pumps, fans, oil circuit breakers, and other apparatus are remotely controlled from this point. A system of relays and signal lamps provides protection and indicates the location and general nature of any trouble. With the exception of the application of high-voltage direct current, the entire system starts up and shuts down in the proper sequence in response to the manipulation of a master control switch.

Direct current at 10,000 volts is supplied to the anodes of the power amplifier tubes by a transformer and rectifier using six standard two-electrode thermionic tubes. The rectified current is filtered separately for each stage of the amplifier. This is necessary to prevent distortion by interstage modulation caused by the common impedance of the rectifier. Effects of this nature become important as the requirements placed on unwanted modulation products become more stringent.

Transmitting Antennas

The antennas at Lawrenceville all have comparatively sharp directional properties. Such antennas are readily realized when dealing with radio waves of very short wavelengths. Although the fundamental principles involved in producing these directional effects have been known for many years, economic limitations effectively prevented their application to transmitting antennas for long wavelengths. These limitations are altered immensely in the case of antennas for short wavelengths and, when the useful propagation properties of short waves became known, great stimulus was given to the development of antennas for directional sending and receiving. The same type of antenna can be used, of course, for both purposes but, since the objectives when sending and receiving are somewhat different, the tendency has been to develop arrangements adapted to each case.

Directional transmission is a very large subject and will only be touched upon sufficiently to describe in a very general way the antennas at Lawrenceville. There are many possible arrangements and combinations and the en-

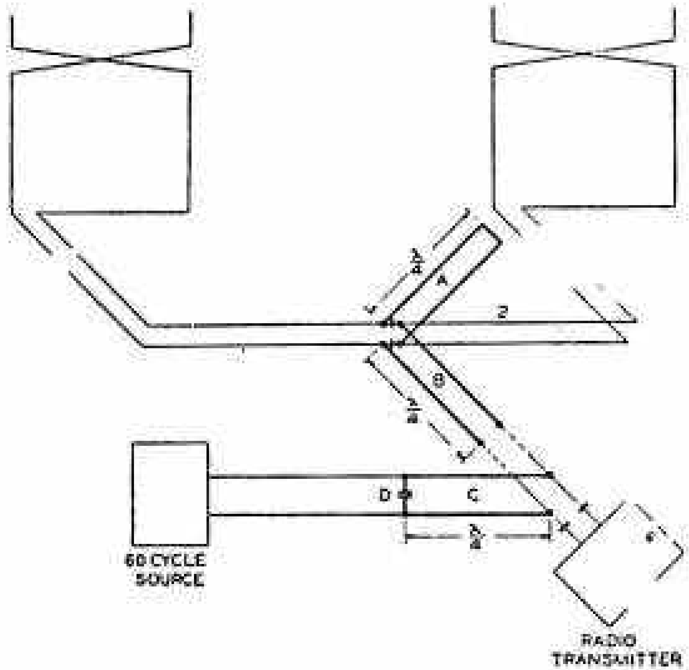


Fig. 53
Antenna Sleet-melting Circuit.

giners must choose from these the ones most suitable for their purpose. In general all of the schemes depend upon producing interference patterns which increase the signal intensity in the chosen direction and reduce it to comparatively small values in other directions.

One of the methods of obtaining a sharply directive characteristic is to arrange a large number of radiating elements in a vertical plane array, spacing them at suitable distances and interconnecting them in such a manner that the currents in all the radiating members are in phase. A simple way of accomplishing this result and the one which is now being employed at Lawrenceville depends upon the manner in which standing waves are formed on conductors. It is generally known that current nodes and current maxima will recur along a straight conductor whose length is an exact multiple of one-half the wavelength of the exciting e.m.f. and that the phase difference between successive current maxima is 180 deg.[4] Such a conductor when folded in a vertical plane as shown in Fig. 52 and with its length adjusted slightly to compensate for the effects of folding, satisfies the aforementioned requirements for producing directional radiation. The arrows in Fig. 3 indicate the relative directions of current flow and the dotted line indicates the current amplitudes along the conductor. It will be noted that the instantaneous currents in all the vertical members are in the same direction and that in the cross members their directions are opposed. Due to these current relations and the physical positions of the elements, the cross members radiate a negligible amount of energy whereas the vertical members combine their effects for the directions perpendicular to the plane of the conductor. In other directions destructive interference reduces the radiation from the vertical members. The system is equivalent to four Hertz oscillators driven in phase, and arranged in two groups one-half wavelength apart, the two oscillators of each group being placed one above the other. Both computation and experiment have shown that with this system of radiation there is an improvement of approximately 6 db. In other words the same signal intensity in the chosen direction is obtained with one-fourth of the power required by a one-element radiator. A second similar conductor system placed directly behind the first in a parallel plane one-quarter wavelength away, will be excited parasitically from the first conductor and will act as a reflector, thereby creating a unidirectional system. It has been found that the reflector further reduces by 3 db. the power required to maintain a given signal intensity in the desired direction, thus bringing the total gain for the system up to 9db. This is also in agreement with the theoretical computations.

It is obvious that the system in Fig. 52 can be extended vertically to include more radiating elements by increasing the length of the conductor and it can be enlarged horizontally by placing several units alongside each other, care being taken to obtain the desired phase relations by transmission lines of the proper length. In this way large power savings may be reflected. At Lawrenceville the maximum gain is about 17 db. (a power ratio of 50) over a vertical halfwave oscillator. The enlarged system lends itself readily to mechanical support and forms so-called exciter and reflector "curtains" which are suspended between steel towers appropriately spaced. Aside from other considerations, which will be mentioned in connection with station layout, the size of the antenna is influenced by the complex and variable nature of the wave propagation through space. At present this determines the degree of directivity which is most useful for the average conditions.

The closed loops of each unit corresponding to Fig. 52 greatly facilitate

[4] This assumes of course that the conductor is in space free from objects affecting its electrical properties and that the ends are free or properly terminated to produce reflections.

the removal of sleet. In addition to loading the antenna mechanically, ice, having a dielectric constant of 2.2 at these high frequencies, adversely affects the tuning. At Lawrenceville sleet is removed by heating the wires with current at 60 cycles. This is accomplished without interfering with the service by employing one of the less familiar properties of a transmission line. The same property also is used to effect impedance matches wherever the transmission lines are branched. If a line, exactly one-quarter wavelength

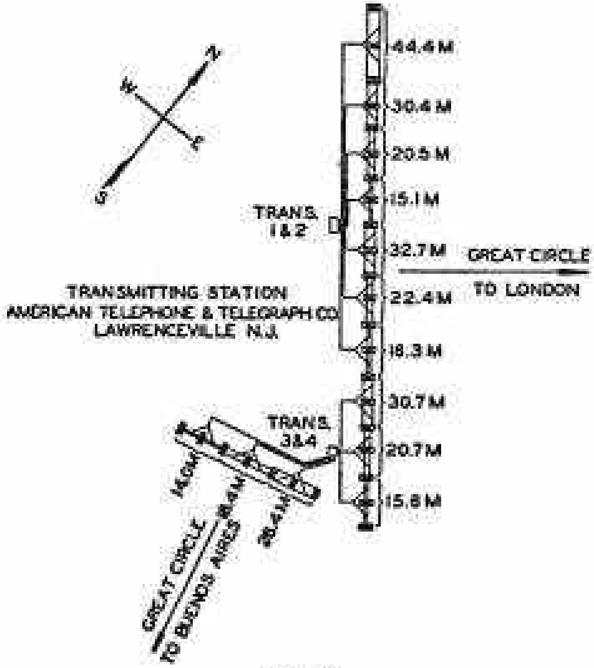


Fig. 54

Arrangement of Antennas at Lawrenceville Transmitting Station.

long, of large impedance Z_0 is terminated with a load Z_R, the sending end impedance Z_s is equal to Z_0^2/Z . If Z_R is a pure resistance the sending-end impedance is a pure resistance. Hence a quarter wavelength line may be used to connect two circuits of different impedances and these impedances may be matched by controlling the value of Z_0 either by varying the diameter of the conductors or their spacing. Likewise, if Z_0 is fixed and Z_R is made very small, then Z_s will be extremely large.

In Fig. 53 two units of the type shown in Fig. 3 are excited through transmission lines 1 and 2 of equal length in order to give the correct phase relations in the radiating elements. The lines are joined in parallel by condensers of low impedance at radio frequencies and they are connected in series for 60-cycle currents by the quarter wavelengths line *A* which, being short-circuited at the one end, presents a very high impedance to radio frequency currents at the other end and therefore behaves like an anti-resonant circuit. The quarter wavelength line *B* serves as a transformer and is adjusted to match the impedance at the junction of lines 1 and 2 with that of the radio transmitter. The quarter wavelength line *C* is effectively short-circuited for radio frequencies by the condenser *D* and acts the same as *A*. These quarter wave lines consist of short lengths of pipe mounted on frames under the antenna curtains as shown in Fig. 5.

Transmitting Station

Among the first radio problems encountered in the design of a transmitting station for several channels are those concerning the size, shape, and number of antennas, their directions of transmission, their relative positions from the point of view of mutual interference, and their grouping around the transmitters.

The number of antennas required for each channel is determined by the hours of operation and the average grade of service which the system is expected to render. For service covering a large portion of each day several wavelengths are necessary. Transmitters Nos. 1, 3, and 4 at Lawrenceville each are assigned three frequencies. No. 2 has five assignments in order to improve the likelihood of at least one channel being available throughout the entire day at all seasons.

The size and shape of the antennas are, of course, determined by the directivity wanted, by the type employed, the frequency assignments, and by considerations of cost. They are governed also by the necessity of connecting several antennas to the same transmitting set. This involves both the spacing and arrangement of antennas to avoid adverse mutual reactions and it requires that attention be given to the losses in the connecting transmission lines, which are by no means negligible. Operating economies suggest concentrating all the transmitters at one point but the cost per kilowatt hour of modulated high-frequency power must be taken into account when considering the use of long transmission lines. It should be recognized, of course, that in the early applications of a comparatively new art, it is impossible to approach anything like accurate evaluation of all the factors entering into economic balances and furthermore very considerable weight needs to be given to the probable future trend of developments.

At Lawrenceville all of the antennas for the three channels to England are arranged in a straight line about one mile long. The direction of this line is perpendicular to the great circle path to Baldock, England, where the signals are received, (Fig. 54). The antennas for the fourth channel are similarly arranged in a line 1,500 ft. long and they are directed for transmission to Buenos Aires, Argentine.

Placing several antennas in a single line reduces the cost of the supporting structure, and all the antennas have a clear sweep in the direction of transmission. By locating them in proper sequence with respect to wavelengths it is possible without objectionable interference, to place the antennas end-to-end and thus use supporting towers in common. Due to the wide difference in wavelength between adjacent antennas and their right-

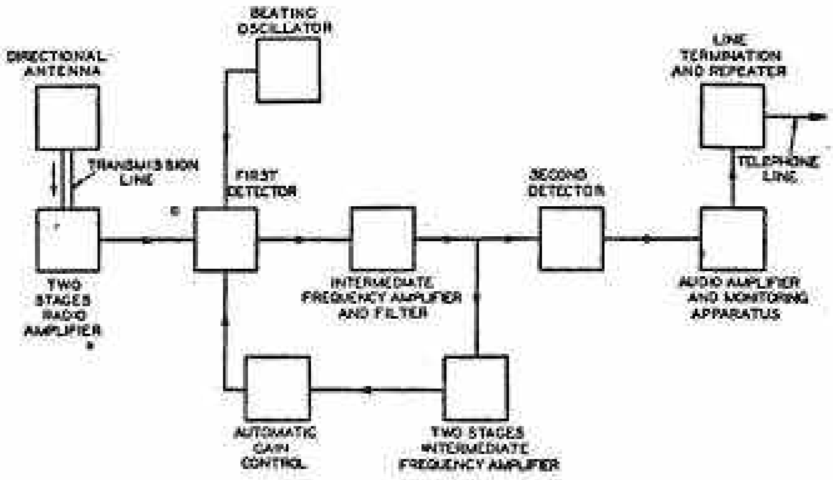


Fig. 55

Block Schematic of Receiving System.

angle position with respect to the line of transmission, their proximity has no appreciable effect different from that of the towers. The proper selection of tower spacing in respect to wavelengths makes it possible to erect a uniform supporting structure. This has the advantage of flexibility and will permit future alterations of either the location or size of a given antenna. At present, each antenna occupies the space between three towers.

In order to avoid undue loss in the transmission lines the radio transmitters are grouped in two buildings. The buildings each contain two transmitters and are identical in layout, in so far as the radio equipment is concerned. Building No. 1 has additional space for the central wire terminating and testing equipment. This apparatus is contained in an electrically screened room which effectively prevents high-frequency fields from interfering with the proper functioning of the apparatus.

Receiving System

Short-wave reception is characterized by less difficulty with static than that encountered with long waves. On the other hand it suffers interference from sources such as the ignition systems of passing airplanes and automotiles, which ordinarily do not disturb long-wave systems. Frequently the incoming radio waves suffer wide and rapid swings in intensity and there are variations in the apparent direction of arrival. On account of the extremely high frequencies the apparatus and antenna structures are very different from those for the long waves; otherwise the general schemes of reception are similar, directional effects and double detection methods being employed for both.

The radio wave is collected by means of a directional antenna array whose prime function is to improve the ratio between the desired signal and unwanted noise or other interference. This it does in two ways: *viz.*, (1) by increasing the total signal energy delivered to the receiver and (2) by discriminating against waves whose directions of arrival differ from the chosen one. Increasing the total energy collected from the incoming message wave permits the detection of correspondingly weaker signals because there is an apparently irreducible minimum of noise inherent to the input circuits of the first vacuum tube in the receiver and this noise establishes a lower limit below which signals cannot be received satisfactorily. Since, under many conditions, the directions of arrival of static and other disturbances including unwanted radio signals are random, it is obvious that sharp directive discrimination aids very materially in excluding them from the receiver. On the other hand, the antennas are not sharply resonant systems and they do not distinguish between waves from substantially the same direction and closely adjacent in frequency. This duty is left to the circuits of the radio receiver.

Having collected the signal with a directional antenna the energy is conveyed to the receiving set by means of concentric pipe transmission lines of small diameter. The use of concentric conductors simplifies the prevention of direct signal pick-up by the lines, it reduces losses and prevents external objects from influencing the transmission properties, thus allowing the line to be buried in the ground or placed a few inches above the surface where it will have no appreciable adverse effect on the antenna performance.

Referring now to Fig. 55, the radio currents arriving over the transmission line are first amplified by two stages of radio amplification involving tuned circuits which discriminate further in favor of the wanted signal. The signal delivered by the radio amplifier is at a suitable level for efficiant demodulation and is applied to the grid of the first detector. By means of a beating oscillator whose frequency is suitably adjusted, the first detector steps the signal carrier frequency down to a fixed value of 400 kilocycles from one in the range 9,000 to 21,000 kilocycles which depends, of course, on the distant transmitting station assignment. The intermediate frequency signal at 400 kilocycles then passes through a combination of amplifiers and filters which further exclude the unwanted interference. The wanted signal reaches the second detector where it is demodulated and the voice currents reproduced. The latter are then amplified and applied to the telephone lines.

A portion of the output from the intermediate amplifier which would normally go to the second detector grid, is diverted and further amplified. It

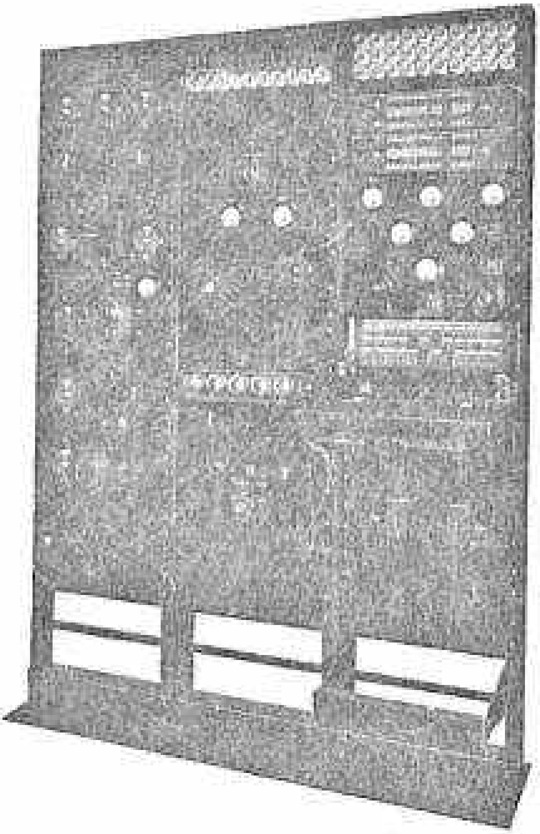


Fig. 56
Short-Wave Radio Receiver, Front View

is then supplied to a device which automatically tends to maintain the receiver output volume constant by controlling the bias potential of the first detector grid circuit. The time constants are adjusted so that this gain control does not respond to the normal variation in signal power corresponding to speech modulation. Otherwise, of course, there would be serious distortion effects. This device partially offsets the ill effects of wide fluctuations in signal intensity but it does not overcome the deterioration in signal quality which usually accompanies the low field strengths during such fluctuations.

Receiving Equipment

At the receiving station the apparatus for each channel comprises, (1) the radio receiving set, (2) a power plant for the receiver, (3) wire termi-

-ting equipment and repeaters. The latter are located at a central point in the station along with certain voice frequency testing apparatus used in common by all channels and supplied with power from a common source.

A radio receiving set which embodies the above described system and

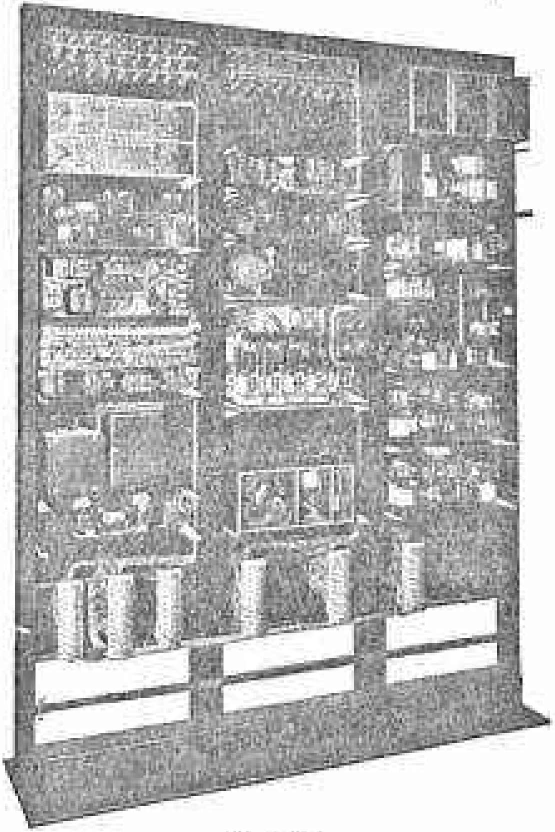


Fig. 57
Short-Wave Radio Receiver, Rear View

of the type installed at Netcong is shown in Figs. 56 and 57. It consists of a large number of individually shielded units mounted on panels and assembled on three self-supporting racks of the type commonly employed in the telephone plant. This permits the use without modification of certain standard pieces of equipment, such as jack strips, fuse panels, meter panels, audio frequency filters, and the like. It also permits the removal and repair or substitution of units with a minimum of delay. The set is required to receive signals at three fixed frequencies in the range 9,000 to 21,000 kilocycles. This involves connections with three antennas through three separate transmission lines. The tuning of the antenna and transmission line terminations are rather lengthy processes requiring precise adjustments. In order to facilitate quick changes from one operating frequency to another without intricate tuning operations, the first stage of radio amplification is provided in triplicate and the switching is done between the first and second stage. Thus the antennas are permanently connected to the set and their adjustments remain undisturbed. The circuits of the second stage require tuning when the frequency is changed. Hence to tune the receiver on any one of the assigned frequencies, the attendant merely moves the dials of the second stage to predetermined settings, switches the grid circuit to a first stage which is already

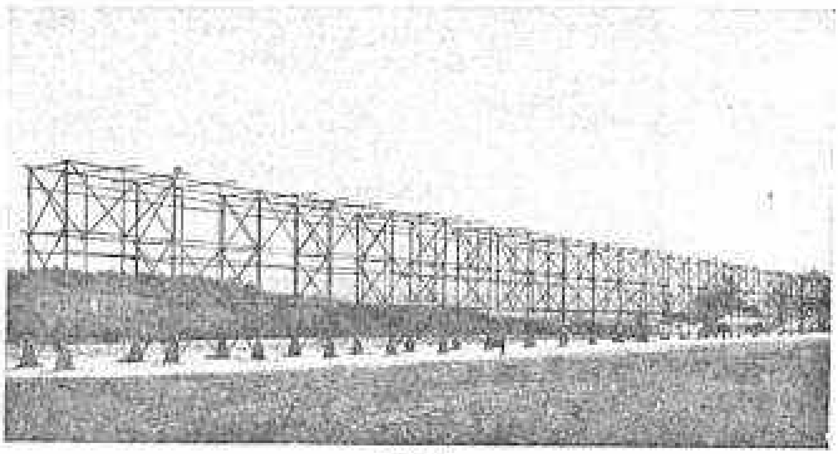


Fig. 58
One of the Receiving Antennas at Netcong. (24.7 Meter Wavelength.)

tuned and connected with the proper antenna and he adjusts the beating oscillator to obtain an intermediate frequency of 400 kilocycles. Screened grid tubes are used for the first two stages of amplification. A key shelf is provided with telephone and telegraph facilities. The power plant consists of standard 24-volt and 130 batteries, rectifier charging units and automatic regulators.

Receiving Antennas

In discussing antennas for directional sending it was mentioned that an identical antenna could be used for receiving purposes, but since the requirements in the two cases are not the same, quite different structures have been developed, although the methods of obtaining directivity are alike. In the sending case the reduction of random radiation ceases to be profitable when the increment thus added to the energy, which is radiated in the direction of the distant receiving station, is a relatively small part of the total. In the receiving case, although the response to the wanted signal may not be increased appreciably by further improvement in the directive pattern, the reduction in noise and interference from random directions justifies additional improvement. Expressed another way, the objective in the transmitting case is a high gain compared to a nondirectional antenna, whereas in the receiving case the objectives are, first, a high average signal-to-noise ratio and, second, a gain sufficient to override the noise inherent to the receiving set. Satisfying the first accomplishes the second.

Improvement of the average directional discrimination means a nearer approach to ideal conditions. Whereas steel towers, sectionalized cables, guys and the like, when properly located relative to the conductors of a sending

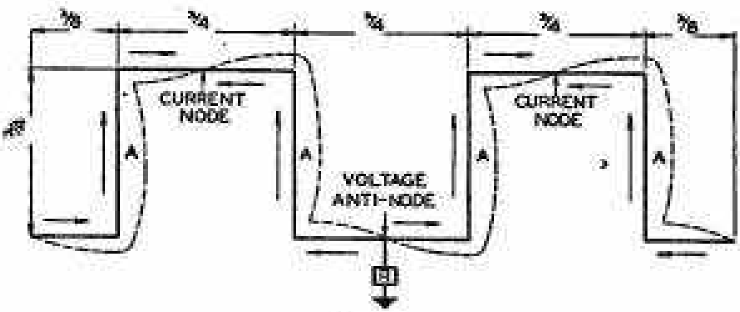


Fig. 59
Diagram of Simple Directive Receiving Antenna.

antenna, do not cause any appreciable power loss, their presence near the receiving antenna may prevent the realization of the extreme directive properties which are wanted. Moreover, there is need for much greater rigidity in the positions of the conductors. For this reason the antennas at Netcong are supported on wooden frames constructed like large crates.

Due to the variable conditions surrounding the propagation of short waves in space, the vertical angle of arrival of the signal wave at the receiving station frequently changes considerably throughout a twenty-four-hour period and is not always the same from day to day. In order to combat this variable condition, it appears desirable to select an antenna arrangement which does not have sharp directional properties in a vertical plane passed through the horizontal direction of arrival. The type of antenna selected for Netcong meets this requirement by having only a single horizontal row of quarter-wave vertical elements in one plane. Another solution, of course, would be to provide several antennas of different characteristics and to shift about from one antenna to another as the conditions warranted.

Fig. 58 is a general view of one of the Netcong receiving antennas. Like the transmitting antennas, the conductors are arranged in two parallel planes one-quarter wavelength apart in order to obtain a unidirectional system. The conductor in each plane is bent and terminated as indicated in Fig. 59 but is much longer than that shown. The vertical members are marked *A*. As in the transmitting case the directional effect depends upon the manner in which standing waves occur along the conductor. A signal wave arriving broadside to the array induces voltages in the vertical members which are identical in phase and amplitude.

Because the vertical members are interconnected alternately at the top and bottom by members of one-quarter wavelength and the last horizontal members are one-eighth wavelength, the net effect of the induced voltages is the establishment of standing current and voltage waves along the conductor. The receiver is connected at a voltage anti-node and the current which flows through it is proportional to the sum of the voltages induced in the vertical members. In the case of a signal wave arriving from the horizontal directions parallel to the plane of the array, the voltages in the vertical members are in successsive quarter-phase relationships, no standing waves are produced, and no current flows through the receiver. Because current nodes occur at the center of each horizontal member, the loss by reradiation from these members is negligible. This is an important feature which contributed to the selection of this type of antenna for Netcong.

The size of the antenna is determined largely by the manner in which the signal waves arrive although costs cannot be wholly neglected. The useful length is limited by the fact that random fading occurs at distances as short as ten wavelengths and it is doubtful if an antenna this long would realize the computed improvement. The cost per decibel gained is small for the initial steps, but it mounts very rapidly as the length of antenna increases. The height also is limited by cost and by the necessity of allowing for considerable variation in the vertical angle of arrival as discussed in a previous paragraph.

The antennas at Netcong are six wavelengths long and the lowest conductors are about 10 ft. off of the ground. The gains over that of a half-wave vertical antenna are in the order of 16 db (power ratio of 40). The average improvement in signal-to-noise ratio is of the same order. There are certain null points toward the sides and rear for which the ratio of directional discrimination is very large.

The transmission lines are constructed of inner and outer copper tubes respectively 3/16 in. outside diameter and 5/8 in. inside diameter. The tubes are held concentric by torroidal-shaped insulators made of Isolantite, a ceramic product similar to porcelain and well adapted for high-frequency voltages. This same material is used for insulating purposes throughout the transmitting and receiving antennas. Transmission lines are supported a few inches above the ground and are connected to earth at short intervals. The lines vary in length from 200 to 1,500 ft. One of the interesting problems in connection with their design is the provision of means for allowing variation in length with temperature. Ordinary expansion joints introduce difficulties with electrical contacts and impedance irregularities. To avoid these the lines are made 10 per cent longer than otherwise necessary and they follow a sinuous course which permits the necessary bending. Sharp turns are not permissible because experiments have shown that they cause reflection disturbances. The measured loss in 1,000 ft. of line at 20,000 kilocycles is 2 db.

Receiving Station

The radio problems encountered in the layout of the receiving station, in general, include most of those already mentioned in connection with the

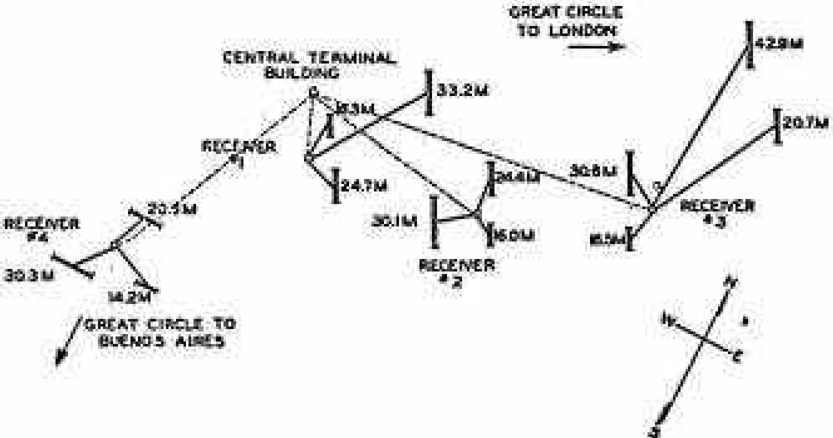


Fig. 60

Arrangement of Receiving Antennas at Netcong Receiving Station.

transmitting station, but their solution in some instances is quite different. In addition there are requirements imposed by sources of radio noise both within the station itself, and in the sourrounding area which is beyond the control of the station.

The number of antennas is determined, of course, by the frequency assignments of the distant transmitting station. Where two assignments are within 100 kilocycles it is possible to use the same antenna for both, but thus far, this has not been done at Netcong.

The size of the antennas is not limited appreciably by the length of transmission lines because other factors make it necessary to separate them rather widely. On this account and also because the receiving apparatus and its power plant are small, comparatively inexpensive units, it is economical to place the receivers in small buildings centrally located with respect to the group of antennas for one channel. In this case the lengths of transmission lines are not controlling factors and the dimensions of antennas are governed primarily by the considerations previously outlined when describing the individual antenna. The small height of the antenna permits them to be placed in the line of reception of other antennas spaced ten wavelengths or more away and of widely different frequencies such as those of one channel. Antennas adjusted for the same order of frequency are separated more than this. On the other hand, to avoid adverse reactions no two are placed adjacent and end-to-end as at the transmitting station. The end-to-end separation at Netcong is in the order of four wavelengths. The areas surrounding antennas are cleared of trees and kept free of all overhead wires or conducting structures to avoid reflection effects which disturb the directional characteristic of the antenna systems.

The locations of antennas are also influenced materially by the necessity of avoiding interference from the ignition systems of internal combustion engines. This imposes a requirement that the station site be isolated from air routes and roads carrying heavy traffic. The antennas are placed as far as possible from secondary roads which cross their line of reception.

The layout at Netcong is shown in Fig. 60. There are thirteen antennas arranged in four groups with a receiver building for each group. A headquarters building located at the road entrance contains the wire terminating equipment, line repeaters, and voice-frequency testing apparatus. The power plant at each receiver and the entire central terminal apparatus at the headquarters building are placed in electrically shielded rooms to prevent radio noise disturbances emanating from them and reaching the receivers directly or via the antennas.

The radio stations described herein are pioneer commercial applications in the development of short wave telephone transmission. Although progress has been rapid and far-reaching, our knowledge of the behavior of short waves is by no means complete. It is reasonable, therefore, to expect that the future holds many improvements and that the information obtained by further fundamental investigations may materially alter both our views of the transmission phenomena and our ideas of what the apparatus and stations should be.

Transoceanic Telephone Service—Short-Wave Transmission New York-London Service

Trunk circuits between London and New York which furnish telephone service between these two cities and also permit successful conversation by means of toll wire extensions between the United States and Europe more generally are being carried over both long waves and short waves. It is the purpose of this paper to consider the transmission side of the new short-wave circuits which the American Telephone and Telegraph Company and the British General Post Office have made available for this service. In doing this we shall proceed from the more general considerations, relating to wavelengths and communication channels, through a discussion of the principles governing the general design of the system, into a brief summary of practical performance results.

The frequency range so far developed for commercial radio use is roughly 20 to 30 million cycles wide, extending from about 10 kilocycles to perhaps 25,000 kilocycles per second. There are two parts of this whole spectrum suitable for transoceanic radio telephony—the long-wave range which is relatively narrow, extending roughly from 40 kilocycles to 100 kilocycles, and the short-wave range which in its entirety is much broader, extending from about 6,000 kilocycles to 25,000 kilocycles.

It is evident that the long-wave region, including perhaps only 50 kilocycles, offers opportunity for development of relatively few telephone channels, particularly in view of the fact that it is in use by a number of telegraph stations. Also it must be borne in mind that for telephony these waves are suitable for only moderate distances of the order of 3,000 miles and for routes in the temperate zones where static interference is moderate. The first transatlantic radio-telephone circuit opened in 1927 was a long-wave circuit (58.5-61.5 kilocycles). In providing the next few channels for the initial growth of the service, the opportunity to determine the utility of short waves was embraced.

The short-wave range is vastly wider in kilocycles but, nevertheless, has its limitations as to the number of communication facilities it affords. For a given route of a few thousand miles a single frequency gives good transmission for only a part of the day. For example, from the United States to Europe a frequency of about 18,000 to 21,000 kilocycles (17 to 14 meters) is good during daylight on the Atlantic. But in the dawn and dusk period a frequency of about 14,000 kilocycles (22 meters) is better. For the dark hours something like 9,000 kilocycles (33 meters) gives best transmission and for midnight in winter an even lower frequency near 6,000 kilocycles (50 meters) is advantageous. Thus, in considering the short-wave range in terms of communication circuits, we must shrink its apparent width materially to take account of the several frequencies required for continuous service.

At the present time the frequency spaces between channels are much greater than the bands of frequencies actually occupied by useful transmission. This elbow room is to allow for the tendency of many stations not to stay accurately on their nominal frequencies but to wander about somewhat. But in spite of this allowance, cases of interference are common and one of the activities which must be carried on in connection with a commercial system is the monitoring of interfering stations and the accurate measurement of transmitting frequencies to determine the cause of the conflict. To permit intensive development of the frequency space offered by Nature, the greatest possible constancy and accuracy of frequency maintenance in transmitting sets will be required.

The fact that channels have been assigned (within wide bands set aside for a particular service) with little regard to the geographical location of stations may result in neighboring channels having much stronger signals than those in the channel being received. When this is so, a severe requirement is placed on the selectivity of the receiver to prevent interference.

Interconnecting With Wire Circuit Extensions

The skeleton of a radio-telephone circuit is in its essentials very simple. It consists merely of a transmitter and a receiver at each end of the route and two oppositely directed, one-way radio channels between them. These two independent channels must be arranged at the terminals to connect with two-

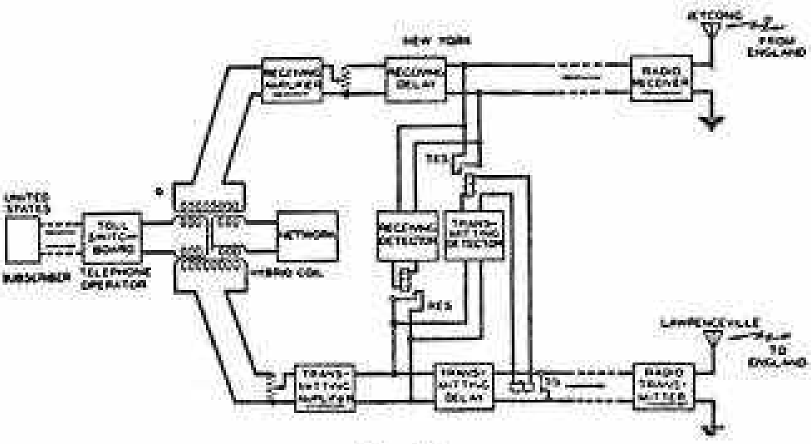


Fig. 61

Circuit Diagram Illustrating Operation of Voice-Operated Switchiñg Device.

wire telephone circuits in which messages in opposite directions travel on the same wire path. The familiar hybrid coil arrangement so common in telephone repeaters and four-wire cable circuits might appear to solve this problem, were there not difficulties peculiar to the radio channels. In the short-wave case large variations in attenuation occur in the radio paths within short intervals of time. These would tend to cause re-transmission of received signals at such amplitudes that severe echoes and even singing around the two ends of the circuit would occur unless means were provided to prevent this.

To overcome these fundamental transmission difficulties, an automatic system of switches operated by the voice currents of the speakers has been developed. These devices cut off the radio path in one direction while speech is traveling in the reverse direction and also keep one direction blocked when no speech is being transmitted. The operation is so rapid that it is unnoticed by the telephone users. Since this system prevents the existence of singing and echo paths, it permits the amplification to be varied at several points almost without regard to changes in other parts of the system, and it is possible by manual adjustment to maintain the volumes passing into the radio link at relatively constant values, irrespective of the lengths of the connected wire circuits and the talking habits of the subscribers.

Fig. 61 gives a schematic diagram of the United States end of one of the short-wave circuits showing the essential features of a voice-operated device which has been used. This kind of apparatus is capable of taking many forms and is, of course, subject to change as improvements are developed. The diagram illustrates how one of these forms might be set up. This form employs electro-mechanical relays. The functioning of the apparatus illustrated is briefly as follows: the relay ES is normally open so that received signals pass through to the subscriber; the relay SS is normally closed to short circuit the transmitting line. When the United States subscriber speaks his voice currents go into both the Transmitting Detector and the Transmitting Delay circuit. The Transmitting Detector is a device which amplifies and rectifies the voice currents to produce currents suitable for operating the relays TES and SS which thereupon short circuit the receiving line and clear the short circuit from the transmitting line, respectively. The delay circuit is an artificial line through which the voice currents require a few hundredths of a second to pass so that when they emerge, the path ahead of them has been cleared by the relay SS. When the subscriber has ceased speaking the relays drop back to normal.

The function of the Receiving Delay circuit, the Receiving Detector, and the relay RES is to protect the Transmitting Detector and relays against operation by echoes of received speech currents. Such echoes arise at irregularities in the two-wire portion of the connection and are reflected back to the input of the Transmitting Detector, where they are blocked by the relay RES which has closed and which hangs on for a brief interval to allow for echoes which may be considerably delayed. The gain-control potentiometers shown just preceding the transmitting and receiving amplifiers are provided for the purpose of adjusting the amplification applied to outgoing and incoming signals.

The relief from severe requirements on stability of radio transmission and from varying speech load on the radio transmitters which this system provides permits much greater freedom in the design of the two radio channels than would otherwise be possible.

The Radio Channels

One of the first questions which comes up in considering the design of a radio system is the power which can be sent out by the transmitter The word "can" is used advisedly, rather than "should," since the present art the desideratum usually is the greatest amount of power that is technically possible and economically justifiable. There are few radio systems so dependable that increased power would not improve transmission results. At very high frequencies the generation of large powers is attended by many technical difficulties but fortunately the radiation of power can be carried out with much greater efficiency than is feasible at lower frequencies. At 18,000 kilocycles (about 16 meters) a single half-wave radiator or doublet is only about 25 ft. long and it is possible to combine a number of them, driven in phase by a common transmitter, into an antenna array which concentrates the radiated power in one geographical sector. In that direction the effectiveness may be intensified 50 fold or more (17 db) and waste radiation in other directions reduced materially. Thus, one of the transmitters at Lawrenceville, New Jersey, used in the short-wave transatlantic circuits when supplying 15 kw. radiates in the direction of its corresponding receiving station as effectively as would a non-directive system of about 750 kw.

The transmitting antennas also give some directivity in the vertical plane, increasing the radiation sent toward the horizon and decreasing that sent at higher angles. It is not yet certain that vertical directivity is always advantageous and this effect has not been carried very far.

At the receiving station the radiated power has dwindled to a small remnant which must be separated from the static as far as possible and amplified to a volume suitable for use in the wire telephone plant. Here again directive antenna arrays are of value. A receiving antenna system sensitive only in a narrow geographical sector, and that lying in the direction from which the signal arrives, excludes radio noise from other directions and thereby scores a gain of perhaps 40 fold (16 db) in the power to which the signal can be amplified without bringing noise above a given value. It also scores against noise which arises in the tubes and circuits used for amplification, since the combined action of the several antennas of the array delivers more signal to the initial amplifier stage where such noises originate.

Thus, it is evident that transmitter power, transmitting directivity, receiving directivity, and quiet receiving amplifiers are of aid in providing signal transmission held as far as possible above the radio noise. In a well-designed system the relative extents to which these aids are invoked will depend upon economic considerations as well as upon the technical possibilities of the art.

There is one other type of noise than that provided by Nature which is of particular importance at short waves—electrical noise from the devices of man. One of the worst offenders is the ignition system of the automobile. The short-wave transoceanic receiving station at Netcong, New Jersey, is so located that automobile roads are at some distance, particularly in the direction from which reception occurs. Service automobiles which produce interference cannot be allowed near the antenna systems unless their ignition systems have been shielded. Also, electrical switching and control systems incidental to the power, telegraph, and telephone wire systems at the station are shielded or segregated.

At both the transmitting and receiving stations at least three antenna systems are supplied for each circuit, one antenna for each of the three frequencies normally employed. The design and arrangement of these are dictated by the requirements flowing from their uses. The purpose of the transmitting antenna is to concentrate as much power as possible in one direction. The purpose of the receiving antenna is to increase reception from the desired direction and to cut down reception at all other angles. In the former the forward-looking portion of the characteristic is of greatest importance, while in the latter the rearward characteristics need greatest refinement.

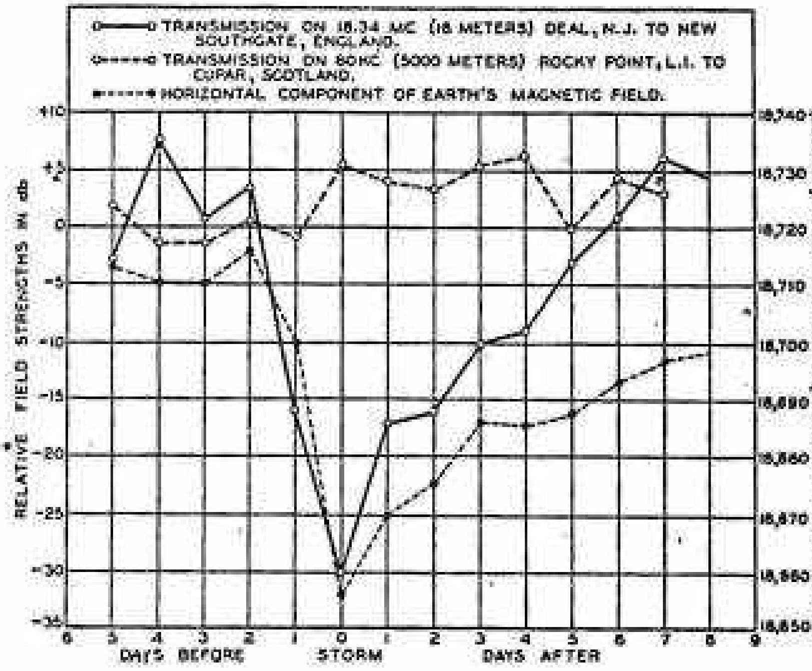


Fig. 62

Effect of Magnetic Disturbances on Radio Transmission.

Transmission Performance

In short-wave telephone systems the width of the sidebands is so small a percentage of the frequency of transmission that tuning characteristics of the antennas and high-frequency circuits are relatively broad and impose little constriction on the transmission-frequency characteristic. A flat speech band is easy to obtain over the range of approximately 250 to 3,000 cycles employed for these commercial circuits. This relieves the short-wave circuits from many of the problems of obtaining sufficient band width which are troublesome in designing long-wave systems.

Short-wave transmission is subject to one frailty which particularly hampers its use for telephony. This is fading. Where fading is of the ordinary type, consisting of waxing and waning of the entire transmitted band of frequencies, automatic gain control at the receiving station is of value and is employed in the transoceanic circuits under discussion. The amplification in the receiver is controlled by the strength of the incoming carrier and is varied inversely with this strength so as to result in substantially constant signal output. Obviously this control can be effective only to the extent that the signal seldom falls low enough to be overwhelmed by radio noise.

When fading is of the selective type, that is, the different frequencies in the transmitted band do not fade simultaneously, the automatic gain-control system is handicapped by the fact that the carrier or control signal is no longer representative of the entire signal band.

Selective fading is believed to result from the existence of more than one radio path or route by which signals travel from transmitter to receiver. These paths are of different lengths and thus have different times of transmission. Wave interference between the components arriving over the various paths may cause fading when the path lengths change even slightly.

If the path lengths differ by any considerable amount, for example, a few hundred miles, the wave interference is of such a character as to affect the frequencies across a band consecutively rather than simultaneously.

With the presence of selective fading there comes into being the necessity of guarding against rapid even though small variations in the transmitted frequency, since if such variations are present, a peculiar kind of quality distortion of the telephone signal results.

The varying load which speech modulation places on the transmitter circuits tends to cause slight variations in the instantaneous equivalent frequency which are known as "frequency modulation" or "phase modulation" depending on their character. To prevent this effect the control oscillator must be carefully guarded against reaction by shielding and balancing of circuits and the design must be such as to preclude variable phase shifts due to modulation in subsequent circuits of the transmitter.

It is apparent that if there are two paths of different lengths, two components which arrive simultaneously at the receiver may have left the transmitter several thousandths of a second apart. If the transmitter frequency has changed materially during this brief interval, trouble may be expected. The trouble actually takes the form of a distortion of the speech as demodulated by the receiving detector.

Defects in short-wave transmission due to radio noise, minor variations in attenuation, fading, and distortion are nearly always present to some extent and, when any or all are severe, cause a certain amount of lost service time. These interruptions are of relatively short duration and, furthermore, there is enough overlap in the normal times of usefulness of the several frequencies available so that shifting to another frequency may give relief. There is, in addition, a kind of interruption which from the standpoint of continuity of service is more serious. At times of disturbance of the earth's magnetic field, known as "magnetic storms," short-wave radio transmission is generally subject to such high attenuation that signals become too weak to use and sometimes too weak to be distinguishable. These periods affect all the wavelengths in use and may last from a few hours to possibly as much as two or three days in extreme cases. They are followed by a recovery period of one to several days in which transmission may be subnormal.

Severe static may cause interruption to both long- and short-wave services at the same time but the short waves are relatively less affected by it and are usually able to carry on under static conditions which prevent satisfactory long-wave operation. On the other hand, severe fading or the poor transmission accompanying a magnetic disturbance may interrupt short-wave service without affecting the long waves adversely, in fact magnetic disturbances often improve long-wave transmission in the daytime. The service interruptions on the two types of circuits are thus nearly unrelated to each other and have no definite tendency to occur simultaneously. This is the principal reason why both long-wave circuits and short-wave circuits appear essential to reliable radio-telephone service.

On routes which are very long or which cross tropical areas which result in static sources facing the directive receiving antennas, long waves cannot as yet be successfully employed and short waves alone are available. However, experience tends to indicate that on North and South routes such as between North and South America, the interruptions associated with magnetic storms are less severe and of shorter duration.

The cycle of events which accompanied a particularly severe magnetic storm in July, 1928, is shown graphically in Fig. 62. The light dotted curve shows the variation in the horizontal component of the earth's field. The heavy solid line follows the daily averages of the short-wave received signal field. It is apparent that the disturbance took two days to reach its peak and the recovery to normal took nearly a week. The heavy dotted line shows received field on long waves (60 kilocycles) and indicates that transmission was improved slightly at the same time the short waves were suffering high attenuation.

The experience with transatlantic telephone service on short waves covers a period of nearly three years, there having been available a one-way channel from the United States to England used as an emergency facility for the first year and a half, a two-way circuit for the next year, and two circuits since June, 1929. It is only in this later period, however, that a circuit has been available operating regularly with the amounts of transmitter power and antenna directivity which have been mentioned.

The performance of the two one-way channels forming this circuit is charted in Fig. 63. The charts are plotted between hours of the day and days

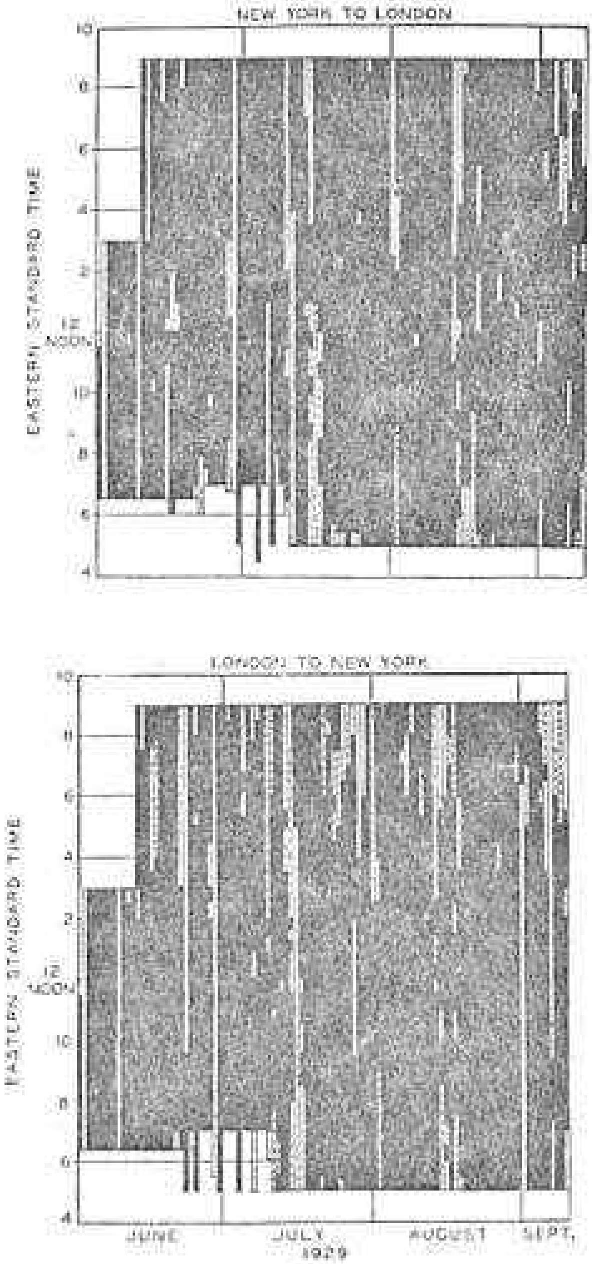


Fig. 63

Chart Showing Transmission Performance of a Short-Wave Transatlantic Telephone Circuit. Black, commercial; Dotted, uncommercial; White, no data.

in the year so that each unit block represents one hour of service time. The solid black areas are time in which commercial operation could be carried on. The dotted strips are uncommercial time. The blank areas are for time in which, for one reason or another, the circuit was not operating and no data were obtained. Perhaps the most outstanding feature of these charts is the tendency of the lost time to fall in strips over a period of two or three days. These strips coincide approximately for both directions of transmission. The principal ones are about July 10 and 15 and August 2 and 17. These are characteristic of the interruptions accompanying magnetic disturbances of the kind which occur at irregular intervals of a few days to several weeks. They are, of course, not as severe as the disturbance illustrated in Fig. 62.

It is apparent that for these three summer months this new circuit gave a good account of itself and furnished commercial transmission for something like 80 per cent of the time that service was demanded of it. In these same months the long-wave system suffered its greatest difficulty from static, and we have concretely illustrated the mutual support which the two types of facilities give each other.

It should not be inferred from these data that the short-wave transatlantic radio links furnish 80 per cent of the time talking circuits as stable and noise-free as good wire lines. Under good conditions they do provide facilities which compare favorably with good wire facilities. One the other hand, they may at times be maintained in service and graded "commercial" under conditions of noise or other transmission defects for which wire lines would be turned down for correction.

Telephone Service to Australia

Regular commercial telephone service was inaugurated by the American Telephone & Telegraph Company between North America and Australia on October 27, 1930.

The circuit to be employed in this service is by far the longest ever established for regular commercial telephony. It consists principally of two radio links, one across the Atlantic and the other between England and Australia. With the wire lines involved in the connection the circuit between New York and Sydney, Australia, is more than 14,000 miles long.

The service will be available to all points in the United States and Cuba and to the principal cities of Mexico. In Australia, it will cover the states of Queensland, New South Wales, and Victoria and the City of Adelaide. This adds nearly half a million telephones, serving a population of some five and a half million, to the network now within the reach of Bell System stations.

The Australian service has been arranged by the American Telephone & Telegraph Company in cooperation with the British and Australian Post Offices and the Amalgamated Wireless Company of Australia. The circuits across the Atlantic are the same as those employed in the telephone service connecting North America with England and the continent. The England-Australia link will be operated by stations near London and Sydney, which established commercial service between the two countries last April. The two radio circuits will be linked through the London Trunk Exchange which now handles all calls between America and Europe. The circuit between England and Australia uses a wavelength of about 28 meters.

The cost of a call between New York and any Australian point will be $45 for the first three minutes and $15 for each additional minute. For calls involving more distant points in North America, an additional charge will be made corresponding to the present zone charge for the transatlantic service.

Among the conversations which passed between the United States and Australia over the Bell System's latest overseas telephone service, recently opened, was the longest commercial call on record. It covered a total distance of more than 15,000 miles, terminating at Sedalia, Mo., and Sydney, Australia. Due to the 16-hour time difference between the two points, the speaker in Australia talked at about two o'clock Tuesday morning, while his words reached the listener in Sedalia, a fraction of a second later, at 10 A.M. Monday.

Following the usual route of conversations over the new speech channel, the call went from a Sydney telephone to the local radio station. There it was amplified and sent to London where it was received, switched to one of the regular transatlantic circuits and forwarded to New York through the American Telephone & Telegraph Company's receiving station at Houlton, Me. It then passed over the regular long distance land lines to Sedalia.

If the conversation had taken place during United States evening or early morning hours, it would have covered an even greater distance. When Australia is in darkness, transmission is better in an East to West direction. By reversing the antenna at London and Sydney, the direction is then altered to send the voice waves south-westward from London, across South America and the Pacific to Sydney. This adds about 4,000 miles to the total.

Other calls to and from Australia the first day included one from Pittsburgh to Sydney.

TERMINAL EQUIPMENTS FOR SHORT WAVE POINT TO POINT RADIO LINKS

In order to secure satisfactory operation from a modern radio link, it is necessary to supply at the ends of the link terminal equipment which shall not only provide the necessary circuit arrangements, but shall also provide means for controlling its technical performance. The arrangements necessary for speech transmission are dealt together with a brief description of the facilities for technical operation and control of the circuit.

The usual radio link connection consists of two one-way radio channels working in opposite directions. These two channels are inter-connected at either end by means of land lines to form a two-wire connection, which may be extended to any of the standard types of telephone systems.

The simplest form of such a system is shown in Fig. 63 (a) in which two terminal stations designated East and West are connected through land lines to the radio transmitting and receiving stations, A and D in the case of the East terminal, and C and B in the case of the West terminal. Speech from the radio transmitter A is received by the radio receiver at B, and that from the transmitter C is received by the radio receiver at D. It will be seen, when considering the terminations at East and West, that this is a special case of a four-wire circuit. The difficulties peculiar to the operation of a circuit of this type are that the attenuation of the radio paths are variable and that speech transmitted from either radio transmitter may in certain cases be received by either of the radio receivers. In the case in which speech is transmitted through the East terminal and the transmitter at A and received by the radio receiver at D, there will be formed a local loop including the terminating set, the lines connecting the terminating set to the radio stations and the short radio path between A and D. As the distance between the radio stations A and D may be small, the loss in this radio path would probably be very small when the radio wavelengths were the same or close together, and unless the network balancing the two-wire extension from the terminating set was exceptionally good, there would be singing round this local loop.

In cases where the attenuation in the radio paths A-B and C-D is small and the balance of the lines and networks connected to the terminating sets at either end is not sufficiently accurate, there may be singing round the complete loop formed by the two uni-directional radio paths, their inter-connecting circuits and the terminating sets.

Anti-singing and Echo Suppressing Device

Even in the case when singing does not occur, the re-transmission of speech that passes across the hybrid coil at one end will appear as an echo at the other end. This echo will reduce the intelligibility and hence it should be suppressed.

The Bell Telephone Laboratories have developed for prevention of singing and echoes in radio links a system which has been installed on the long-wave transatlantic circuit between New York and London, and similar equipments have been designed for use on the short-wave link between Madrid and Buenos Aires.

In order to prevent singing it is necessary to ensure that the attenuation round the whole loop shall always be greater than zero. The method of attaining this result is to arrange the circuit so that one or other of the paths is always inoperative. In the arrangement shown on Fig. 63 (a), a relay (a) is associated with the transmitting line which normally short circuits this line, thus preventing transmission and therefore singing round the loop. The am-

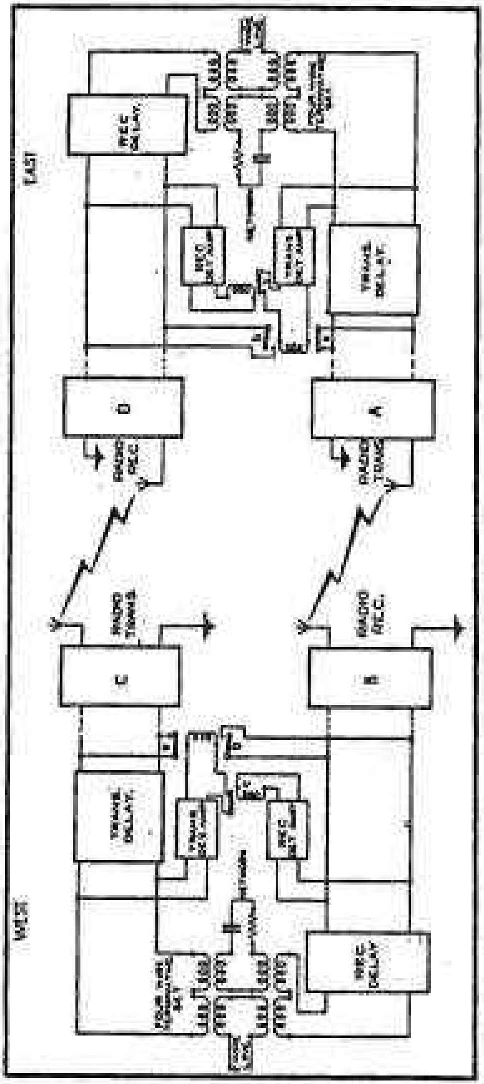


Fig. 63 (a)
General Schematic of Complete Radio Link

plifier detector is bridged across the transmitting line at some point before the short-circuiting relay (a), and when speech enters the circuit the amplifier detector operates the relay (a) to remove the short circuit, thus allowing speech to be transmitted to the radio transmitter and so over the remainder of the circuit. In order to ensure that one of the paths is always blocked, a second relay (b) is arranged to be operated just before the relay (a) which removes the short circuit from the transmitting line; this second relay (b) short circuits the receiving line. In addition to these relays associated with the transmitting circuit there is an additional relay (c) associated with the receiving circuit to prevent the operation of the relay (a) controlling the transmitting circuit and relay (b) short circuiting the receiving circuit when speech is being received. This additional relay (c) is operated by an amplifier detector bridged across the receiving circuit at a point after that at which the line is short circuited during transmission. The equipment at either end of the four-wire circuit formed between the radio link and its interconnecting lines is similar.

The operation of the circuit is as follows:

In the normal condition when there is no speech on the circuit, both the transmitting paths are short circuited. Speech entering one end of the circuit clears its own transmitting path and short circuits the receiving path, thus preventing any disturbance entering the radio receiver and interfering with the talker or the apparatus controlled by his speech. The speech is transmitted over the radio link, received by the distant receiving station and enters the line connecting the receiver to the terminating set. This speech causes an amplifier detector to operate a relay (c) which prevents operation of the relays (a) and (b) controlled from the transmitting circuit.

Amplifier Detectors and Delay Networks

As mentioned above, the speech to be transmitted has to clear its own path and unless this clearing operation can be performed instantaneously part of the speech will be lost. It is possible to design an amplifier detector and relay train which operates so quickly that although the initial part of speech is lost it is not possible to tell that the whole has not been transmitted. This involves the use of a very sensitive detector amplifier. In practice there is always a certain amount of noise associated with speech on land lines and somewhat more noise on radio circuits. This noise limits the sensitivity at which the amplifier detector can be operated since, if the amplifier detector were very sensitive, it might either be held permanently operated or subject to false operation by noise. When a somewhat insensitive amplifier detector operates the relay to clear the transmitting path, there is noticeable clipping of the speech although the operating time of the combination is very small; the reason for this clipping is that the energy contained in the initial parts of speech may be very small and thus insufficient to operate the relays. The relays in this case do not start to operate until some time after speech has started and the amount lost is determined more by the characteristics of speech than by the operating time of the relays. One way of preventing this clipping of speech is to introduce between the input of the amplifier detector and the normally short circuiting relay, a network to delay the speech until after the relay has operated. The amplifier detector is then arranged so that it will not operate from the weak initial pulses of speech, but will operate when these have built up to some greater amplitude. The time lost during the building up of the speech currents is compensated for by the delay introduced by the network. By increasing the delay introduced and decreasing the sensitivity of the amplifier detector it is possible to arrange that only the peaks of speech shall be of sufficient amplitude to cause operation of the relays; the arrangement may then be subjected to noise, the amplitude of which approaches that of the peaks of speech, without false operation. A network having a delay of 20 or 30 milliseconds is usually sufficient when dealing with the speech to noise ratios met with in a commercial circuit.

It has already been mentioned that the amplifier detector bridged across the receiving circuit is arranged to open the one connected to the transmitting circuit. This ensures that speech arriving at the radio receiver and passing across the terminating set into the transmitting circuit (owing to insufficient balance between the line and network) shall not cause false operation of the transmitting relays. It is necessary to make provision against false operation by noise occurring in the radio link, and the sensitivity of the receiving amplifier detector is thus limited. It is also necessary to ensure either that the amplitude of the received speech reaching the amplifier detector which controls the transmitting circuit shall be insufficient to operate the transmitting relay or that the relay controlled from the receiving side shall always be operated by the received speech.

The ratio of the speech energy available for the two-wire line to that reaching the transmitting amplifier detector depends on the accuracy with which the impedance of the balancing network simulates that of the two-wire line. Since speech may be required over a large variety of circuits it is impracticable to provide balancing networks to simulate the impedance of all such lines. It is therefore evident that only a small discrimination can be relied upon between speech received from the land line which it is required to transmit and received speech which it is not required to transmit.

Since a very sensitive amplifier detector connected to the receiving circuit may be falsely operated by noise currents, it is desirable to provide means whereby only currents approaching the peak values reached by speech shall operate the relays. The provision of a delay network in the receiving circuit between the receiving amplifier detector and the terminating set will allow time for the speech voltage applied to the receiving amplifier detector to rise to some considerable value before this speech, after passing through the terminating set, can reach sufficient amplitude to operate the amplifier detector connected to the transmitting circuit. The relays associated with the receiving circuit thus have time to operate and disable those connected to the transmitting circuit without unduly increasing the sensitivity of the receiving amplifier detector and so increasing the risk of false operation.

As in the case of the transmitting delay circuit, the length of the receiving delay circuit is determined by the maximum speech-to-noise ratio with which good operation is required with the modification that "clipping" is not important. The speech-to-noise ratio in the receiving circuit is usually considerably worse than that in the transmitting circuit and for this reason it is desirable to make the receiving amplifier detector somewhat less sensitive than the detector transmitting amplifier. The first condition would lead to a delay network having a delay approximately equal to the operating time of the relay which is less than 5 milliseconds. In practice it is found that from 5 to 10 milliseconds delay with a less sensitive amplifier detector will switch any circuit which, from a talking point of view, has a speech-to-noise ratio within commercial limits.

Gain Control

The introduction of variable attenuators either side of the terminating set allows some discrimination to be obtained between the speech received from the radio receiver and that from the two-wire extension. The discrimination obtained depends on the effective loss between the receiving and transmitting amplifier detectors. Thus with any given condition of balance between the line and the network connected to the terminating set, the sum of the added losses must have some minimum value. The level of speech arriving from the line determines the setting of the transmitting attenuator since this attenuation loss must be adjusted to load fully the radio transmitter. The loss in the receiving side is adjusted to give either a suitable output level or the minimum value determined by the other conditions, the latter case only being necessary under bad noise conditions on the radio circuit.

Circuit Arrangements

Fig. 63 (b) shows the arrangement of the terminal equipments at Madrid and Buenos Aires in some detail. It will be seen that the two-wire extension is connected through an ordinary four-wire terminating set to the apparatus associated with the transmitting and receiving lines. Considering first the apparatus in the transmitting line, there is a gain control panel associated with a volume indicator, so that the technical operator can change the amplification in this circuit to keep the level of speech delivered to the line for the radio transmitter constant and sufficient to load fully the radio transmitter. The output of this gain control panel is connected to the input of one side of a four-wire repeater whose gain is so adjusted that its output shall be that required by the interconnecting line to the radio transmitter. Across the output of this repeater is bridged the input of the transmitting amplifier detector which controls the relays associated with the transmitting path and the relay for short circuiting the receiving path. Next comes the transmitting delay network with its equalizer, low pass filter to limit the upper frequency to be transmitted, and repeater for compensating its attenuation at various frequencies; next, two repeating coils which include the short circuits which are normally on the transmitting path for the prevention of transmission when there is no speech. The privacy equipment is located between these repeating coils and the line to the transmitting station.

At the receiving side of the circuit the line from the radio receiver is connected to one-half of a four-wire repeater adjusted to increase the received level to that required for the operation of the equipment and thence through the privacy equipment to a coil group which is arranged in connection with a relay panel to perform the switching operation. This coil group is connected to the receiving delay network and at the junction of these is bridged the receiving amplifier detector. The receiving delay network is associated with an equalizer and a repeater as in the case of the transmitting delay network and is then connected through a gain-control panel and repeater to the four-wire terminating set.

It will be noticed that each separate part of the circuit is associated with a repeater. The object of this is to make both the delay network and privacy system each have zero attenuation, thus making it possible for them to be patched out of the circuit without affecting the transmission characteristics of the whole.

Voice Operated Relay Circuits

The relay switching is arranged in each case so that the break of the switching relay performs the switching operation. This reduces the operating time of the switchgear and thus minimizes the lengths of the delay networks necessary for a given amplifier detector sensitivity. From the transmitting side transmission is normally prevented by the use of a short circuit, and the break of the relay will remove it. In the receiving side, however, the circuit is normally in the transmitting condition and it is required to interrupt transmission by breaking contact. From considerations of balance it is undesirable to break the circuit. To avoid this, two repeating coils are connected into this circuit, as shown on Fig. 63 (c). It will be seen that when the relay contact is made, these repeating coils are so connected that their windings are in series aiding, with their center points joined. When the contact is broken the connection between the center points is severed and the windings of the coils are in series but opposing one another, so that the transmission of currents from one coil to the other is prevented.

Speech entering the terminating set from the two-wire side enters the

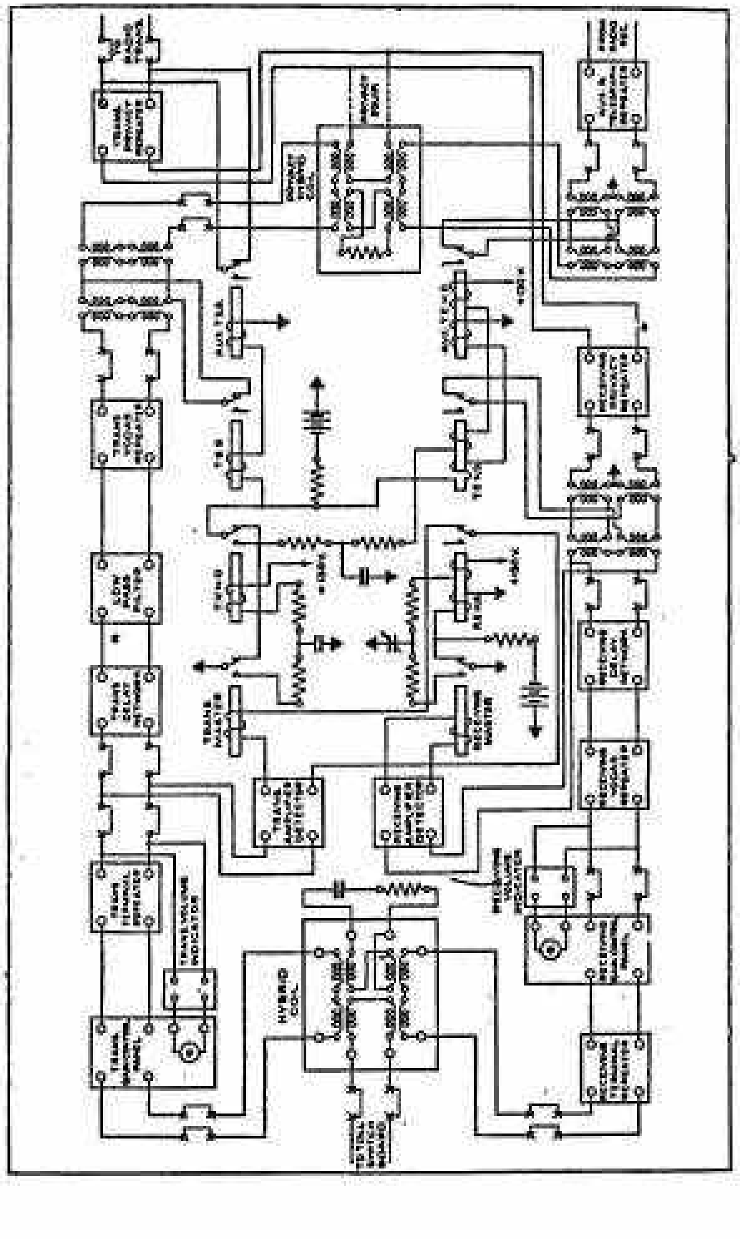


Fig. 63 (b)
Terminal Equipments at Madrid and Buenos Aires

transmitting half of the amplifier detector and operates the transmitting master relay. When the armature of this relay leaves its back contacts, relays TEHO[1], Aux. TEHO[2], TSS[3] and Aux. TSS[4] operate; when this armature makes its front contact relay TVHO[5] operates. The operation of relay TEHO puts the coil group in the receiving circuit in a non-transmitting position. The operation of relay TSS removes the short circuit from the transmitting side and the operation of relay Aux. TSS removes a similar short circuit beyond the privacy equipment. During the operation of these relays speech has been traversing the transmitting delay network and can then pass through the remainder of the circuit and the privacy equipment to the radio transmitter. The receiving circuit is disabled between the radio receiver and the receiving amplifier detector, thus preventing either operation of the amplifier detector or interference of the talker by currents from the radio receiver.

The release of the relays operated by the transmitting master relay is controlled by the charge of condensers through resistances. The condensers and resistances associated with the contact of the transmitting master relay and the winding of the relay TVHO control the release time of relay TVHO which in turn controls the release of the TSS and TEHO relays. The TSS relays release immediately after the TVHO relay reaches its back contact, but the release of the TEHO relay is held up during the charging period of a condenser resistance circuit, thus ensuring that the transmitting path is blocked before the receiving path is opened.

The release time of the TVHO relay is so arranged that it will hold during pauses between words to reduce the number of times the circuit is switched during talking from this terminal. This relay must, however, release sufficiently early to prevent clipping of the reply. Since the total transmission time of the circuit determines the time which elapses before a reply can arrive, it is safe to make the TSS relay hold up for twice this time, thus allowing for the last word to reach the distant station and an instantaneous reply to return.

After spech in the transmitting path has ceased and the relays have released, speech may enter the receiving path and the receiving amplifier detector and operate the receiving master relay. The armature of this relay on leaving its back contact causes the REHO[6] relay to operate and break the connection between the transmitting half of the amplifier detector and the transmitting master relay, thus preventing the speech operating this relay and the relay train controlled by it. The release time of the REHO relay is controlled by the charging of condensers which have previously been dis-

[1] TEHO indicates Transmitting Echo Hangover.
[2] Aux. TEHO indicates Auxiliary Transmitting Echo Hangover.
[3] TSS indicates Transmitting Singing Suppressor.
[4] Aux. TSS indicates Auxiliary Transmitting Singing Suppressor.
[5] TVHO indicates Transmitting Voice Hangover.
[6] REHO indicates Receiving Echo Hangover.

charged by the action of the receiving master relay making its front contact. This release time is adjusted to take care of echoes in any circuit which may be connected to the two-wire side of the four-wire terminating set. The relay circuits shown on Figure 63(b) include only the operating connections and do not include either biasing windings or testing circuits.

The relays used in this equipment are all polarized telegraph relays of the same type which are very sensitive and operate quickly. A special panel is provided for adjusting these relays.

Switching of Privacy Equipment

The circuit is arranged to operate with a single privacy equipment which can be used alternatively in the transmitting and receiving sides since the system is always in a one-way condition. This assumes that the privacy systems at the two ends are complementary. Fig. 63(b) shows the transmitting and the receiving circuits connected to the opposite sides of a hybrid coil arrangement, the network terminals being closed through 600 ohms and the input of the privacy equipment being connected to the line winding. The output of the privacy equipment is connected to both transmitting and receiving circuits.

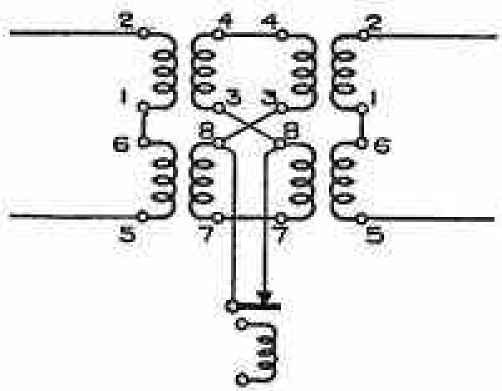


Fig. 63 (c)
Special Coil Group for Receiving Circuit.

In the normal condition the transmitting circuit on both sides of this connection is short circuited by the TSS and the Aux. TSS relays. Speech can then enter the privacy equipment from the receiving circuit and pass through the hybrid coil back into the receiving circuit without interfering with the transmitting circuit or being subjected to interference from this circuit.

In the transmitting condition the TSS and Aux. TSS relays are operated to remove the short circuits from the transmitting path. The TEHO and Aux. TEHO relays are also operated and prevent transmission from the receiving circuit entering the privacy equipment, and also prevent transmission from the privacy equipment to the remainder of the receiving circuit. Speech from the transmitting circuit can then pass through the privacy equipment to the radio transmitter.

It will be noticed that a repeater is placed between the output of the privacy equipment and the short circuit on the transmitting line to prevent this short circuit being directly on the output of the privacy equipment. A similar repeater is also used in the receiving circuit. The necessity of having a repeater in the transmitting circuit to isolate the privacy equipment from the short circuit renders it impossible to include one repeater in the privacy equipment instead of one in each line.

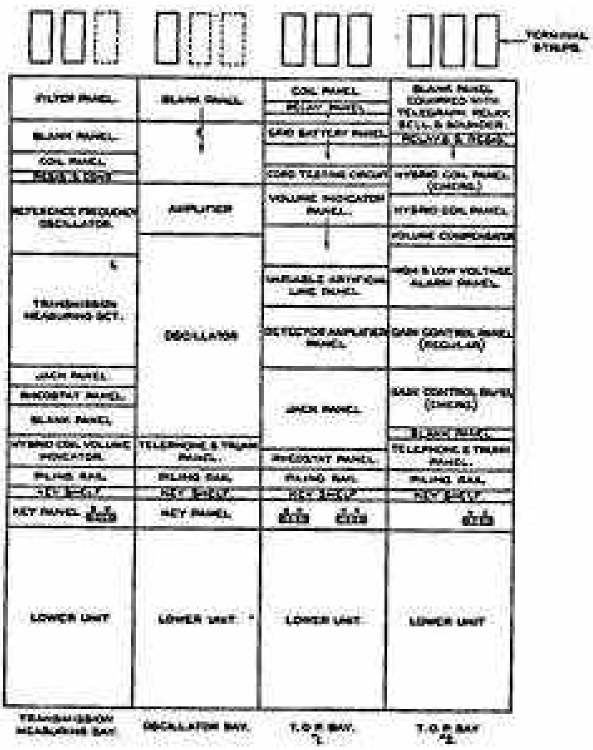


Fig. 63 (d)
Technical Operator's Position—Front Equipment.

Monitoring and Control

The equipment for the switching and the control of the circuit is arranged with suitable monitoring apparatus. A technical operator monitors continuously on the circuit and adjusts the gain controls and amplifier detector sensitivities to give the best service obtainable at any moment. The two-wire line is connected through to jacks on an operating position in a toll exchange and traffic is handled in a similar manner to that adopted on ordinary toll circuits.

Equipment

The terminal equipment apparatus is grouped on two racks, one comprising all the panels which require adjustment is known as the Technical Operator's Position, and the other is equipped with the voice operated apparatus and known as the V. O. D. A. S. rack. The privacy apparatus is grouped on a special rack and forms a complete unit apart from the terminal equipment.

Figure 63(d) shows the technical operator's position. It consists of four bays. The two bays on the left are equipped with transmission measuring apparatus and the two bays on the right comprise the gain control panels, amplifier detector panels and volume indicators, telephone and trunk panel, etc. By means of this apparatus the technical operator can monitor on the circuits at various points and has all important controls within easy reach for making the adjustments required for optimum performance of the system under prevailing conditions.

From the technical operator's position order wire circuits run to the toll switchboard, toll testboard, the radio transmitting station and the radio receiving station, so that the technical operator can readily communicate directly

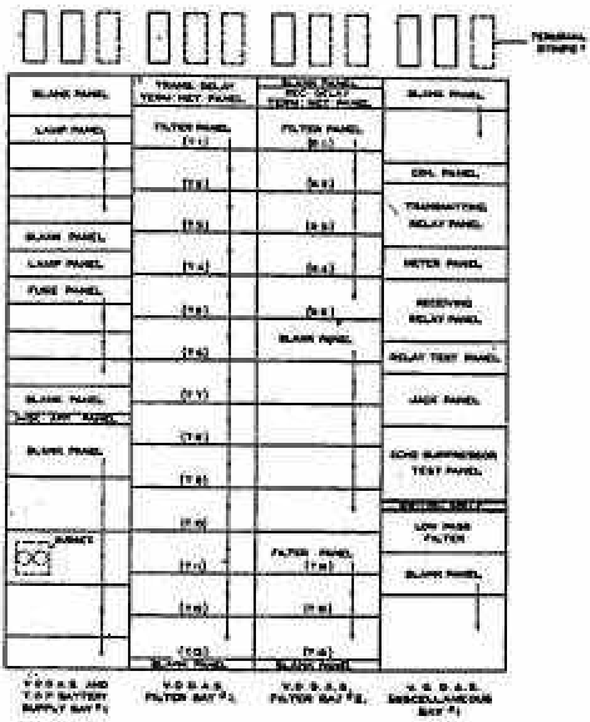


Fig. 63 (e)
V. O. D. A. S. Rack—Front Equipment.

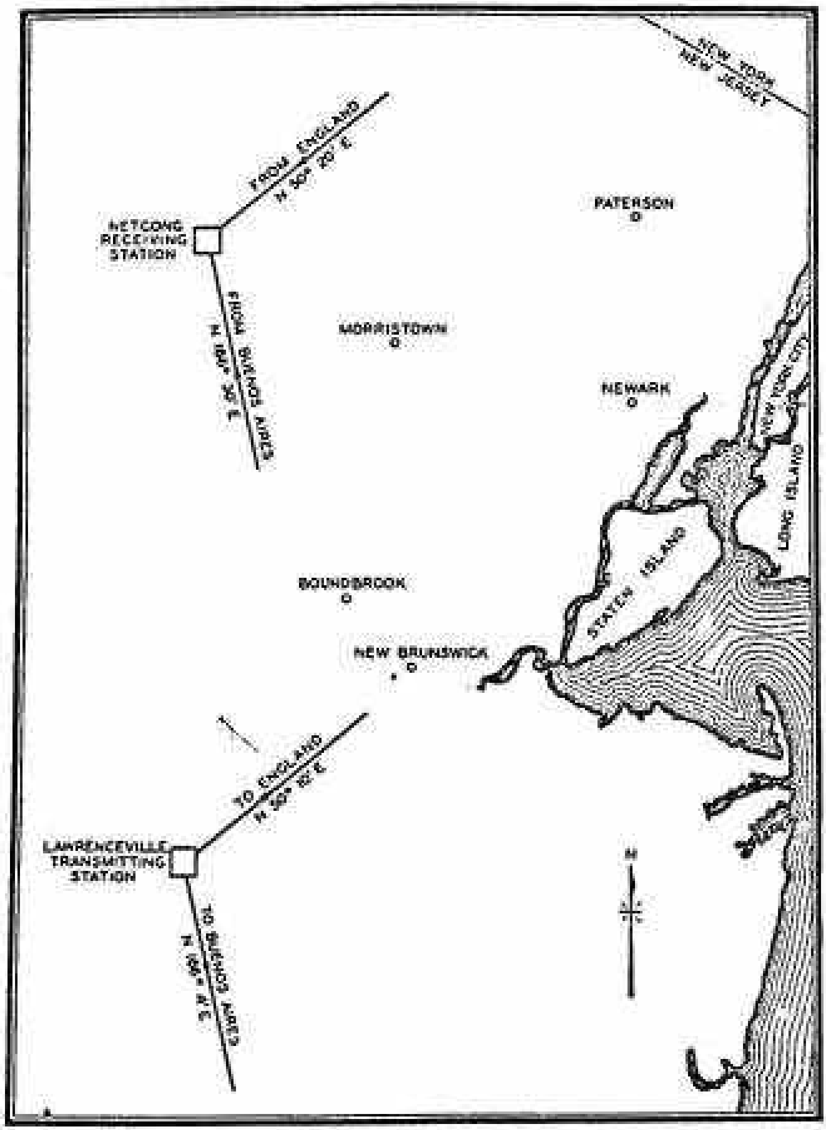


Fig. 64
Map Showing Transmission Considerations Affecting Location of Stations.

with all operators and attendants at important points on the circuit. He can also communicate with the home as well as with the distant subscriber.

Figure 63(e) shows the V. O. D. A. S. rack comprising a battery supply bay, delay network bays and a bay containing the voice operated switching arrangements with their testing apparatus. The relay testing apparatus comprises a testing and adjusting panel for the polarized telegraph relays and an echo suppressor testing panel for testing the operating hangover times of various relay trains.

Jack fields are provided on both the technical operator's position and V. O. D. A. S. rack. These jack fields permit easy testing of parts of the circuits and afford means by which the circuits can be modified to meet special requirements.

Thermionic Vacuum Tubes for Short Waves

The advent of the use of short waves brought in its train many new difficulties for the vacuum tube designer especially when the demand arose for more and more power. For small powers up to and including the 250 watt tube, the air-cooled form of tube already used for long waves proved suitable also for short waves. However, the high-power long-wave water-cooled tube which had reached a high state of perfection for wave lengths over 60 meters required various modifications for short-wave working.

Vacuum tubes intended for very short waves retain the feature of an external anode cooled by a circulated liquid but must be specially designed in order that the following difficulties may be avoided:

1. Heating effects caused by high frequency losses in dielectrics.

2. Heating effects caused by the very large high frequency currents which are encountered and the very high value of the high frequency resistance, due to skin effect.

3. External insulation difficulties due to the ease with which the air breaks down at very high frequencies.

4. The demand for low electrode capacity.

The first trouble is one which probably causes the greatest difficulty in the design of these tubes.

The effect usually shows up at places where high electrostatic fields exist. If these fields pass through the glass envelope for example, the dielectric loss which occurs is often sufficient to raise the temperature of the glass to the softening point very quickly, and a very characteristic failure is caused in which a small hole is made in the envelope, with the edges rounded and pointing inwards in accordance with the way the glass is pushed in by the air pressure, forming a kind of dimple. Very often the shape of these holes is such as to indicate quite clearly the direction of the field at the point of failure.

Sometimes the heating is not sufficient to cause an actual fusion of the glass but, on the other hand, long continued operation causes a small evolu-

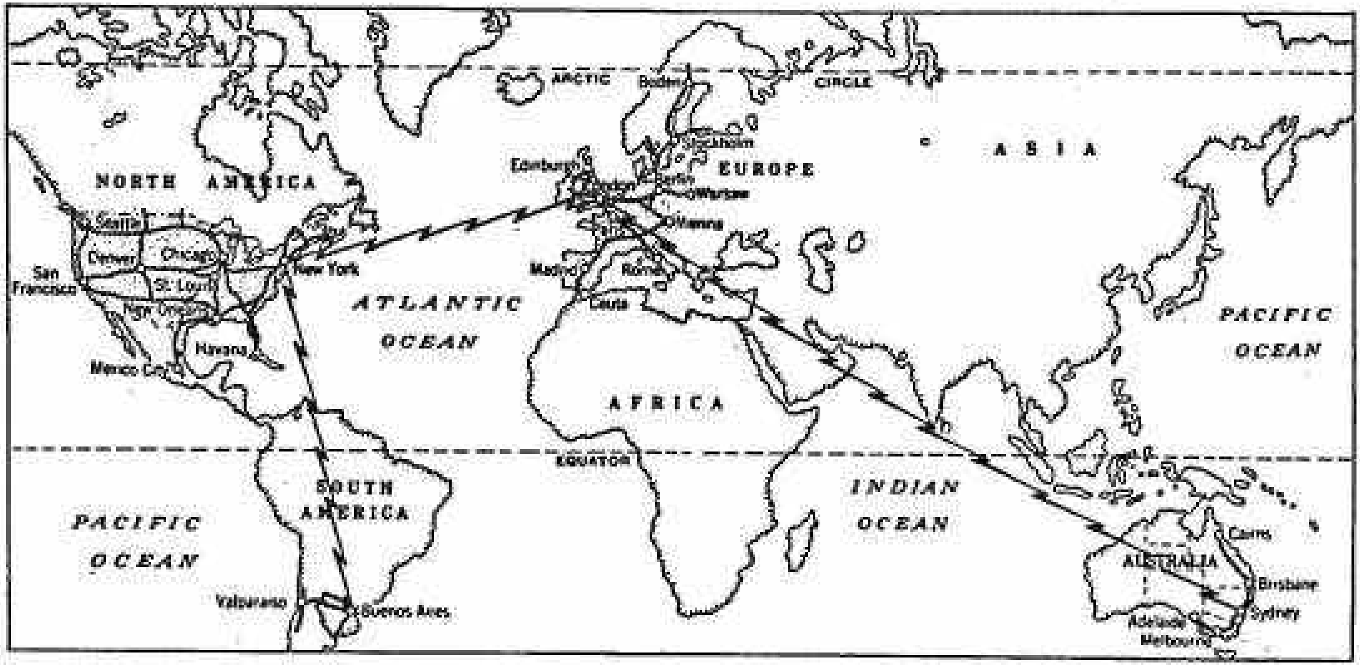


Fig. 64 (a)

Short-Wave Radio-Telephone Links Now in Service. In Addition There is Another Link, Madrid to Buenos Aires. When Necessary, Communication from New York to Australia Can Be Routed; New York-London-Madrid-Buenos Aires to Sydney.

tion of gas which ruins the tube. When the heating occurs quite close to one of the electrodes, there may be a considerable electrolysis of the glass which leads to an early failure either by cracking or by "softening" of the tube.

In the same way, the use of dielectrics in the active part of the tube for supporting or separating portions of the structure is very considerably limited. "Steatite" and other similar materials which are commonly used for such purposes may easily be melted into a vitrified mass if placed in such a position as to be subjected to an intense high frequency field.

On account of the difficulties enumerated a series of tubes for short waves have been developed in which a special system of shielding has been incorporated. The use of the screen for the anode has been considerably extended. This screen is electrically connected to the anode within the tube and extends beyond the end of the copper glass seal. In long wave tubes for very high voltages this serves as a protection for the glass at the edge of the seal where piercing by electronic bombardment occasionally occurs. In the case of the short-wave tube, however, the danger of piercing is not very great, but by means of this shield the intense field at the edge of the anode is removed from the glass and distributed uniformly round the vacuous space. At the same time, when necessary, the tubes are provided with shields on the grid and filament to distribute the field in the vacuum in the best manner possible and to diminish the field which intersects the glass.

In the higher power vacuum tubes the anode is made with a glass bulb

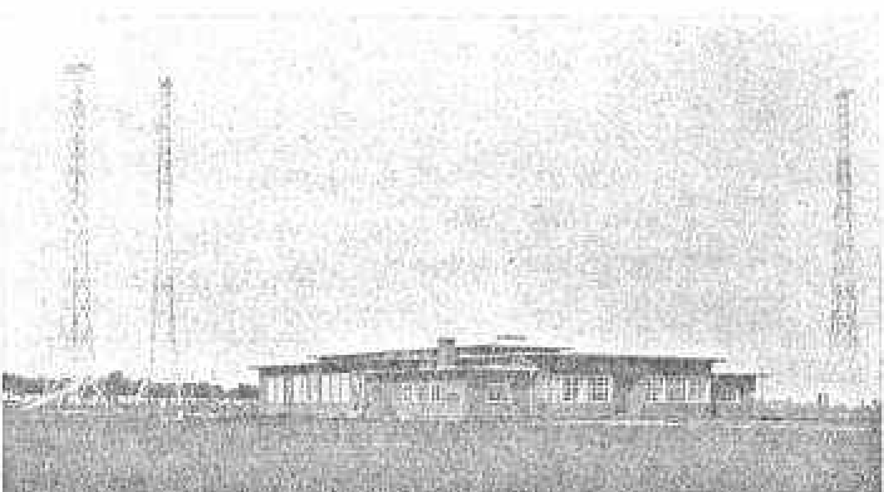


Fig. 64 (c)

Bank of Short-Wave Transmitters, Nauen, Germany.

at each end, the grid being sealed into one end and the filament into the other. This arrangement improves the tube very much but considerably increases the difficulty of manufacture, especially the operations of sealing the filament and grid into the anode. The difficulty will be realized when it is considered that the glass blower has to manipulate the anode assembly with its two bulbs while sealing in each electrode, and that owing to the use of the screens in the anode it is impossible to see the far end of the electrodes in order to make sure that it is centrally situated. To overcome this difficulty an ingenious method is employed: a small spark coil is connected between the anode and the electrode being sealed in, and a parallel spark gap is used of such a length that when the glass blower has sealed the electrode exactly in the correct position the spark passes over the auxiliary spark gap instead of within the tube. However, an entirely new design of tube is now being developed and will probably be soon available, in which the sealing-in is done in such a way that the electrodes are automatically centered during the operation.

The high values of high frequency currents and the magnitude of the factor of skin effect may cause so much heating of apparently quite large conductors within the vacuum tubes that very special consideration has had to be given to the dimensions of the leads, and they have been designed so that the metal in physical contact with the glass does not carry current.

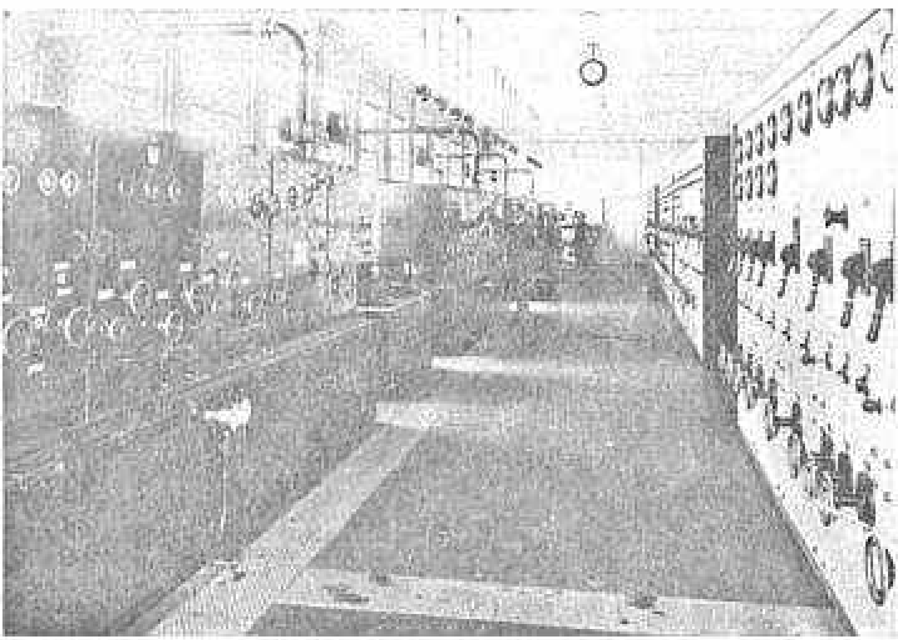


Fig. 64 (b)

One of the Short-Wave Transmitting Stations at Nauen, Germany.

For the design of circuits and for easier operation it is very important that the capacity between the electrodes of short-wave tubes should be kept down to as low a value as possible; the double-ended arrangement in which the grid and filament are brought out at opposite ends is one very effective means by which this capacity can be appreciably reduced. At the same time, since it gives an improved tube from the operating standpoint, the tube with lower capacity is preferable because the high frequency currents through the leads are reduced.

With the double-ended type of construction it is possible to use a self-contained water jacket or a separate water jacket through which the tube is inserted. The former method has been adopted for the following reasons:

1. A much more satisfactory water flow around the anode can be obtained.
2. There is less danger of breaking the tube when changing tubes.
3. There is less danger of flooding the transmitter when changing tubes.
4. A separate water jacket is of necessity extremely large and clumsy.
5. It is difficult to make water-tight joints at both ends of a separate jacket.

The combined water jacket has the disadvantage that it is more difficult to clean the anode if it becomes very dirty; this, however, is not a very serious objection because these tubes are operated in equipments where a closed circulating system is employed, and in order to avoid electrical leaks through the water supply, soft water, which leaves practically no deposit, is used. The connections to the water jacket are threaded for a standard pipe fitting, and it is a very simple matter to make the connections by means of a standard union.

The water jacket carries four lugs by which it can instantly be put into position or removed from the set. Of course, in the case of the low-power tube, which is single-ended, a standard water jacket is used and the anode is inserted in the same way as the anode of a long-wave tube, using a screw-down ring to compress a packing ring which makes a water-tight joint with a bead on the top of the anode.

As these tubes are practically always used in push-pull arrangements, very great care is taken to insure that they have characteristics sufficiently uniform to operate under the above mentioned exacting conditions without any difficulty.

The pumping arrangements for double-ended tubes are of necessity somewhat different from those for single-ended tubes, but by the methods adopted it is possible to secure for all these tubes a vacuum of the very highest order, such as is obtained in the long wave vacuum tubes.

These tubes have been tried out in commercial short-wave transmitters with highly satisfactory results, giving in all cases the required output with continuous operation.

STANDARDIZED SHORT-WAVE VACUUM TUBES

Tube	Type	Filt. volts	Filt. amps.	Emission	Anode volts	μ	R_p	Capacity in $\mu\mu f$			Max. anode dissipation continuous	Max. Output
								g f	f p	p g		
SS. 1966-2	Single-ended	14	24	2.6 amps.	4000—5000	23	8500	16	6	20	10 KW.	1 KW.
SS. 1966-3	Single-ended	14	36	4 amps.	4000—5000	23	7000	18	6	20	10 KW.	1.5 KW.
SS. 1968	Double-ended	22.5	41	5.5 amps.	8000—10000	40	6000	14	11	30	15 KW.	10 KW.
SS. 1971	Double-ended	20	64	9.5 amps.	8000—10000	18	3000	10	11	26	15 KW.	15 KW.

The following table gives some information on the characteristics of the various water cooled tubes which have been standardized. The values of the constants vary somewhat from tube to tube and the figures are given only as an indication. The maximum anode dissipation is that which the anode can support continuously with a rapid water circulation, and practically speaking is a function entirely of the anode dimensions and has nothing to do with the electrical characteristics of the tube. The maximum output given is only given as an indication of the power that can be obtained when operating as an efficient oscillator. The actual power obtainable in any circuit depends on a number of factors and thus is limited by the method of operation.

W2XAF Schenectady

Out of years of research and experimentation by radio engineers at Schenectady, N. Y., has grown a transmitter which is probably without parallel in the radio art. Today it is used by W2XAF, one of the group of short wave stations of WGY, to sustain that station's standing as the unofficial ambassador of the United States to the nations of the world.

Here is a single transmitter so built that three musical programs can be simultaneously broadcast without interference.

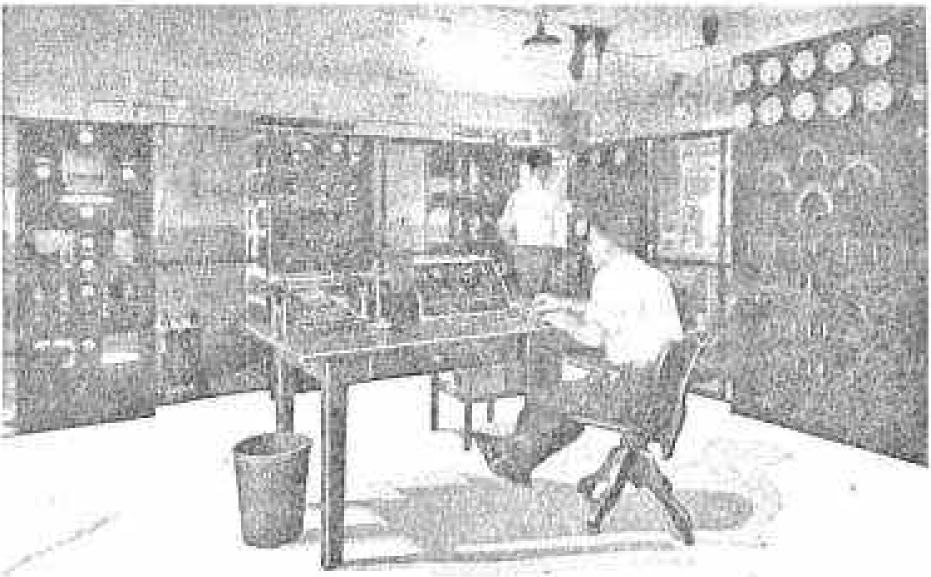


Fig. 64(c)

Looking From Left to Right There Are the Low Power Speech Amplifier and Modulator Unit, the power Supply and Control, the 1 Kw. Radio Frequency Unit Whose Output is Modulated With the Modulator Unit, the Intermediate 5 Kw. Amplifier, and Finally the Power Amplifier Which Supplies the Antenna With 35 Kw. of Carrier Power 100 Per Cent Modulated. The Operator's Desk is Located in the Foreground.

Six separate, independent and non-interfering voice channels are available. In other words, should occasion demand, and the federal license permit, addresses by six different people could be transmitted by the same equipment, on six different wavelengths without interference.

The same transmitter may be used for television signals up to sixty-line scanning at twenty pictures per second.

The transmitter may be used for television and voice transmission at the same time. That is one channel may be used for picture and another for voice.

When the demand for service is created W2XAF'S new transmitter may be used for the simultaneous transmission of eight still pictures (facsimile) each in its own channel or independent wavelength.

All that is needed for multi-service is the addition of crystal control, low power intermediate amplifiers and low power modulators of standard design for each additional program.

Several Antennas

W2XAF is equipped with three independent antenna systems for broadcast purposes: a single doublet of special construction to avoid corona discharge on high powers; a horizontal checker-board antenna directive on South America; a similar directional antenna for transmission to the Far East. The directional antenna steps up the power, directionally from 35 kilowatts, the maximum power of the transmitter, to an equivalent power of 240 kilowatts.

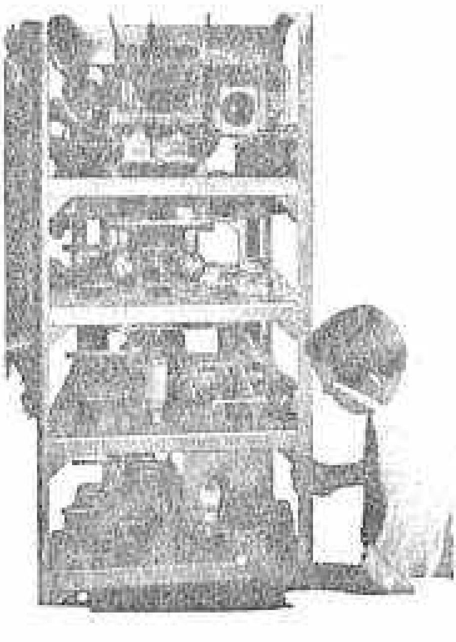


Fig. 64(d)

This Unit Comprises the Crystal Oscillator and Multipliers and Larger Air Cooled Amplifier Tubes. The Crystal Oscillator for this Transmitter has an Especially Effective Automatic Temperature Control. No Neutralizing Condensers are Used in this Unit, for Use is Made of Screen Grid Tubes Throughout With the Exception of the Three, Electrode Crystal Oscillator Tubes. This Unit May be Tuned From 13 to 56 Meters. Six Quartz are Available in the Oven for Wavelength Changes.

When used for telegraph purposes this outfit, combined with a directive antenna, will give a signal equal in strength to that picked up from a 1,000 kilowatt transmitter using a simple antenna.

W2XAF, located at the South Schenectady transmitter laboratory of the General Electric Company, five miles south of Schenectady, is licensed by the Federal Radio Commission for experimental relay broadcasting on 40 kilowatts.

The carrier frequency of 9,530 kilocycles is generated by a quartz crystal oscillating at one-fourth the carrier frequency or 2,382.5 kilocycles. Effective operation of the crystal is possible only when the temperature surrounding it is constant. To gain this uniformity of temperature an ingenious automatic temperature-controlled oven has been devised. The oven consists of

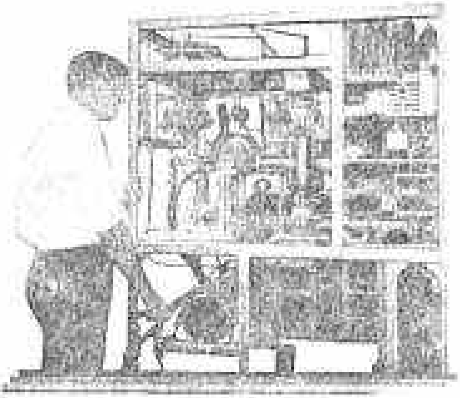


Fig. 64(e)

This Amplifier Follows the 1 Kw. Modulated Stage and Increases the Power to 5 Kw., Where it is Applied to the Input of the Final Power Amplifier. The Tubes Used in this Stage are Water Cooled Screen Grid Tubes. Note the Water for Cooling the Tubes Actually Enters the Tube and Flows Within the Hollow Plate. This Unit is Capable of Supplying 20 Kw. as a Telegraph Transmitter.

a number of compartments arranged one within the other. Each compartment acts as an insulating chamber to protect the crystal from the temperature variations of the transmitter room. The crystal is housed in the final compartment in a metal box where the temperature deviation is so slight as to have no effect on its frequency.

The output of the crystal oscillator is amplified and multiplied in frequency until a power of one kilowatt is available at 9,530 kilocycles. At this point modulation takes place. The modulation equipment is unique in that frequencies from 25 to 50,000 cycles may be used and the maximum variation throughout the band is less than 10 per cent—an amount so small as to be negligible. The result is incomparable fidelity over an exceptional range of frequencies. The modulation equipment is so arranged as to make possible the modulation of one kilowatt radio frequency amplifier 100 per cent without distortion. The unit is then coupled to an intermediate amplifier whose output voltage varies rectilinearly with the input voltage. The output of this stage is about four kilowatts. This stage, in turn, is used to excite the large power amplifier which is connected to the antenna system. The power amplifier utilizes six 30-kilowatt vacuum tubes arranged in a push-pull circuit with three tubes on each side. The last amplifier has been tested up as far as 134 kilowatts continuous antenna output, such as might be used in c. w. telegraphic communication.

W2XAF'S new transmitter employs thirteen different types of tubes, or 27 tubes in all. Twenty gallons of water per minute are pumped through the set to cool the plates of the tubes.

W2XAF, using 20 kilowatts of power on its old set, was capable of reaching Europe, Australia and South America, with exceptional reliability and generally with a fair signal. When directional antennas were used the signal invariably reached the country to which it was addressed. For example, for months, special two-way conversations were carried on one day a week with Sydney, Australia. During the period Admiral Byrd and his expedition were at Little America, Antarctica, W2XAF, using a directive antenna, put its program to the explorers fortnightly, on a Saturday night.

With the new transmitters, and 35 kilowatts of power, W2XAF should put an exceptionally strong signal east, west or south. In fact engineers believe that the ratio of signal to noise or static should be such that the station may be held continuously by a listener during a broadcast.

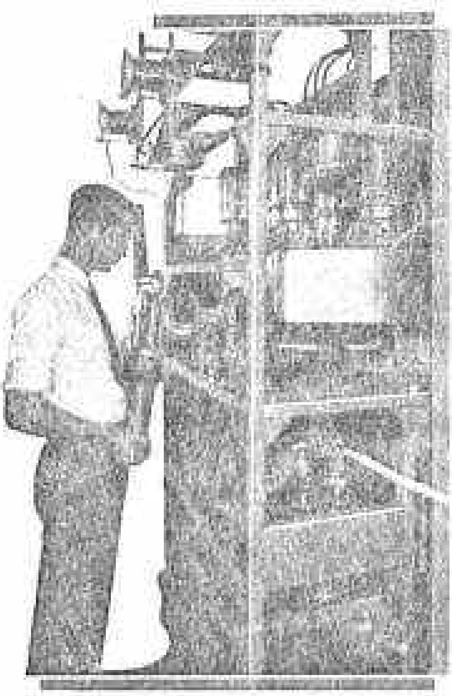


Fig. 64(f)

This Amplifier Takes the Modulated Power at a 5 Kw. Level and Amplifies it by Means of a 6 Powerful Short Wave Vacuum Tubes to a Power Level of 35 Kw. Carrier for the Antenna. This Unit is Capable of Supplying 135 Kw. Continuously to the Antenna as for Telegraph Work. The Output of this Unit may be Switched to Either a Simple Antenna for Normal Broadcasting, or to Directional Antenna for Transmission to South America or Australia. The Man Shown in the Picture is Holding One of the UV858 Vacuum Tubes Used in This Power Amplifier.

CHAPTER IV

Ship to Shore Radio Telephony

In view of the developments which have recently taken place in the field of ship-to-shore radio telephony, it would appear appropriate to review the state of the science and to discuss the problems which have arisen, the facilities which have been installed, and the general results obtained.

The ship-to-shore radio telephone system, which is here described, was opened for public service between the *Leviathan* and the United States on December 8, 1929. This was the first extension of the public telephone service to a ship at sea and enabled calls to be made betwen the vessel and any Bell System subscriber. The system as set up is intended primarily for giving telephone service to the larger passenger-carrying vessels as an extension to the wire network, and should be distinguished from the more simple uses which have been made of radio telephony in the marine field, such as that of enabling a coastal station operator to talk with coast guard vessels, fishing trawlers, etc.

This paper is concerned with the developments which have been carried out in the United States, including the establishment of transmitting and receiving stations on the New Jersey coast, the equipping of the *Leviathan* and the establishment of service to that ship.

It is significant of the wide-spread interest in this type of service that developments have also gone forward rapidly on the European side where the British, Germans, and French are preparing coastal stations and equipping some of the larger ships for public telephone service. The British have already initiated service to two of the White Star Liners, the *Olympic* and the *Majestic*, and before long it is likely that half a dozen of the larger trans-atlantic vessels will be undertaking this service, connecting with both the American and the European networks.

Early Developments

Attempts to apply telephony in the maritime field date back to the pioneer work on radio telephony itself, but it was not until the applications of the vacuum tube were developed that radio telephony for any service became finally practicable.

Following the long distance, point-to-point radio telephone experiments of 1915, there was carried out in the following year what is believed to have been the first trial of two-way radio telephony from the wire telephone system to a vessel at sea. This trial was conducted by Bell System engineers in co-operation with the Navy Department. On that occasion the Secretary of the Navy, in his office in Washington, carried on two-way conversation with the captain of the *U. S. S. New Hampshire* off Hampton Roads.

Following the further development of radio telephony during the War, there was undertaken, in the years 1920-1922, an extensive development of ship-to-shore radio telephony, looking toward the linking of ships at sea with the land line telephone network. At that time there was built a coastal radio telephone station at Deal Beach, N. J., and several ships were equipped on a trial basis. Extensive engineering tests were made and a number of demonstrations carried out which proved the physical feasibility of establishing such connections.

While the trials were successful from the technical standpoint, the development was not carried into commercial use because the adverse economic conditions existing in the post-War period did not appear to justify the initiation of the new service at that time. Furthermore, the waves in the range of 300-500 meters, which had been used in these early trials, were soon thereafter assigned for broadcasting.

In the last few years the whole outlook has changed considerably. The development of short-wave radio systems has greatly increased the message-carrying capacity of the radio spectrum and has made it feasible to maintain communication over a greater range of distances than was previously practicable for ships. Transoceanic radio telephone services have been inaugurated, and with the large increase in steamship travel there has arisen a renewed interest in the extension of telephone service to ships at sea.

When it became evident that short-wave transmission might be desirable for ship-to-shore telephone service, there was undertaken a program involving the measurement of the strength of the electric fields received aboard ship from a shore transmitter. This work was part of a general program intended to obtain fundamental data upon short-wave transmission for purposes of point-to-point, as well as for ship-to-shore telephone services. The tests were first made in 1925 on vessels running betwen New York and Bermuda. Further measurements were made on other ships in subsequent years.

Fig. 65 is an example of the result of these earlier tests. Transmission was from Deal Beach on 4.5 megacycles (66 meters). The curve shows the relatively weak field which was received as the vessel left dock, due to the considerable stretch of land which intervened in the transmission path, the rise of the field to high values as the ship passed out of the harbor, and the gradual diminution as the vessel continued on her course. It will be observed that transmission on this frequency was effective at night all the way to Bermuda, but that during the daytime the transmission failed for distances greater than a few hundred miles. Corresponding measurements showed that daylight transmission could be secured by means of a higher frequency, such as 9 megacycles (33 meters). Measurements of this kind, supplemented by data obtained for a wide range of distances over land, and for transatlantic distances, have built up a fairly complete set of quantitative data on short-wave transmission over different distances and for various times of the day and year.

Along with this study of transmission conditions, there was carried on the development of short-wave apparatus technique for telephony. The first application was in the field of point-to-point transatlantic operation and considerable art built up there including the design of transmitters, receivers, directive antennas, and the working out of two-way operating methods,

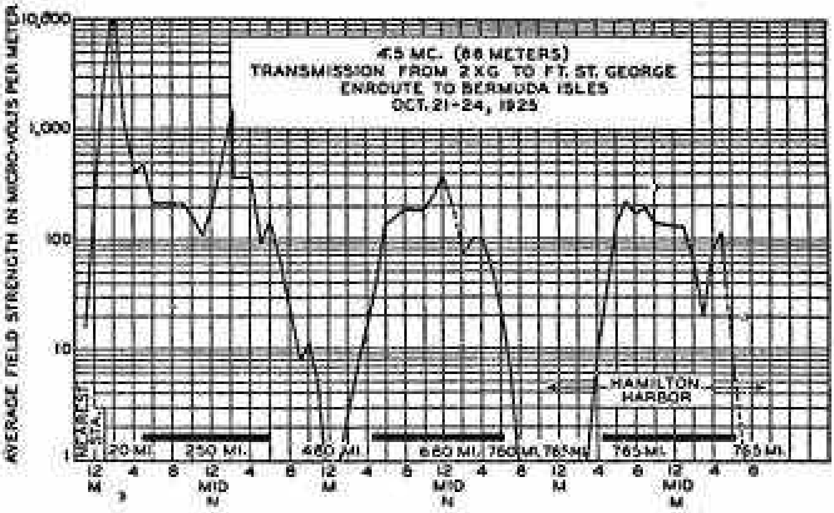


Fig 65

Received Fields, New York-Bermuda Run, 1925.

served as a very useful basis from which to develop the coastal and ship stations for the maritime system.

With this background of development, preparations were made to set up a two-way, short-wave radio telephone system for commercial service. This service was centered upon New York because of the large concentration of ocean-going traffic at that port.

The Technical Problem

One of the most important problems to be solved in the design of a short-wave system is that of determining the frequencies necessary for giving the service involved. The frequencies which are best suited to the different distances, time of day, and season of the year for transmission over the North Atlantic are indicated in the curves of Fig. 66. The curves for the greater distances refer to the transmission which appears to take place in the upper regions of the earth's atmosphere and is usually referred to as sky-wave transmission. Each of the sky-wave curves traces the optimum frequency-distance relation for the time of day and season of the year indicated. The curves merely give a general picture of the frequency relation and do not take account of other effects, such as fading, magnetic storms, etc.

The figure brings out very clearly the necessity for using a variety of wavelengths if the ship lanes are to be adequately covered. Fortunately, there is a considerable band on each side of the curves shown, in which good transmission can be obtained, and this enables one to choose a small number of frequencies in the short-wave range which are adequate to cover the conditions. Actually, it is found that a set of about four frequencies will suffice to cover the North Atlantic. For distances greater than a few hundred miles this characteristic is obtained irrespective of whether the transmission is over water or over land, by reason of the fact that the transmission appears to take place in the upper regions of the earth's atmosphere.

Closer in to the transmitting station, however, there is the so-called surface component, the attenuation of which is much less over sea water than over land. It will be seen that the surface wave may be relied upon for distances of the order of 200-300 miles, for frequencies of about 4 megacycles. The transmission of this component is much more stable and reliable than is the transmission of the sky wave. It seemed important, therefore, to utilize the surface wave to the maximum extent possible.

With this in mind, a series of transmission measurements was made over a stretch of water between New Jersey, Long Island, and Nantucket for the purpose of more accurately evaluating the effectiveness of the surface wave component, particularly in so far as it bears upon the question of how close to the water front the coastal station need be placed. Transportable transmitting and receiving stations were used in these tests. It was found that as the transmitting or the receiving station was moved away from the water front, the attenuation increased materially. For example, moving either terminal a mile back from the coast line increases the attenuation some 8 decibels at 4.5 megacycles. On the other hand, a narrow stretch of land, such as a sand bar, out a few miles from the coast, introduces relatively little loss. These results indicate that if full advantage is to be obtained from the more reliable surface-wave component, the coastal station should be immediately upon the seacoast or a salt-water bay.

An important factor in connection with radio reception on shipboard is that of electrical interference. The modern steamship requires for its operation and its service a large amount of electrical machinery. In addition to this, it is equipped with various radio telegraphic services. The operation of all of this electrical equipment produces interference in a receiver which is much in excess of that normally encountered in a shore receiving station which can be so located as to be reasonably free from electrical disturbances. Furthermore, there is on the ship another source of disturbance which is due to charging and discharging of various parts of the rigging in the strong electromagnetic fields of the various radio transmitters. These various sources of disturbance were found in the earlier shipboard experiments and the high noise levels are, in general, the predominant factor in limiting the communication range. These factors made it desirable to employ at the shore end as powerful a transmitter as was available and to use whatever benefit could be obtained from antennas designed to be roughly directive along the transatlantic ship lanes. A transmitting set of the type used in transatlantic communication, but adapted for the ship-to-shore wavelengths, was therefore employed.

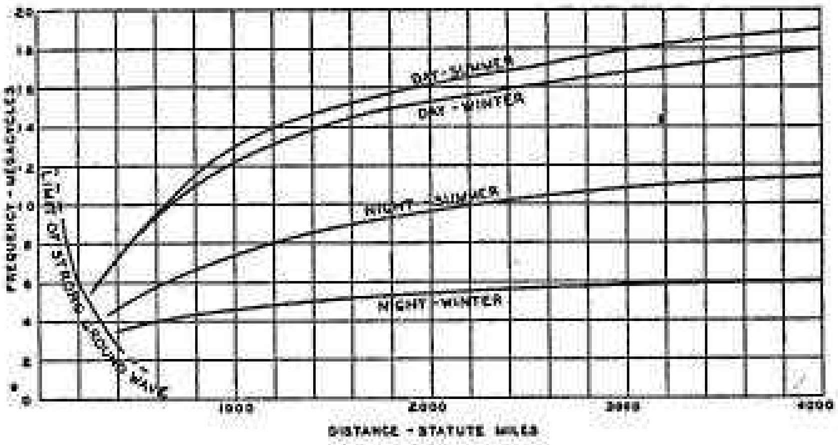


Fig. 66

Distance-Frequency Characteristic.

Since the shore receiver can be located in a comparatively quiet situation and since use can also be made of roughly directive receiving antennas, there is no advantage in transmitting as large an amount of power from the ship as from the shore. The actual power radiated by the *Leviathan's* transmitter is of the order of 500 watts. The shore receiver is of the type used on the transatlantic radio telephone circuits, working with a directive antenna. The arrangement provides a fairly well proportioned system, the channels being substantially equally effective in the two directions.

The Shore System

The general setup of the system is illustrated in Fig. 67. The coastal stations, sending and receiving, are located about 60 miles south of New York on the New Jersey shore, at Ocean Gate and Forked River. The course followed by the transatlantic ships is indicated on the map of Fig. 68. The directional bearing of this course and the directivity characteristic of the New Jersey shore station antennas are illustrated in Fig. 69. It will be observed that the breadth of the transmitted beam is adequate to take care of the variation of the directional bearing of the course. For steamship routes other than the transatlantic, as for example the coastal route to the South, other antenna arrangements will be required.

In general, the whole coastal station, including the transmitting and receiving units, taken together with the wire line connections and control position in New York, is similar to one end of a transatlantic point-to-point circuit. The transatlantic facilities have been described in previous papers and reference should be made to them for more detail than is given below. The

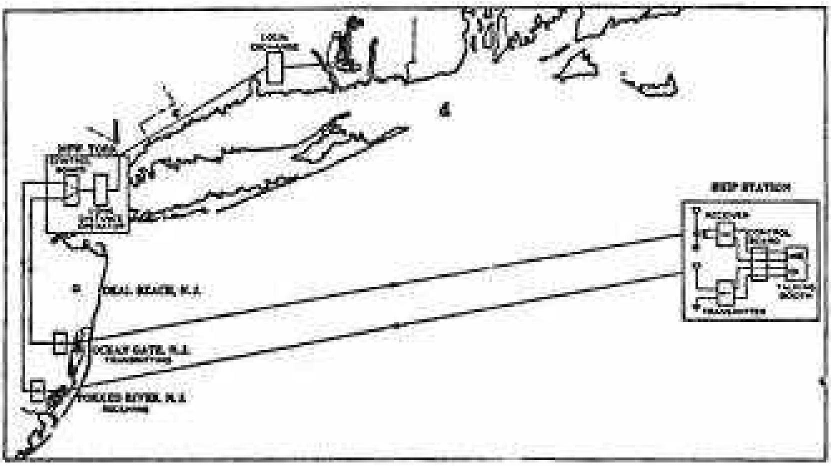


Fig. 67
U. S. Coastal Station, Circuit Between New York and Ship.

transmitting set has been adapted to cover the frequency range used in the service. It has a power of 15 kw. output of unmodulated carrier and is capable of delivering 60 kw. peak power. A photograph of a similar transmitter at Deal Beach, which is being used for this service pending the completion of the transmitting station at Ocean Gate, is shown in Fig. 70. The antennas are simpler and less directional than those employed in the transatlantic circuit, and give a transmission gain of 8 to 10 db as compared with a single half-wave antenna.

The receiving station at Forked River has been in operation since the opening of commercial service last December. A photograph of the receiving set is shown in Fig. 71. The receiver is of the double-detection type, of high gain and selectivity, and employs screen-grid tubes. It is provided with automatic gain control. The apparatus shown includes not only the receiving set proper but also the equipment which is required for monitoring the circuit and for connecting with the wire line into New York. The receiving antennas

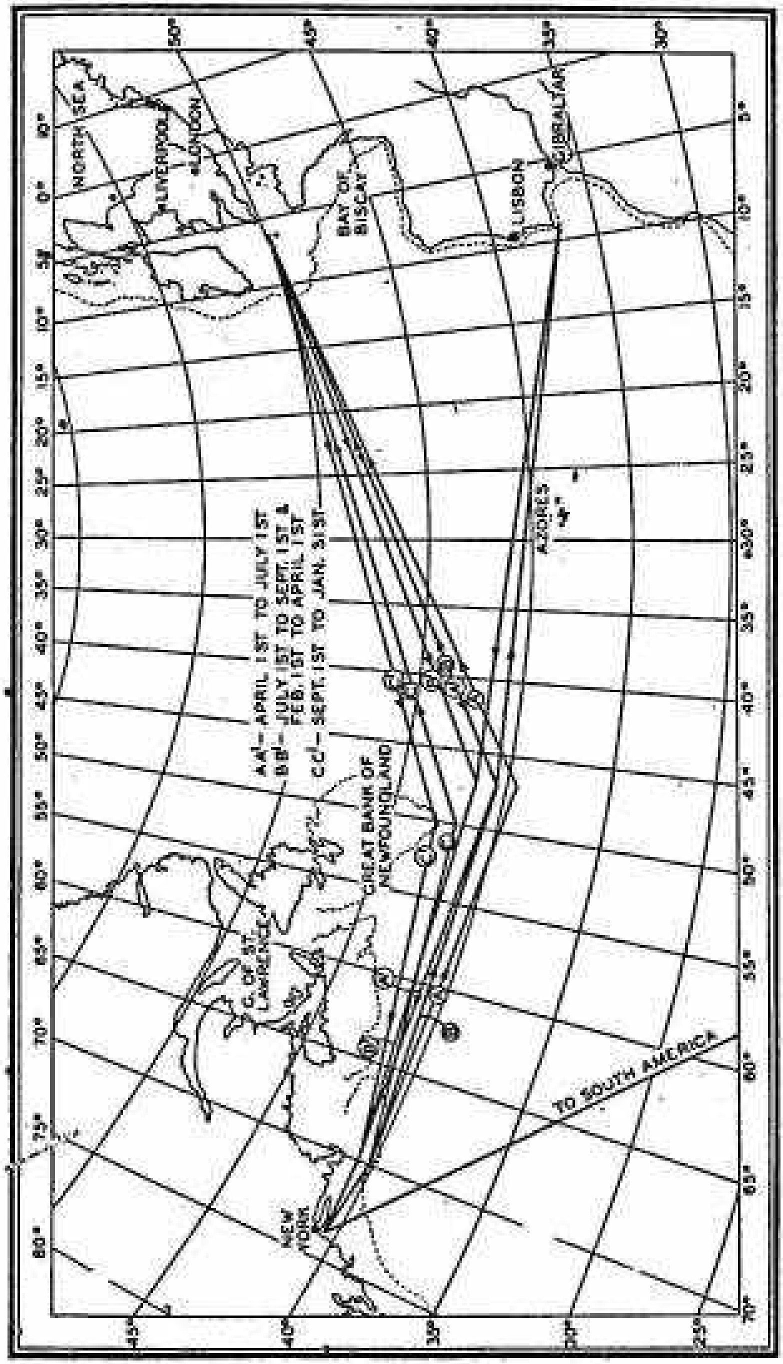


Fig. 68
North Atlantic Ship Lanes.

are of the same general type as those used in the transatlantic system, which consist of a row of quarter-wavelength verticals connected alternately top and bottom by quarter-wavelength conductors. In the case of the longer wavelengths used in the ship-to-shore service, the vertical conductors are reduced in height and the horizontal links correspondingly elongated. A photograph of the station at Forked River and two of the antennas is shown in Fig. 72.

The control and operating terminal equipment in New York is identical with that in use on the transoceanic radio telephone circuits. The control positions, as they exist in the New York long-distance telephone building for both transatlantic and ship-to-shore circuits, are pictured in the fronticepiece. These control positions have associated with them such things as voice-frequency repeaters, indicators of the volume being transmitted and received

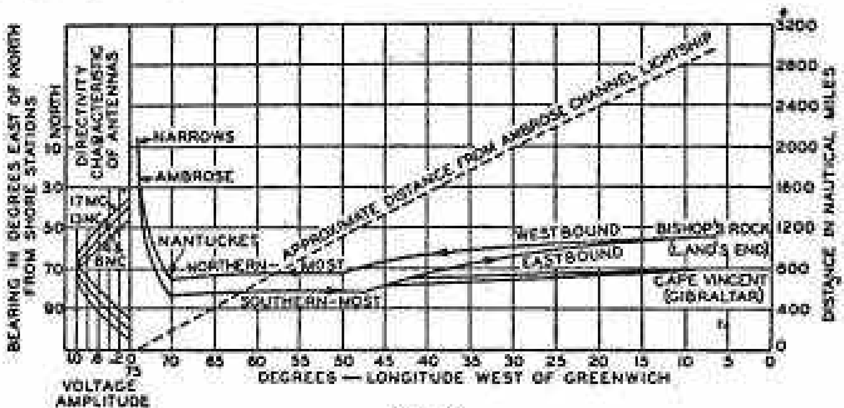


Fig. 69
Directional Bearings.

over the circuit, gain controls, monitoring and testing facilities, and voice-current operated switching devices. The latter prevent the speech received from the ship from being reradiated from the shore transmitting station and permit independent adjustment of amplification in the circuits leading to the transmitting and receiving stations. Thus, the volume sent to the transmitting station may be kept substantially constant, despite variations in speech volume received from different land line subscribers and full modulation of the transmitter may be obtained for over-riding noise on the ship. The function of the technical control operator is that of maintaining the circuit in the correct technical condition for talking. In general, it is the intention that the shore transmitting and receiving stations should function, as far as possible, merely as repeater stations, with the control of the over-all circuit from New York to the ship resting in the New York technical operator.

The circuit terminates as an operating facility before a traffic operator at one of the long-distance telephone boards. In Fig. 73 is shown an illustration of the traffic positions for the transatlantic radio telephone circuits, including, at the right, two positions devoted to the ship-to-shore service. The duty of one of these two girls is confined to the radio circuit itself in that she

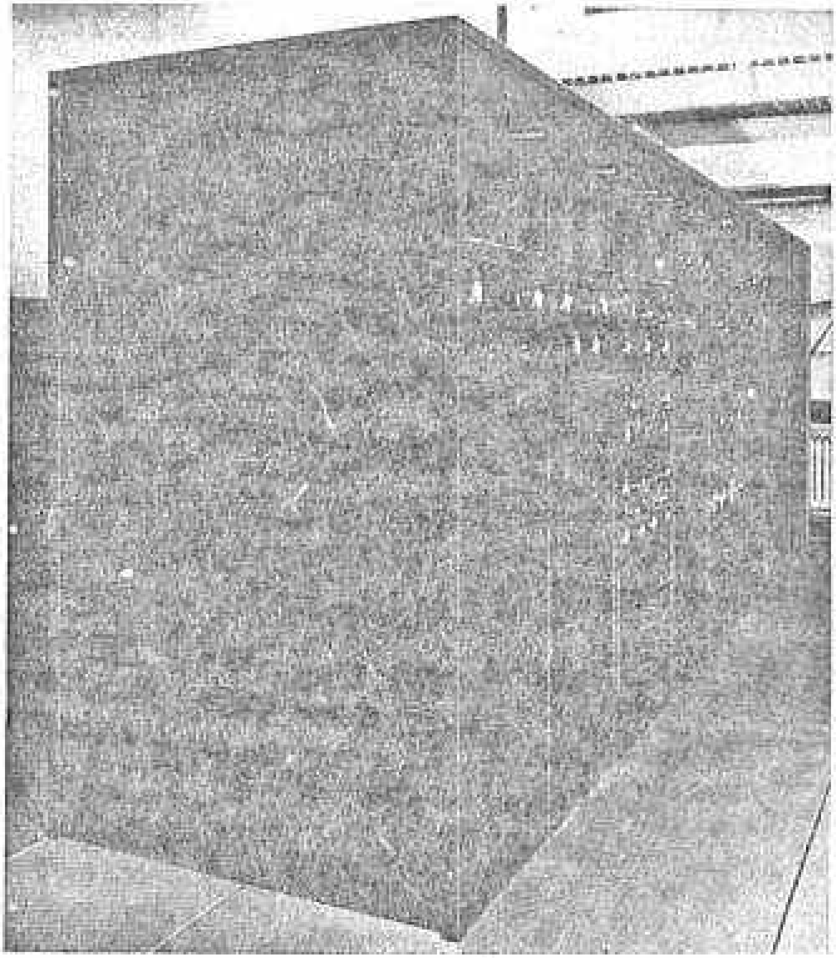


Fig. 70
Deal Beach Transmitting Set.

talks to the ship operator, passes and receives information as to calls, and is generally responsible for completing the connection betwen the ship circuit and the land line subscriber. The adjacent operator is concerned more particularly with the land subscribers, answering inquiries and recording calls outbound to ships and, in turn, getting in touch with and holding land line subscribers for inbound calls.

The Ship Station

The *Leviathan's* radio transmitter was designed to supply about 500 watts, 80 per cent modulated radio frequency power to an antenna at fre-

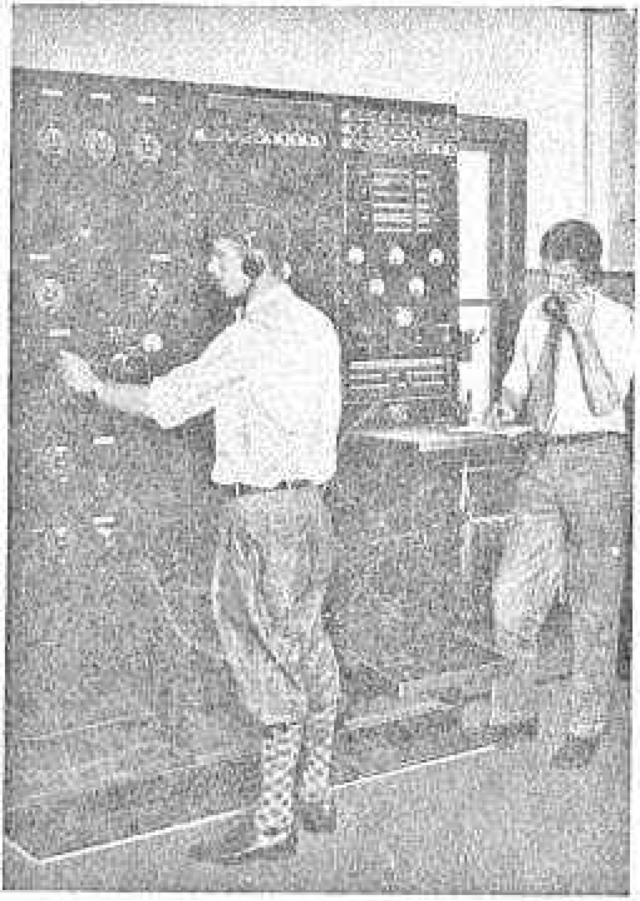


Fig. 71

Forked River Receiving Set.

quencies from 3 to 17 megacycles. To insure satisfactory operating conditions, the carrier frequency stability was made as good as that required for point-to-point service and the transmitter has been designed with the object of holding the frequency within 0.01 per cent. This facilitates the establishment of contact between the ship and shore and obviates the necessity for frequent returning of the shore receiver. The background noise on the unmodulater carrier, due to commutator ripple, etc., is inappreciable and the audio-frequency characteristics from 200 to 2750 cycles is flat to within ± 2 db.

In addition to these electrical requirements, the mechanical design must be such as to withstand ship's vibration, permit easy access to the interior so as to facilitate wave change, and at the same time protect the operators from electrical shock.

The transmitter consists of a crystal oscillator and associated amplifiers. The crystal provides the necessary carrier-frequency accuracy and stability and the amplifiers step up the power of the carrier to the desired level. Audio-frequency filters are placed in all voltage supply circuits to eliminate background noise. The modulation system with its associated transformers is designed to produce the requisite audio-frequency quality. A diagram of the circuit is shown in Fig. 74.

Very thorough electrical shielding is necessary between amplifier stages

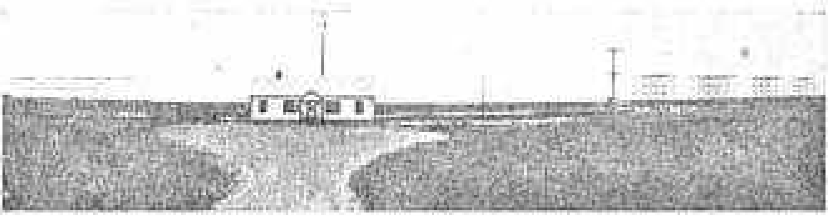


Fig. 72

Forked River Station with Antenna.

to prevent singing. This shielding makes the changing of coils, which is necessary for the changing of wavelengths, very unhandy and hence the crystal control and amplifier system, except the last stage, is provided in duplicate, one side being used for the longer and the other for the two shorter waves. Wave changing, except for the output circuit of the power stage, is then accomplished by connecting the proper amplifier to the power stage.

The quartz plates used in the crystal control system are circular, being approximately one inch in diameter, and are clamped rigidly in the holder. This clamping serves to prevent any change of frequency with mechanical vibration. The holder with its crystal is mounted in a small oven, the temperature of which is held constant at 50 deg. cent. to better than ± 0.1 deg. cent. The thermal system of this oven is so designed that the change of internal oven temperature with temperature changes of the surrounding air is negligible.

As shown in the figure, the crystal is connected between the grid and filament of a 5-watt vacuum tube which, together with the parallel resonant circuit connected to the output of this tube, forms the crystal oscillator. The radio-frequency voltage developed by the crystal oscillator is applied directly to the grid of a 7½-watt screen-grid tube which can be used either as an amplifier or a frequency doubler. The output of this tube, except in the case of the higher frequencies, is applied directly to the grid of a 50-watt screen-grid amplifier. For the higher frequencies a second frequency doubler can be switched into the circuit. The output of the 50-watt tube is coupled through a balanced transformer to the final amplifier stage. The amplifier or frequency doubler stages are separately shielded and radio-frequency filters are provided in all power supply leads.

The power amplifier consists of an air-cooled, three-element, one-kilowatt tube. Neutralization is accomplished by the familiar balancing arrangement shown in the figure. The output circuit of this stage consists of a parallel resonant circuit with provision for tapping in the connection to the antenna.

Modulation takes place in the plate circuit of the final amplifier stage, the plate current supply being fed through a special transformer, the secondary of which is connected to two 250-watt tubes connected push-pull and fed by a 50-watt amplifier.

The power supply is obtained from motor-generator sets operated from the 110-volt, d-c. ship supply. Protection of the operators and apparatus is provided by means of relays and contactors in the high-voltage supply circuits which prevent the high voltages from being applied if the filament or grid circuits are not closed or if the doors of the transmitter are open.

An illustration of the ship's transmitter is shown in Fig. 75. The picture is somewhat out of perspective owing to difficulty in taking the photograph in the limited space available on shipboard.

The receiving problem on shipboard is complicated by a number of factors. The transmitting and receiving frequencies must be within a few per cent of each other if the best transmission conditions for the time and place are to be utilized and if the frequencies are to remain in the bands assigned internationally to the mobile services. This requirement, as well as the noise conditions on shipboard, calls for a receiver of high selectivity which is obtained, in the present instance, by the use of a double-detection set. The over-all selectivity is accomplished both by having a number of highly selective circuits ahead of the first detector and by using tuned circuits in the intermediate frequency stages, the high-frequency selectivity being used primarily to prevent overloading of the first tube and the intermediate frequency circuits being used to obtain the final selectivity required.

A reduction of the disturbances due to stay noises and better discrimination against the transmitted carrier is obtained if the transmitting and receiving antennas are widely spaced. On the other hand, for operating reasons, it is desirable to have the transmitter and receiver located in the same room. In the case of the *Léviathan* installation, the transmitting antenna is located directly above the radio room, between the second and third stacks, and the receiving antenna is placed as far as possible behind the third stack. The receiving antenna is connected through a suitable step-down circuit to a shielded transmission line, the other end of which is connected to the receiver, the receiver itself being very thoroughly shielded to avoid direct interference from the transmitter. On account of limited space, only two antennas are provided to handle the four frequencies, each antenna representing a compromise between the most efficient antennas which could be put up to handle*the separate wavelengths.

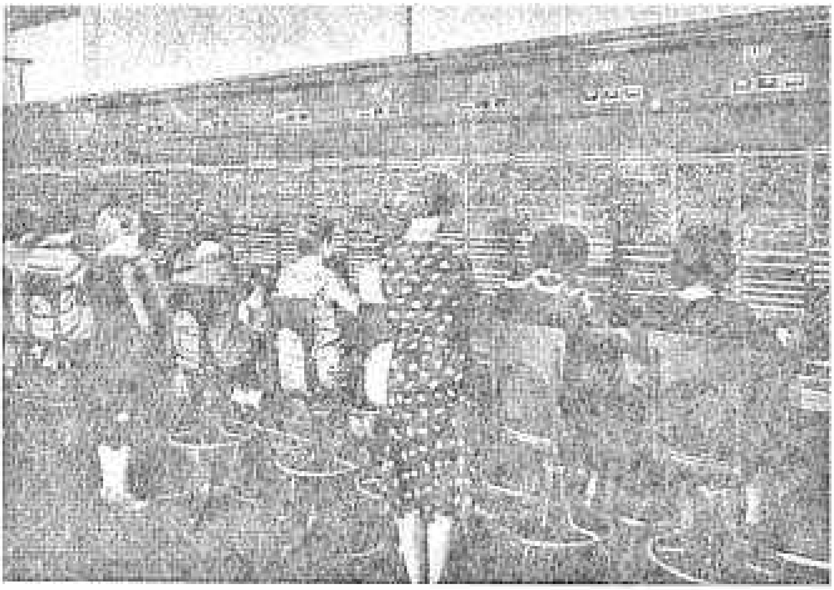


Fig. 73
New York Traffic Positions.

As stated above, the receiver itself is of the double-detection type, using heater type tubes throughout. Screen-grid tubes are used for the first detector and intermediate frequency amplifiers and three-element tubes in the remaining positions. A photograph of the receiver and associated voice-frequency equipment, as it is installed on the *Leviathan*, is shown in Fig. 76, and a diagrammatic representation of the receiver is shown in Fig. 77. The high-frequency selective system consists of four separately shielded tuned circuits, coupled by small capacities. The use of a screen-grid tube in the detector circuit gives a two-fold advantage over the use of a three-element tube in that a higher input impedance is maintained at the higher frequencies and the necessity for neutralizing against the reaction of the beating oscillator on the input circuit is eliminated. The beating voltage is made of the order of 75 to 100 volts for the purpose of reducing the effective tube noise in the detector plate circuit. With this arrangement no d-c. plate voltage is ordinarily required. The screen voltage is 22 volts. The output circuit is tuned to the intermediate frequency of 300,000 cycles and connection with the first intermediate amplifier is effected by means of a low impedance transmission line. The intermediate frequency amplifier stages are coupled by means of doubled tuned circuits. The use of properly designed circuits of this type makes it possible to obtain a high degree of selectivity against undesired frequencies while obtaining sufficient band width to maintain ease of tuning and to pass the desired frequencies. The second detector is of the

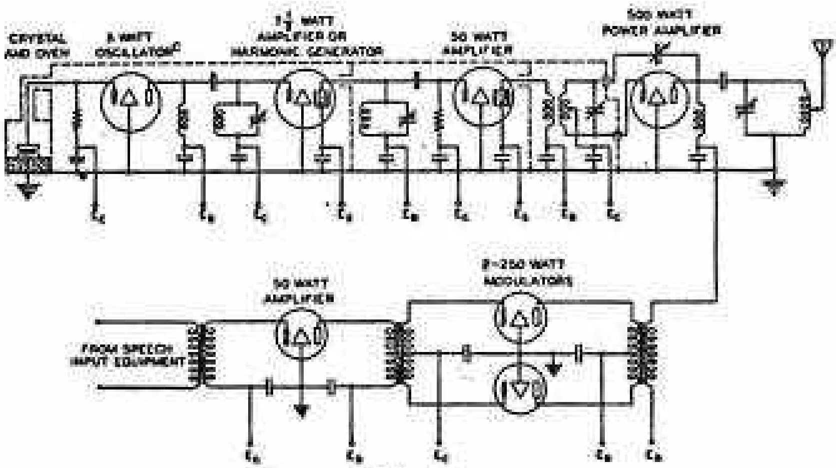


Fig. 74

Ship Transmitter's Schematic Diagram.

conventional grid bias type. Automatic gain control is provided in which a certain amount of the carrier is taken at the end of the intermediate frequency stages, amplified and rectified. The resulting d-c. current produces a voltage drop across a resistance, which is applied to the grid of the first detector in such a manner that an increase in the intermediate frequency output brings about a reduction in the total set gain and vice versa. Manual gain control for following wide changes in the received fields is accomplished by variation of the voltages applied to the grid and the screen of the first detector.

The voice-frequency equipment, in addition to the desk telephone set located in the subscriber's booth, comprises a technical operator's position located adjacent to the ship's receiver, and an attendant's desk located on a lower deck in a room adjacent to the subscriber's booth. The control equipment consists of repeaters, volume control devices, and volume indicators, by means of which the levels of the incoming and outgoing signals can be properly adjusted. Keys are provided which enable the technical operator to talk either over the radio circuit or to the ship subscriber. The booth attendant has facilities by which he can talk either to the subscriber or to the control operator and has a connection with the ship's telephone system for

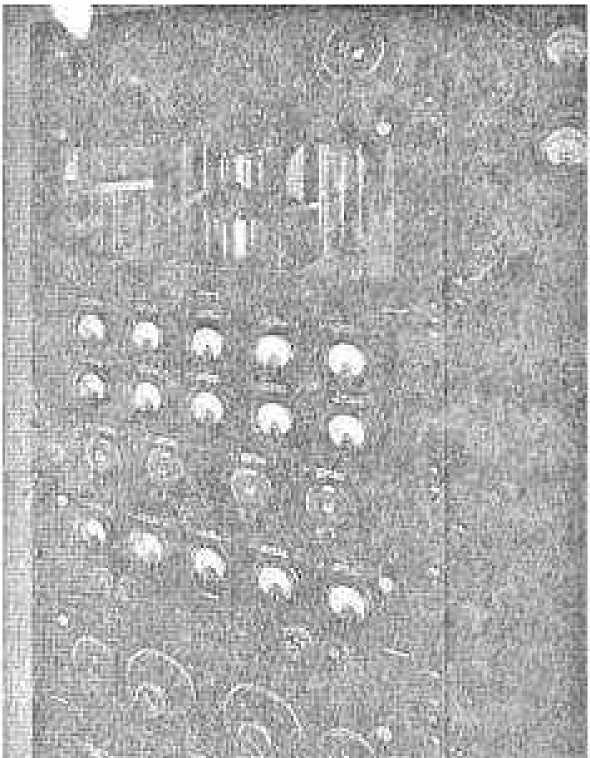


Fig. 75
Leviathan Transmitter.

the purpose of locating persons on the ship and calling them to the radio telephone booth. The subscriber's booth is provided with a desk telephone set having a high-grade transmitter. The outgoing and incoming circuits are shielded from each other and brought separately to the transmitter and receiver of the subscriber's set. An illustration of the subscriber's booth on the *Leviathan* is shown in Fig. 78.

The Wavelength Situation and Simultaneous Telephone and Telegraph Operation

Communication between ship and shore is carried out by the use of a pair of frequencies, one for transmission in each of the two directions, separated from each other by about 3 per cent. The specific frequencies which were first assigned by the Federal Radio Commission to the shore station and the *Leviathan* were necessarily chosen on a more or less makeshift basis, in the absence of any comprehensive wavelength plan for this new service. The Commission has recently had under study the setting up of more adequate provisions for ship-to-shore telephone channels, whereby it is hoped a series of frequencies may be designated for telephone service exclusively and whereby there may be established the relation between the telephone and the telegraph frequencies necessary for the avoidance of interference between the two services. Especially is coordination of the two sets of frequencies necessary on the larger vessels in order that simultaneous telegraph and telephone service may be given without mutual interference. On the larger liners simultaneous use of the radio telephone and radio telegraph service must be provided for. This means that the transmitters of both services must keep accurately on their frequencies and be free of spurious components, and that the receivers must be highly selective. It further entails that the transmitting and receiving frequencies in each of the two cases be so coordinated that the transmission frequency of one service does not lie too near the receiving frequency of the other, and bespeaks a considerable amount of mutual cooperation between the operating agencies involved. Difficulties of fitting in the two services were encountered in the early work on the *Leviathan* and, although the problem has not been worked out to final solution, sufficient progress has been made, in cooperation with the engineers of the Radio Corporation of America, to enable the telegraph and telephone services to be conducted simultaneously without undue interference.

In view of the fact that ships of a number of nations are already preparing to give radio telephone service on the transatlantic routes and with the probability of this service also extending to other parts of the world, it would appear to be a matter of importance that the whole question of marine frequency allocations be worked out in the near future not merely on a national but also on an international basis.

Transmission Results

The transmission results which have been obtained with the *Leviathan* on her first trip of commercial service are summarized in Fig. 79. It will be noted that practically continuous 24-hour communication was maintained for distances within 1000 miles of the shore, corresponding to two days out. The service at greater distances was more intermittent. This was largely due to the fact that during this first trip the effort was concentrated on covering reliably the more important nearer-in distances, and the ship was not prepared to transmit on frequencies above 8 megacycles. The service proved to be much in demand by the passengers as is indicated by the number of calls completed each day, particularly on the return trip. A similar number of test and demonstration calls was made during the voyage. The calls were completed without undue delay, there being only one ship involved, and a fairly high grade of communication was obtained.

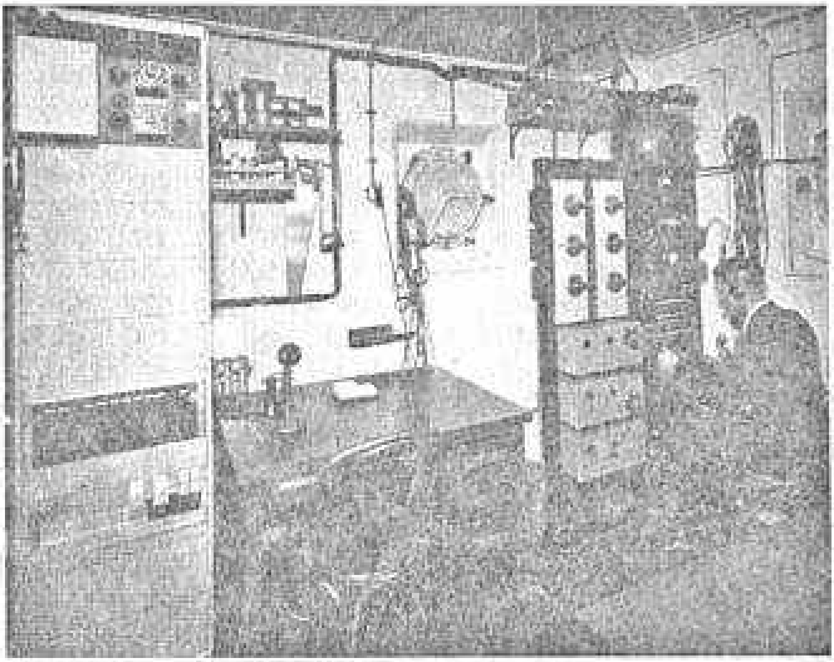


Fig. 76
Leviathan Receiver.

In conclusion it will be realized that the solution of the technical problem of ship-to-shore telephony is now well in hand and has been carried to the point of having proved the practicability of giving this service. Further problems are naturally arising in carrying the development into more general effect, particularly operating problems and those concerned with the international coordination of the service. The indications are that the larger transoceanic ships will be rather generally equipped for telephony and that the service will become one of permanent value in the maritime field.

The two crack liners *Bremen* and *Europa* are both equipped with elaborate short-wave transmitting and receiving apparatus. At the present time the equipment is being subjected to a series of experiments, prior to establishing any definite services. The system is suitable for both radio telegraphy and radio telephony. Communication is carried on between these two boats and from the boats to a main station in Germany.

In due course it is expected that the radio telephone service will be available to the passengers to allow communication with telephone subscribers on land, similar to the service now in use on certain American and English liners. This equipment while manufactured in different countries will probably in the future be standardized so as to be suitable for use with the land receiving stations and the associated equipment supplied by the telephone companies.

This same short-wave equipment would of course be suitable to pick up international short-wave broadcast and reproduced for the benefit of the passengers. Likewise it would be possible for the liner to put out a short-wave entertainment program which could be picked up in various parts of the world and rebroadcast if desired at those points.

It is interesting to note some of the details of the equipment on the *Bremen* and *Europa* by referring to the accompanying photographs. In the first place there are a number of different radio receivers and transmitters so

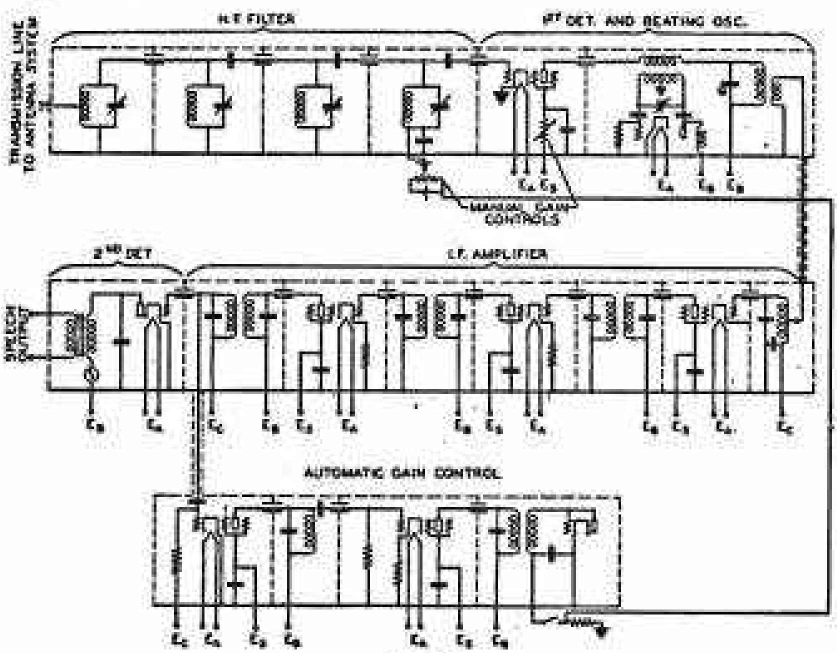


Fig. 77
*Ship Receiver Schematic Diagram.

that communication can be carried on with different wavelengths simultaneously. These receivers are of modern design scientifically shielded. In the case of radio-telegraph signals, the transmission can be taken directly by the operator or transferred to machine tape recorders.

Similar apparatus is also installed on the modern steamship *Columbus*. In each case at the present time, the radio-telephone conversations are being held on wavelengths of 160 and 190 meters. For telegraph work on short waves the *Bremen* is working on 19.2 and 36.5 meters, the reception being taken at the German coastal radio station Elbe/Weserradio (Cuxhaven Radio). The accompany photographs illustrate this modern equipment.

Fig. 78

Subscriber's Booth on *Leviathan*.

Early Experiments Ship-to-Shore Radio-Telephony

Considering the great progress made with ship-to-shore radio-telephony in the past few years, it is of extreme interest to study the comparative results as obtained with the early experiments some years ago.

The Bell System decided to start trials along these lines as early as 1919. The fundamental condition laid down was that there should be developed a system by which any telephone subscriber of the Bell System could carry on a conversation with a telephone station located on a ship, and that from the point of view of the speakers, the operation should be similar to the carrying on of an ordinary toll call between land-wire subscribers. It was also desired that it be possible to carry on three simultaneous and independent conversations between three ships and one land station since a final commercial system would involve the establishment of several circuits simultaneously. These two-way conversations were to be obtained without the use of an excessive frequency band.

The first plans called for the establishment of experimental land stations about 200 or 250 miles apart and to try for communication with a ship at distances up to 200 miles. Other problems involved included elimination of interference (radio and static), secrecy, possibility of cross-talk and initial signaling to establish contacts prior to commercial conversations.

It must be remembered that at that time the engineers were handicapped by the size of the transmitting power tubes available and by the selectivity of the receivers which had been developed up to that period. In the beginning it was thought that to cover the required 200 miles, about one or one and one-half kilowatts in the antenna would be necessary. The best tube available at that time was the W. E. 250-watt transmitting tube and it was decided to use those.

The greatest economy in power and in wavelength range may be secured by transmitting only one side band of the modulated wave. Furthermore, this method has the decided advantage that variations in the transmission characteristics of the medium do not cause as great variations in the received signal. This is because the received signal is proportional to the product of the carrier and side bands and if the carrier is supplied locally instead of being transmitted, it is not affected by transmission factors. The use of such a system, however, or one in which only the carrier is suppressed, creates a difficult problem at the receiving end due to the fact that a constant oscillator frequency must be obtained and most ships at that time were equipped with detectors only. This would prevent inter-communication in an emergency. In addition it also restricts the type of transmitter to one where the power tubes are used as amplifiers, and it was known that some difficulty would be experienced in operating a number of 250-watt power tubes in parallel if it should be necessary to transmit on wavelengths as low as 300 meters. In

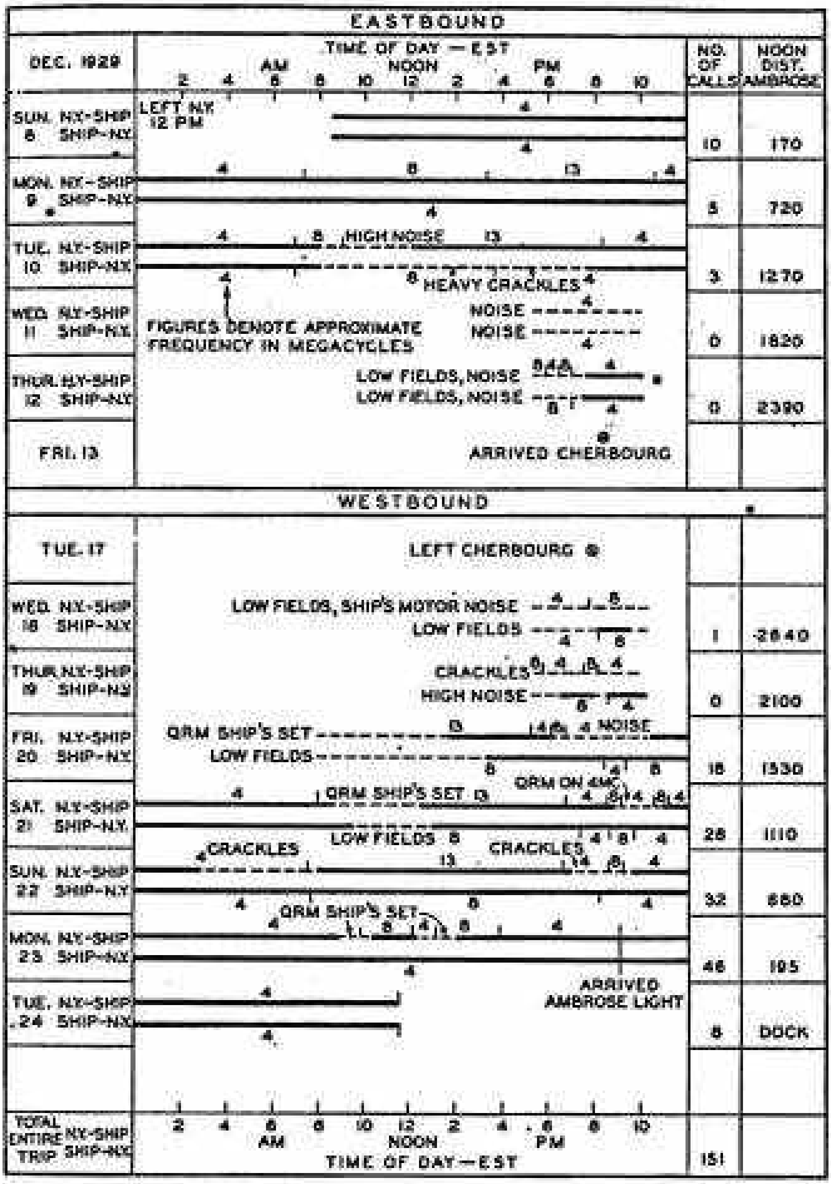


Fig. 79

Transmission Results Between S.S. *Leviathan* and New York.

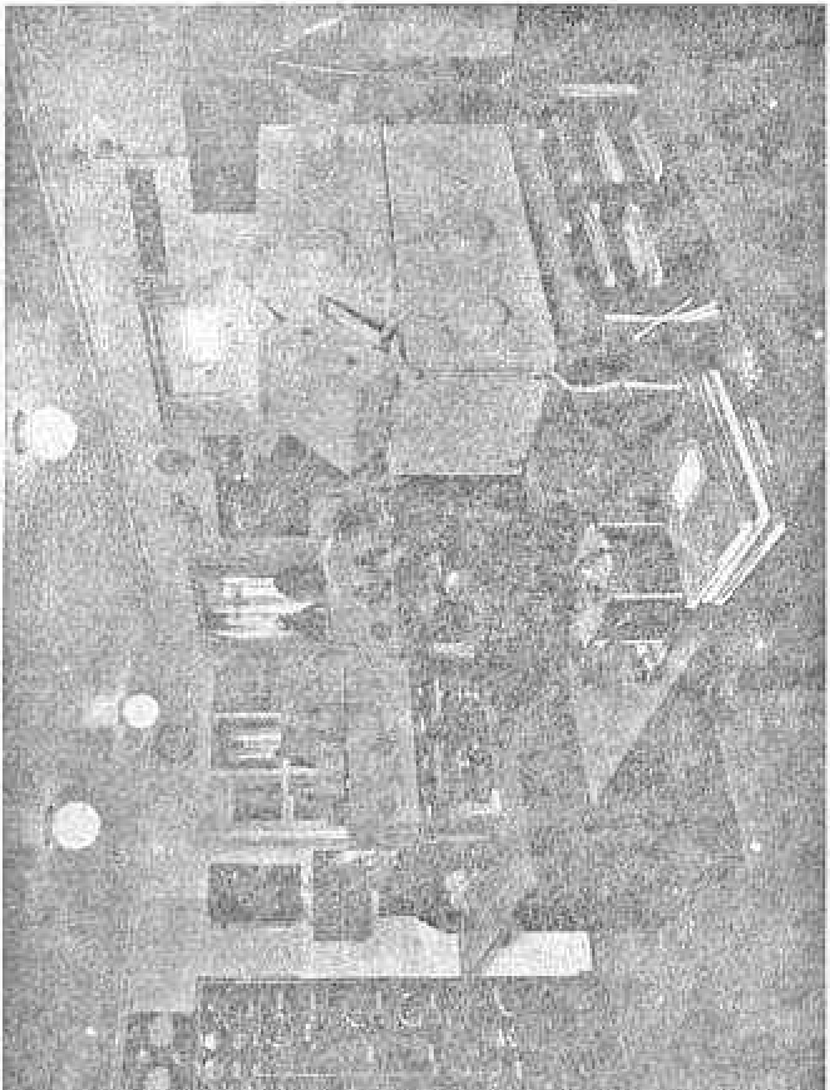


Fig. 79 (a)

Main Transmitting Radio Room, S.S. *Europe*, showing Short-Wave Receivers and to the left the Short-Wave transmitting apparatus. Complete telephone intercommunication systems are provided to the executive officers.

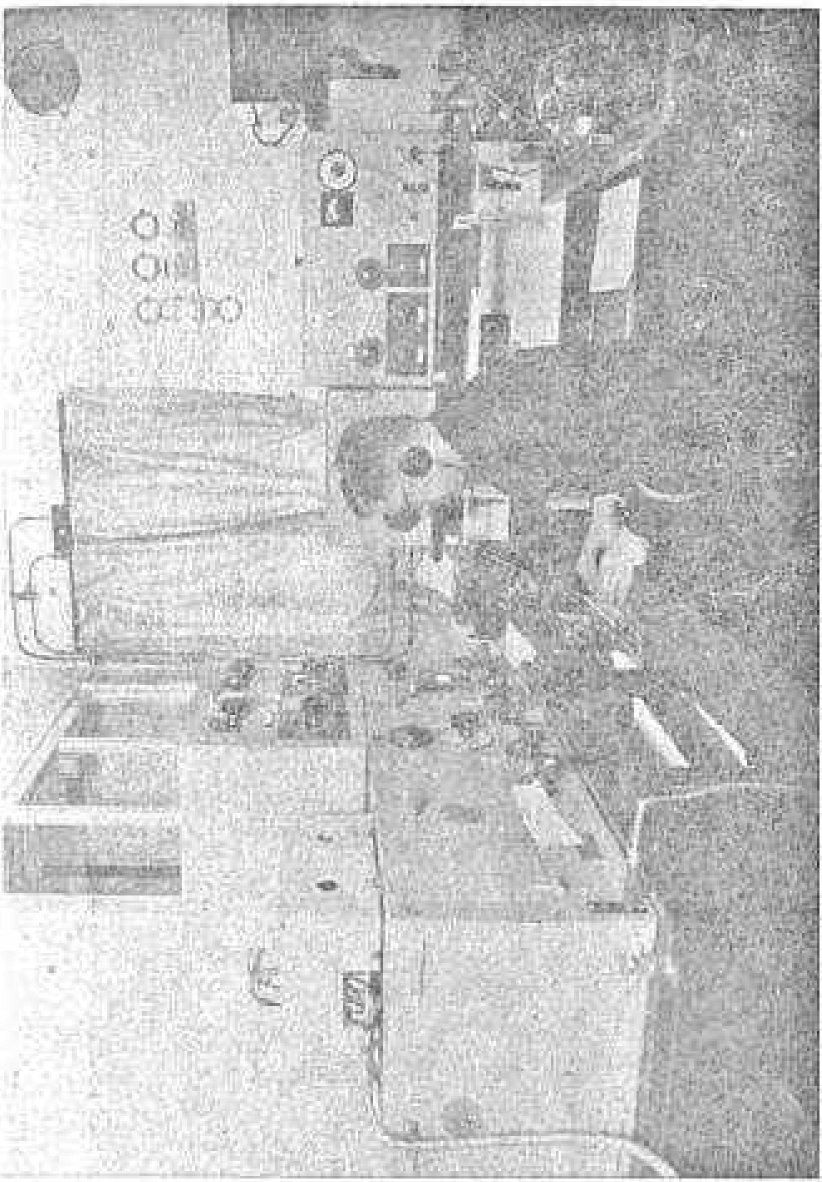


Fig. 79 (b)

Short-Wave Receivers on the S.S. *Europa*, the operator is shown busy taking Transoceanic press from Nauen. The telegraphic code signals are transferred direct from the received signals to the typewriter.

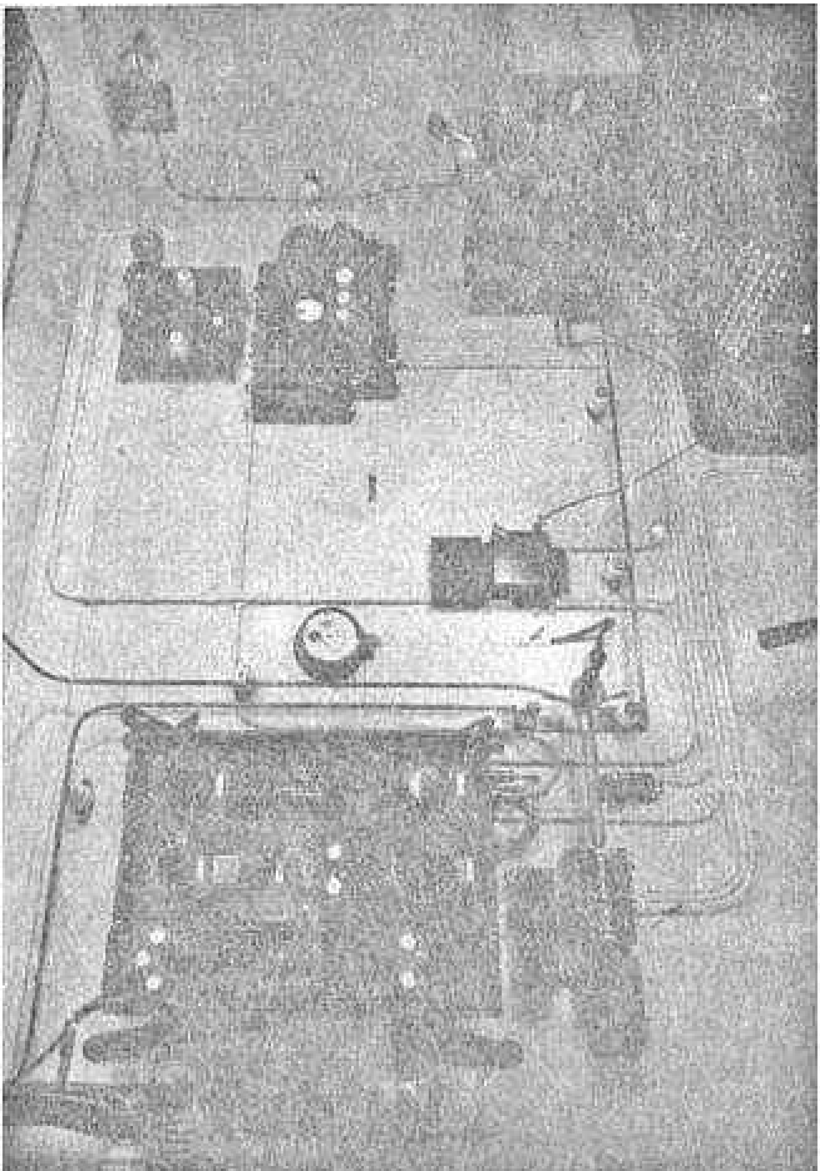


Fig. 79 (c)

On the left is shown the Transmitting Short-Wave Apparatus on the S.S. *Columbus* (140 and 190 Meters), the North German Lloyd boat working in a schedule with the S.S. *Bremen* and S.S. *Europa*.

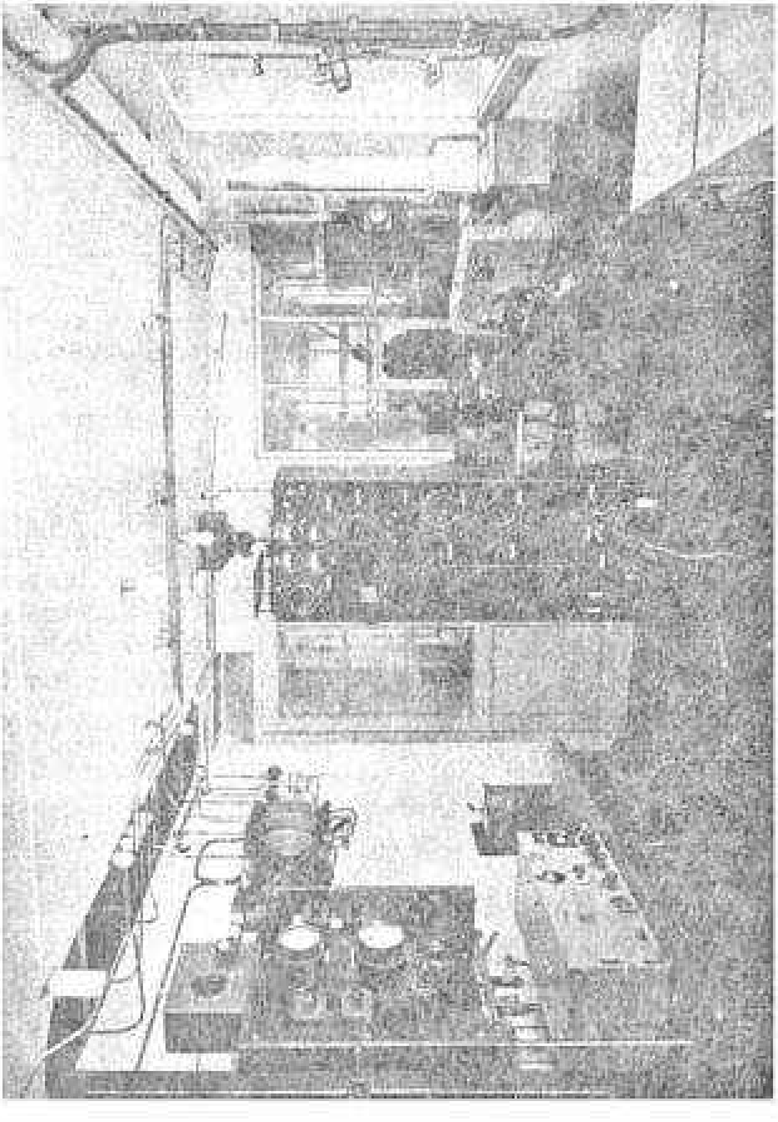


Fig. 79 (d)

Part of the main Transmitting Room of the S.S. *Bremen*, showing in the center the Short-Wave Transmitting Apparatus by means of which transmission is carried on from port to port over the entire steamship lines.

view of this situation it was decided to use a simple system in which the constant current method of modulation was obtained and which required an equal number of modulator and oscillator tubes; the carrier contained all the components of the modulated wave.

The simultaneous transmission on three channels could at that time have been accomplished in several different manners. For example: it is possible to use a single antenna which is multi-tuned or to use three separate antennas. It is also possible to transmit three channels on a single antenna by using a special system of double modulation which had been used on United States battleships several years prior. In all these systems there are many disadvantages and the analysis of these and other proposed methods of operation resulted in the decision to employ at that time three separate but closely adjacent antennas and three separate transmitting sets using the constant current modulation system.

The next important problem was that of securing two-way operation for combined radio and wire operation. There are several ways in which this can be accomplished including the simple method of manual switching, voice-operated relays an electric balance where the radio receiving circuit is balanced with respect to the transmitting antenna circuit, the use of different frequencies for the two transmissions relying upon frequency-selecting circuits for effecting separation. Of the above possibilities it was finally decided to use a system where different frequencies were used for sending and receiving.

After the first three receivers and transmitters were erected, initial tests were made on frequencies of 725, 750 and 775 kilocycles. These were quite satisfactory, the only objectionable feature being the interference encountered from spark transmitters (these spark transmitters are practically obsolete at the present time).

These experiments were followed by the construction of improved transmitters, more effective antenna systems and experiments continued. At the same time a two-way telephone set for use on shipboard was constructed and in the Spring of 1921 one of these sets was installed on board the steamship *Ontario*. By the Fall of 1920 all this construction work was completed and in December of the same year demonstration of simultaneous three-channel operation from the main station to ships was carried out with entirely satisfactory results. Test programs from the main transmitting station conducted on 400 meters brought reports from several hundred amateurs throughout the country which showed that audible radio signals were often received at a distance of 1,000 miles.

The transmitter used had a master oscillator carefully shielded to maintain constant frequency which operated into a two-stage amplifier, the last stage being 50-watt tubes, and from there into a bank of six radio-frequency power tubes each capable of a plate dissipation of 250 watts. Thus both the radio-frequency and speech-frequency currents are brought up to the high power level before modulation takes place (this is the exact opposite to the system now in use).

As there was a total of four transmitting stations, conversation could be carried on through four channels and reception was taken care of by four loop antennas operating into four receiving sets.

The receiving sets as finally developed were extremely selective and passed a band of speech of the proper width and with a large attenuation outside that band.

In the entire system it is necessary that the magnitude of stray currents be so kept down in comparison to the transmission current to eliminate noise interference in telephone conversation. During these tests this requirement was very difficult to realize in the radio link principally because of static and, especially in the vicinity of New York, interference from spark telegraph stations. The actual range limit of the radio link is set by this interference, caused by the presence in the ether, on the wave band being used, of extraneous wave components. Actually it was found that in transmission on 400 meters in the vicinity of New York the receiving field strength could not be permitted to go below an average of 200 microvolts per meter and even then under some circumstances the spark interference was prohibitive.

Additional tests included field-strength measurements at the ships at varying distances from the transmitting station. For example: working on 820 kilocycles tests on the S.S. *Gloucester* showed that at a distance of 130 miles the field strength was 400 microvolts per meter and gradually increased to a value of 2,200 microvolts per meter with the ship a distance of 50 miles from the transmitter. Similar tests made on the S.S. *America* in March, 1922, working on approximately 378 meters showed an enormous difference between the field strength received by day and night. For example: at a beginning of 1,250 miles from the transmitter at a time when it was both sunset at the station and sunset at the ship, the first signals received had electric field strengths of approximately 30 microvolts per meter. These increased in intensity during the night and at the following sunrise when the ship was a distance of 1,100 miles away the signals dropped to a value of only 2½ microvolts per meter. No reception was possible during the following day. The following night when the ship was a distance of approximately 800 miles from the transmitter reception was affected over a short period with received signal strength of from 5 to 100 microvolts per meter. Reception was again interrupted until the following sunset when communication was established and with increased field strength. Communication from there on was established with increased signal strength which finally reached a value of 5,000 microvolts per meter as the ship approached New York. Enormous variations between day and night in received field strength which occurs at distances of the order of 1,000 miles using wavelengths of approximately 350 meters presented a serious problem at that time. The observations showed that there was a variation of the order of 100 to 1 which corresponds to a power ratio of 10,000 to 1. This means, for example, that it will require 10,000 times more power to establish communication during the day as during the best times at night. These enormous day to night fluctuations are familiar to broadcast listeners. These curves indicate that it would be impossible to give continuous ship-to-shore telephone service at these relatively short wavelengths for distances as great as 1,000 miles. It was figured at that time that much longer wavelengths would have to be used as well as more transmitting power.

During the period in which these experiments were made, the ship's radio-telegraph transmitters were of the spark type and it was, of course, impossible to carry on telephone and telegraph communication simultaneously. To correct this situation, in 1922 the S.S. *America* was equipped with a radio-telegraph transmitter of the continuous-wave type and this transmitter and the radio-phone transmitter were arranged to use different antennas. This allowed simultaneous operation of the two radio transmitting equipments, telegraph operating on 2,100 meters and telephone on 375 meters. Another arrangement has been worked out theoretically where both the telephone and telegraph signals can be transmitted on the same carrier. This is mentioned to show the ultimate possibilities of combined operation and it is not put forward as one which is sufficiently practical, all things considered, for use in the immediate future. As previously mentioned, one of the most important reasons for establishing ship-to-shore contact was to allow the use of the transcontinental telephone lines for extended communication. A practical demonstration of this type was given in February, 1921, where a ship approaching New York was placed in communication with New York and conversations relayed over the transcontinental long distance lines to Long Beach, California, and from there to the Catalina Islands in the Pacific thus bringing together the two oceans. Reviewing these early experiments, one of the most interesting points is the fact that the engineers believed that the obstacles encountered could be remedied by using longer wavelengths and higher power. This was some years ago. The contention, of course, was true but not feasible from a point of economy particularly if the ranges were to be extended over the contemplated distance of 1,000 miles.

In the meantime new developments with short waves have indicated that instead of using longer wavelengths the short wavelengths are more desirable and not only enable communication over a distance of 1,000 miles but allow continuous service with the ships from one continent to the other as described in the first part of this chapter.

The descriptions and discussions given in this book have of necessity been confined to commercial applications, the naval authorities being reluctant to disclose details of their developments. It is reasonable to assume that the importance of these developments are fully realized by the military authorities and arrangements planned to use these facilities in the case of an emergency.

Recalling the incidents of the World War, communication facilities at that time were of relatively primitive proportions. The practical use of short waves was really unknown and communications established over long distances were principally by chance. A good percentage of the aircraft used was without any radio facilities and that which was equipped had a very limited range. No provision was made for secrecy other than the use of code messages.

The transmitters aboard ship were principally of the spark type which had a limited range, particularly during the daytime. These transmitters were subject to interference by transmitters of the enemy and had the further disadvantage that their use disclosed their position. This feature was used by both sides to advantage where possible.

During the World War, radio developments were practically equal on both sides but in some instances the German Government had superior equipment including a portable Trench Set of a suitable size; two men could carry the entire apparatus and accessories. This equipment enabled communication between the trenches and rear lines which was more desirable than telephones or runners. The radio equipment on the dirigibles and sea-raiders' was generally very satisfactory and proved effective but the successful operation of this apparatus in many cases was due to individual efforts; that is, this apparatus in the hands of an experienced radio operator would be of considerably more value than when operated by a student or operator with a limited amount of training. An example of this is the fact that during the period when spark transmitters were used, each transmitter had an individual signal "tone" or "note" and could be identified by this signal even if the signature call letters were omitted. In a like manner, different operators had an individual characteristic in their method of sending radio-telegraph signals and even the operators could be identified in this manner. This is not unlike the present situation where a broadcast station can sometimes be identified by the announcer's voice, and even in some extremes some broadcasting stations can be identified by the characteristic quality of their reproduction.

Communication is of course an important consideration in times of war. In any future emergency systems could now be installed which would be far in advance of anything used to date. Naval headquarters could be in instant communication with all naval vessels regardless of what part of the world they were located in. Aircraft attached to aircraft carriers or to a base would always be in communication with their base. Nations which were allied together would be in constant communication with each other regardless of cable facilities. Through the use of directional transmitting systems, communication could be carried on between certain points without any possibility of the signals being heard at other points. Elaborate methods of maintaining secrecy have been developed making it practically impossible for the enemy to intercept or interpret the conversations. These advantages will of course work both ways.

While these military considerations are interesting and must not be overlooked, it is of course the hope that radio and its future developments will be a means of bringing the different foreign nations still closer together both commercially and socially.

It is not difficult to imagine the facilities that will be available ten years from now if the radio developments are continued at the present pace. The radio-telephone and telegraph service to ships will be supplemented by television—probably television in colors. This does not mean simply that the two parties to a conversation will be able to see each other as the television feature will have other more important applications. For example: weather charts will be continually available to the captain and the passengers will have the advantages of news service, either as full pages reproduced or as an instantaneous reproduction of the actual event involved. Fast liners, if necessary, could be preceded by a fast pilot boat equipped with television apparatus which would in turn transmit the picture viewed back to the captain. This would be useful during the iceberg season. This same feature would of course have a more important military value between a scouting vessel or aircraft and the main fleet or squadron.

New plans are in progress to extend radio facilities to the liners. One company plans to equip the liners with stock and news tickers, the latter installed in a special cabin aboard ship and automatically operated from a main transmitting station or stations. Early tests along these lines were made using long-wave transmitters and receiver. The operation at the receiving end to be automatic requires that the signals directly operate a relay and inking recorder. This would be a relatively simple problem if channels of a reasonable band width were available and free from other telegraphic interference and static encountered was within practical limits. It must be remembered that it is difficult to design a receiver for long wavelengths (for installation aboard ship) which is highly selective. In view of this, in addition to the signals which are intended to operate the recording relays, there are interfering signals and static interference, both atmospheric and from electrical devices on board. In view of this condition the early experiments were not encouraging.

The short-wave channels and the new associated apparatus developed for radio-telephony could be used for ticker and news service as supplementary to the regular service, as it was previously pointed out that telephone and telegraph communications could be carried on simultaneously on the same carrier. The development of world-wide ticker service and the supplementary telegraphic order service will mean that eventually a customer located in any part of the world can trade with members of the New York or London Stock Exchange as conveniently as another customer located only a few miles from the exchanges. It is believed that when these rapid communication facilities have been developed that the business of these exchanges will expand to proportions that never have been dreamed of.

The radio equipment on board ship will eventually include supplementary apparatus for entertainment purposes. Recently the *Leviathan* on a trip from the Dry Dock in Boston to New York, sent out an entertainment program on short waves. This was received and relayed to the National Broadcasting Co. over the telephone lines and distributed to a number of stations on their chain. This will likely become an interesting feature on the radio in the near future. In a similar manner the radio receivers aboard the liners can be equipped with supplementary apparatus which can pick up broadcast programs from practically unlimited distances and distribute them throughout the ship with a public address system amplifier and a number of loud speakers. This will become more and more important as the quality of the broadcast programs improves, that is from a general interest standpoint.

Radio has of course added much to the safety of travel on the seas, many notable rescues have been made. With the new facilities being added this degree of safety is being increased every day. On the *Bremen* and *Europa*, the system of nesting the lifeboats and arranging for their launching is unique and ideal. In addition the lifeboats are individually equipped with low-power radio transmitters and receivers. It is not difficult to imagine that in past marine disasters in many instances the lifeboats were successfully launched but in certain cases, one or more lifeboats drifted from the scene and were lost. This can be eliminated with radio installations on the lifeboats. An operator is not required as the operation can be automatic (following a reasonable amount of instruction to a member of the crew) and the position of the lifeboat will be determined by the rescuing ship with its directional finding equipment.

While radio beacon service is at present of prime importance to aerial navigation, there are conditions where similar facilities might be extended for ocean travel. Rotating beams of this type could supplement ordinary lighthouses and as a matter of fact equipment of this general type is in operation at the present time, but more to give the ship its bearing than for any other purpose. These transmitters have characteristic signals and that together with the assigned frequency determines its identification.

A concentrated beam working on an extremely short wave would be useful in indicating the incoming and outgoing channels in a harbor or through a difficult passage. It might also define a ferry route and prove useful during conditions of poor visibility, and a second reflecting beam used to locate other objects in the immediate vicinity.

There are an unlimited number of applications for radio which will be developed in the future and the progress will only depend upon the number of workers available together with the capital that can be interested.

CHAPTER V

Directional Antennas

Short-Wave Directive Transmitting and Receiving Antennas

As is well known, radio waves are similar in physical nature to light waves, both being electromagnetic phenomena propagated through space by vibrations or disturbances in the ether. The two differ from each other only in the frequency with which the vibration occurs. Radio waves range in frequency from about 10 kilocycles to 10 megacycles. At the latter point radio waves merge into the infra red portion of the light spectrum.

Since radio waves are similar to light it is to be expected that they could be reflected and focused into a beam as are light rays. In fact, in Hertz's original experiments he used a parabolic reflector very similar to a light reflector. The wavelengths used in long wave radio communication, however, are so great that any type of reflecting or directive structure would be prohibitively large and expensive. It was not until short waves began to be used for radio communication that it became possible to build efficient and economical directive antennas.

The short-wave antennas on the Buenos Aires-Madrid radio channel do not employ the parabolic reflector of Hertz. Another property of electromagnetic waves, that exhibited in the refraction of light, is made use of. If a simple vertical Hertz half-wave antenna is excited by signals of its characteristic frequency, it will radiate disturbances into the ether. Viewed in a horizontal plane these disturbances will be equal in all directions about the wire. This is the condition shown in Fig. 81(a). If now a second antenna is placed one-half wavelength from the first and excited in the same phase, it will be seen that in a direction normal to the plane of the two wires and at a point remote from the antenna the radiations will both add together. In the plane of the wires, the radiations from one antenna will be one-half wave behind those from the other and hence will completely cancel. The distribution of field about such an antenna system is shown in Fig. 81(b). It will be seen that with this arrangement radiations occur in either direction normal to the plane of the two wires.

If now two vertical antennas are placed one-fourth wavelength from one another and excited so that the voltage in one leads that in the other by 90°, the distribution of field shown in Fig. 81(c) occurs. In other words, the field cancels on one side of the antenna while it adds on the other, a reflector effect being obtained. By combining the effects shown in Fig. 81(b) and 81(c) the elements of directive antenna employed in the Buenos Aires-Madrid channel is obtained.

All the transmitting antennas described below depend for their action

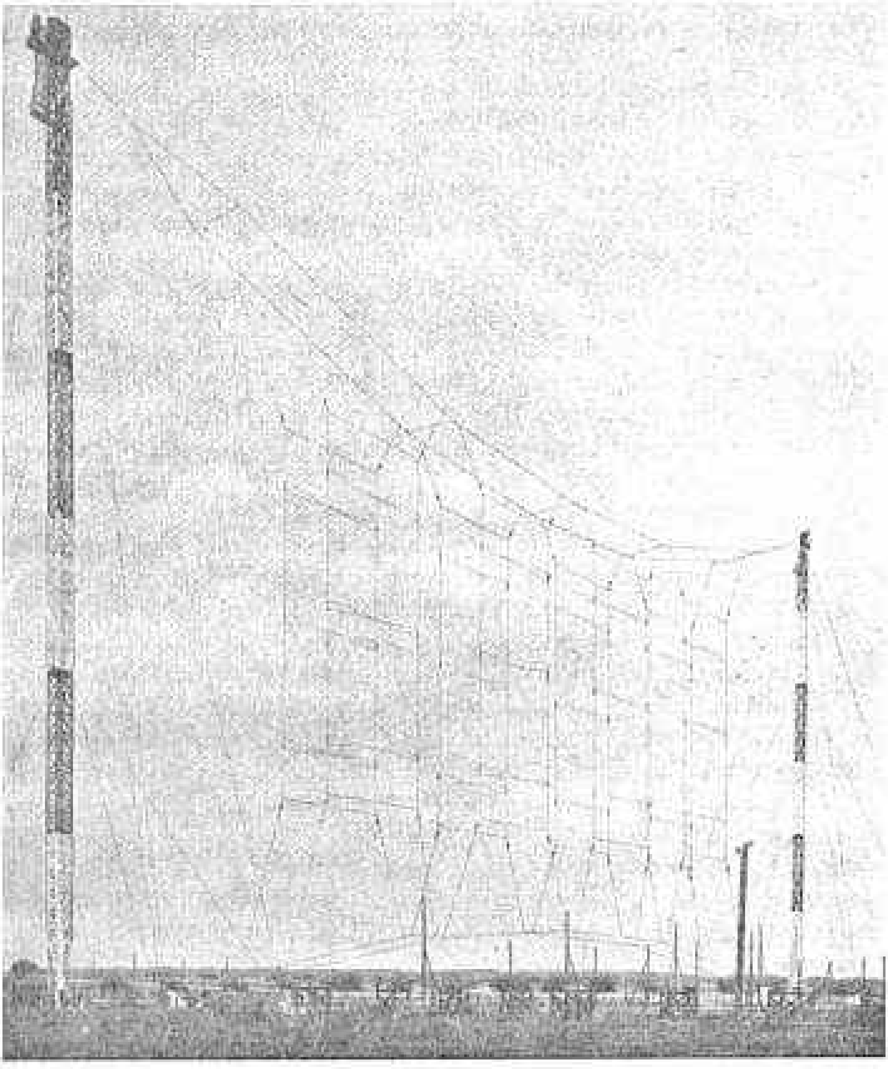


Fig. 80

Fifteen-meter Antennae Curtain with Masts 60 Meters High—Type Used at Madrid.

on these principles. Instead, however, of employing only two phased radiators one-half wavelength apart, as shown in Fig. 81(b), as many as sixteen are placed one-half wavelength apart in one plane, each being backed by its reflector, as shown in Fig. 81(c). The reflectors are ordinarily parasitically driven by the radiator. In like manner, placing of properly phased conductors vertically above one another produces a similar directive effect in the vertical plane. The greater the number of superimposed radiators the sharper will be the vertical directivity. The function of a transmitting antenna is to radiate the output of the transmitter in the desired direction as efficiently as possible. The transmitting antenna of a point to point system should there-

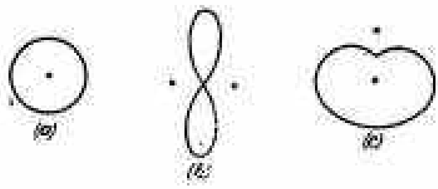


Fig. 81
Antenna
Radiation
Patterns.

fore be as directive as possible, both horizontally and vertically. The horizontal directivity is limited by the economical length of the antenna and the physical accuracy with which it can be directed toward the desired objective. The vertical directivity should be about 10° to 15° for frequencies of 20,000 Kc. and about 20° for the frequencies of 10,000 Kc. Vertical directivity greater than this can be secured but results in a ray so sharply directed that its operation is erratic, due to sudden changes in the height of the Heaviside Layer.

If we consider the vertical wire A. B. C. D. . . OP (Fig. 82) on which are present stationary waves and bend it according to the pattern of Figure 83, the currents will then be distributed as shown in Figure 83. It will be seen that in the vertical portions the currents are in phase, while in the horizontal portions the currents cancel out due to opposite phase. In the end sections O N and G F, the currents are equal and in reverse phase in each of these half sections. The radiation of the horizontal portions is therefore practically nil.

The arrangement shown in Figure 83 constitutes a group of vertical antennas in phase. The antennas of the Buenos Aires-Madrid channel consist in general of 6 to 8 groups of this type placed one-half wavelength from one another in the same plane. Each of these groups is energised by high frequency transmission lines, consisting of two wires, at a point of current maximum such as R and S, and in such fashion that the current in the vertical sections is in phase for all groups. Behind this curtain is another similar antenna curtain which serves as a reflector. The horizontal directivity for such an array is shown in Figure 84.

Transmitting Antennas †

The antenna curtains and reflectors at Madrid are suspended on two cables between guyed masts 60 m. high (See Figures 80 and 85). A spreader consisting of a steel tube $\frac{\lambda}{4}$ wavelength long separates the cables supporting each curtain. The strain at the top of the towers is 5 tons and is automatically regulated by a counterweight. The two supporting cables are attached to winches in order that the curtains may be raised and lowered. A messenger cable to which a counterweight is attached maintains the tension at 5 tons when the antenna is being raised and lowered. The vertical wires of each curtain are kept in tension by counterweights acting through a system

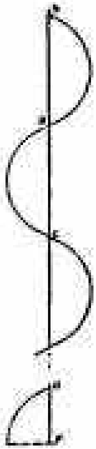


Fig. 82

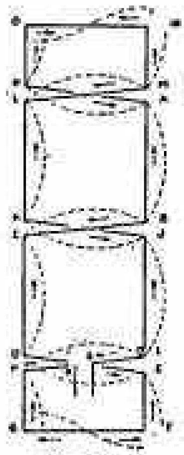


Fig. 83

Vertical Wire Bent According to Pattern of Fig 85; Illustrating Current Distribution.

of pulleys. Very large factors of safety have been adopted and in no case does the tension in an element of the curtain exceed 150 kgms.

At Buenos Aires precisely the same antenna is employed as far as theoretical considerations are concerned. Practically, however, the antenna curtains are suspended from 175′ steel masts. Seven of these masts are employed for an antenna system consisting of three frequencies. The masts are anchored by means of head guys and the curtains can be raised and lowered completely independently of the head guys by means of winches. The method of feeding the antenna curtain, illustrated in Figure 86, differs slightly from that in use at Madrid. A view of the completed Buenos Aires antenna is shown in Figure 87. On any given frequency the gain of such a system over a single vertical half wave antenna is approximately 15 to 20 db.

† Due to the speed with which this project was consummated, the transmitting and receiving antennas originally installed differ somewhat from the description given in this text.

Transmission Lines

The transmission lines which simultaneously feed all the antenna groups should satisfy the two following conditions:

(1) All the antennas should be excited by currents in the same phase and equal in magnitude.

(2) At no point in the line should there be reflection of energy back toward the transmitter.

If the antenna groups of the same curtain are excited by branch lines from the transmission line, it is necessary in order to satisfy the first condition that the length of transmission line be the same to each antenna element from the transmitter and that the branch lines be symmetrical. Since the speed of propagation is the same in the identical branch lines and the length

Fig. 84

Distribution of Field in a Horizontal Plane of an Antenna Array Having Both Radiators and Reflectors.

of the latter are equal, the dephasing due to these equal distances will be the same for all groups of antennas.

To satisfy the second condition and avoid the presence of stationary waves on the transmission lines between the transmitter and the antennas, it is necessary to match the impedances of the transmission line in such a fashion that the line will be terminated by an impedance equal to its characteristic impedance.

Receiving Antennas

The directive properties of the antennas described in the first part of this paper were explained on the basis of a transmitting antenna. It will be seen that the theory is equally applicable to a receiving antenna. Assuming in Fig. 81(b) that the two antennas are so interconnected they are in phase for transmission, an incoming signal will produce a disturbance in each antenna. If the signal arrives from a direction normal to the plane of the two antennas the voltage induced in each wire will be in phase and the two resultant currents will add. If, however, the signal comes from any other direction, impulse will arrive at one antenna before it reaches the other with a result that the currents will not be in phase.

For various reasons, however, a transmitting antenna does not make a particularly satisfactory receiving antenna. It is desirable that the transmitting antenna deliver a raw very narrow in the vertical plane. It has been found that an incoming signal arrives at the receiver at all angles from horizontal to vertical, depending on the manner in which it has been reflected during its passage. The most common angle is between zero and sixty degrees from the ground and an efficient receiving antenna should be equally responsive over this range. The antenna is preferably constructed on a wood frame avoiding as much as possible the use of steel towers or other extraneous reflecting objects which will reduce the directional properties of the antenna by introducing unwanted reflections onto the antenna elements.

A type of antenna which answers these requirements is that shown in Figures 88 and 90. This type of receiving antenna is used both at Madrid and Buenos Aires. It consists essentially of a long wire so folded in space that the vertical elements act as signal collectors while the horizontal members act as interconnecting lines. Both vertical and horizontal members are each one-quarter wavelength long. The voltages induced in the vertical elements by the signal are equal, but the phase relations depend on the direction of approach of the wave. A signal from a direction broadside to the antenna causes, in the vertical elements, voltages which are all in phase. By alternately connecting the tops and bottoms of the vertical elements the wire currents caused by the signal voltages are also in phase and reinforce one another. The voltage and current relations for a broadside signal are shown in Figure 89.

A signal approaching end on to the array, however, produces an entirely different effect, since the incoming wave arrives progressively at each of the vertical members, producing out of phase disturbances. Hence the wire currents are likewise not in phase and cancel one another. Another advantage of this antenna is that the current distribution to a broadside signal is such that a current node is found in the center of each horizontal section. Thus there is no current flowing in the horizontal sections and hence no loss due to the resistance of the wire.

$$AB = MN = \frac{\lambda}{8} \quad BC = CD = DE = FG = \frac{\lambda}{4}$$

The antennas of this type constructed on the Buenos Aires-Madrid link have a total length of structure of five and a half wavelengths. They deliver to the receiver a signal about 15 db. higher than a single vertical half wave antenna. The improvement in the ratio of signal to unwanted static is likewise about 15 db.

Figure 88 shows a method of connecting such an antenna to the receiver. An oscillating circuit LC is connected on one side to the antenna and on the other side to the reflector between voltage maximum points such as A and R in such a fashion that the length of wire AB connecting the point A to the oscillating circuit is $\frac{\lambda}{4}$ shorter than the length RD connecting the reflector to the point D of the oscillating circuit. This is to say:

$$RD = AB + \frac{\lambda}{4}$$

When a wave of length λ arrives in the direction of the arrow F, it induces in the antenna and reflector, currents separated in phase by $\frac{\pi}{2}$ since the distance between the antenna and the reflector is $\frac{\lambda}{4}$. Hence at points A and R, which are voltage maximums, there will be equal voltages but dephased by $\frac{\pi}{2}$. These currents in order to reach the oscillating circuit will require a time proportional to the distance. Since the distance RD is greater by $\frac{\lambda}{4}$ than the distance AB, the voltage coming from the reflector will lag an additional $\frac{\pi}{2}$ and the oscillating circuit LC will be excited at the points B and D by two voltages of the same character and amplitude but dephased by π. If V is an absolute value of the voltage between the points AR, the voltage acting on the oscillating circuit LC will be equal to 2V. It is possible to arrange a number of other types of couplings.

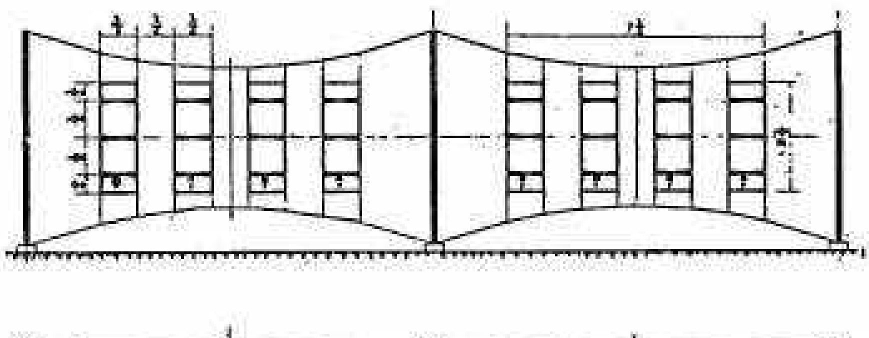


Fig. 85
Plan of Madrid Transmitting Antenna.

Directional Antennae as Used in England

In England, the British Post Office operates radio service in several branches including ship to shore radio telegraphy, long distance long-wave operation from Rugby, point-to-point radio-telegraphy service to a number of European countries, point-to-point radio-telephony service and radio

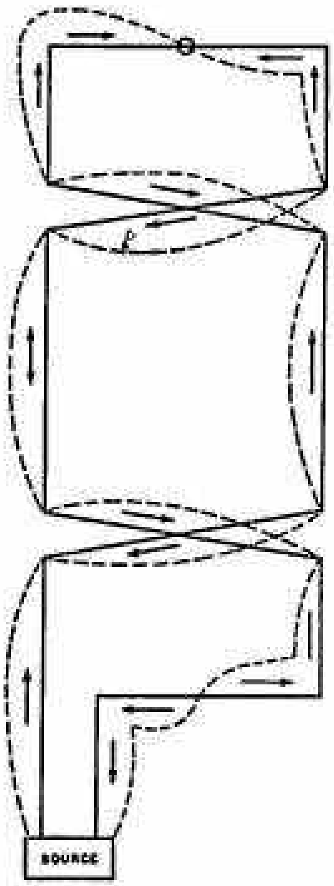


Fig. 86

Typical Antenna Panel—Buenos Aires Transmitting Antenna.

-phony to ships. An important part of these services is conducted on short wavelengths.

The long range ship service is taken care of from Portishead (transmitting) and Burnham (receiving) stations. In addition to the long-wave installations there are two short-wave transmitters which can communicate with ships in any part of the world. These short-wave transmitters operate on 8,210 kc. (36.54 meters) and 16,840 kc. (17.81 meters). The tube used in these transmitters consists of a 3½ kw. silica valve with a tuned circuit in series with the grid and anode. This special oscillating circuit was developed by the Post Office for this service and has the merit of great simplicity, and together with other features included, gives a frequency constancy well within the requirements specified. The supply current, rectified and partially smoothed out, gives a characteristic 600 cycles note.

The 16,840 kc. transmitter is coupled to a horizontal array with a 2-wavelength aperture mounted on a lattice steel girder which is capable of rotation on a vertical axis. Fig. 91 is a photograph of the rotating aerial system. The rotation of this beam system and the keying of the transmitters are controlled from the receiving station at Burnham. For the 8,210 kc. transmitter a ½-wavelength vertical dipole is used as a radiator.

At the Burnham receiving station in addition to the long-wave receivers there are short-wave receivers for the 36 and 17 meter ranges. As a matter of comparative interest is should be mentioned that the long-wave receivers

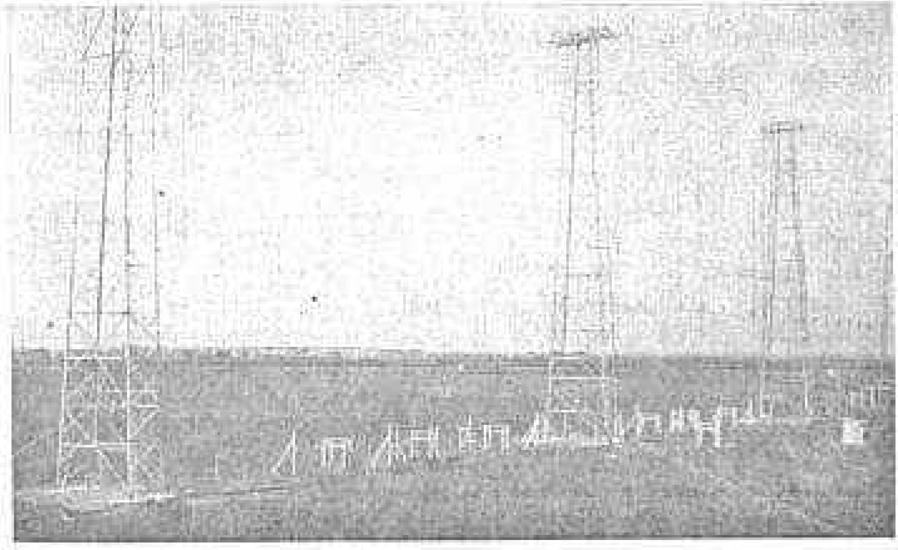


Fig. 87

Buenos Aires Transmitting Antenna.

are provided with large frame aerials and verticals providing a cardioid diagram for directional reception, and have a six-stage high-frequency amplifier, separate oscillator, and also low-frequency band filters. A rotating array similar to that at Portishead is provided for the directional reception of the 17-meter service.

The use of a beam antenna for reception and transmission gives a substantial improvement on any short-wave service, and the use of a rotatable system has solved the problem of adapting the directional array for ship service. After locating the ship desired by means of the receiving system, the transmitting array is directed on the ship by remote control from the receiving station.

Horizontal dipoles with open transmission lines are used for the 36-meter service.

There is a complete chain of British short stations for ship-to-shore service and as they operate on commercial wavelengths they will not be described. It should be mentioned however that at the receiving stations, special frame aerials are used to secure directional reception which in addition to providing the location of the ship also reduces interference from other stations.

At Rugby there is a high-power long-wave station and experiments have been conducted in measuring the field strength at distances up to 8,000 miles from this transmitter. These results have been plotted and at the same time the corresponding noise level measured. While the signals from Rugby decrease gradually with distance, there are points where the noise level is ex-

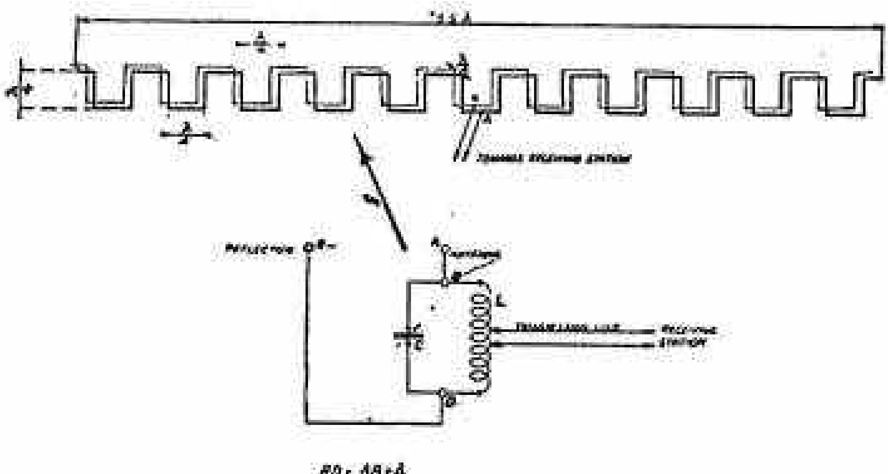


Fig. 88
Directional Receiving Antenna of the Frame or Zigzag Type.

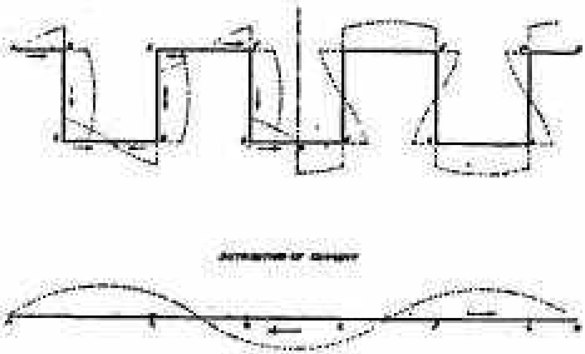


Fig. 89

Distribution of Current and Voltage in a Frame or Zigzag Type of Antenna.

tremely high, particularly at distances of 4,000 to 6,000 miles and under which conditions communication was not possible. To overcome this disability advantage has been taken of the fact that short waves are much less affected by atmospheric interference and long and short waves do not always fade simultaneously, and a short-wave service is now operated parallel with the long-wave service for press dispatches.

The point-to-point radio-telegraph services are carried out on both long and short-wave transmitters, particularly the latter during the summer months when atmospheric conditions are severe. The transmitters are located at Rugby and Leafield and the receiving station at St. Albans. These stations are controlled from the Central Radio Office at London, no operating being done at St. Albans. Most of the reception is taken on automatic perforators and printers.

At the St. Albans Receiving Station, in addition to the long-wave receivers, there are four short-wave receivers. These sets are of the double detection type with band filters. Each amplifying stage comprises two tubes arranged in push-pull and each stage is carefully screened. Suitable limiting and recording tubes are provided and the receivers are capable of working up to speeds of 400 words per minute.

In the point-to-point radio-telephone service the plant at Rugby has grown from one long-wave transatlantic transmitter installed in 1926 to one long-wave and six short-wave transmitters in 1930. It is anticipated that by 1933 one long-wave and at least six short-wave transmitters will have been added to the present plant. A plan of the site showing the layout of the mast and buildings is shown in Fig. 91 (a).

The existing long-wave transmitter was installed in 1925 by the Standard Telephones and Cable Co., Ltd., under the direction of the Bell Telephone

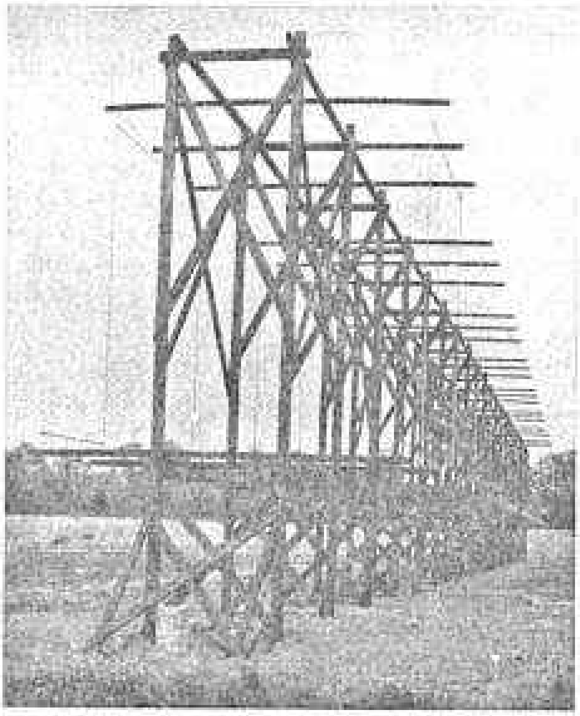


Fig. 90
Zigzag
Receiving
Antenna.

Laboratories and in coöperation with the British Post Office. It was with this transmitter that the transatlantic telephone service was opened in 1927.

The first experimental short-wave transmitter was installed in 1928 and used as an auxiliary to the long-wave circuit on the transatlantic service. Later this was repalaced by a new transmitter in 1929. In 1928 plans were prepared for a new building to house an additional long-wave transmitter and nine short-wave transmitters. During 1929 two additional short-wave transmitters were placed in service and during 1930 still two more short-wave transmitters, one for ship-to-shore service and the other for telephone service to Australia.

The transmitters ordinarily have a modulated power output from the final rtage of 8 to 12 kw. depending upon the wavelength. If desired the penultimate stage can be switched on to the aerial transmission line in lieu of the final stage when a power output of 3-5 kw. is obtained. Balanced push-pull circuits are used throughout on the amplifying stages. The crystals are fitted with thermostatic temperature regulators.

Each transmitter is capable of operating on three or four wavelengths in a band of from 15 to 50 meters, facilities being providea for rapid change from one wave to another.

For the reception of signals from Rock Point, N. Y., it was decided to use directional type aerials, which would eliminate atmospheric disturbances from the opposite direction and which in this particular case was the direction from which the disturbances were of the greatest intensity. The antenna system at Cupar for long-wave telephone reception consists of six large loops with associated vertical antennas arranged in three pairs as shown in Fig. 91 (b). Each unit of a pair is spaced a quarter of a wavelength, i.e., 1,250 meters, from its partner in the direction of the received signal and pairs are spaced 0.62 of a wavelength apart in a direction normal to that of the received signal.

The signals from the antenna units (each consisting of a loop and vertical) are led to the receiving station by six pairs of transmission lines. These signals are combined to give best directive characteristic.

Each loop antenna consists of four turns of silicon bronze wire supported by two 130-ft. steel lattice self-supporting towers spaced apart a distance of 200 yards. The top of the loop is 110 ft. above the ground and the bottom 20 ft. above the ground. The turns are spaced four feet apart. The vertical antenna consists of a single horizontal portion stretching the full distance between the towers and therefore 130 ft. high, with the down lead at the center

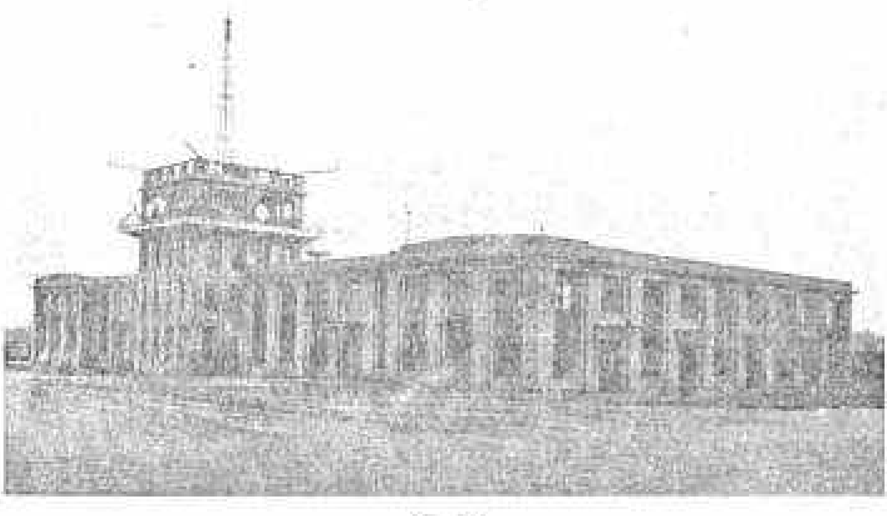


Fig. 91

London Terminal Airport at Croydon.
The radio control room is on the top floor of the control tower. On the roof a 54-foot mast supports a Marconi Ballini-Tosi aerial made of two double triangular loops at right angles to each other.

of the system. The outputs from the loop and vertical are combined by the apparatus shown in Fig. 91(c). When atmospheric disturbances are unusually severe, the vertical can be disconnected by relays and the loop used exclusively.

The loop systems have been in use on the transatlantic telephone system since May, 1928, and satisfactory service has been obtained throughout, except at some of the sunset periods and for a few days when forward end storms have occurred. Before the above date, a wave antenna was used. A direct comparison between a double broadside of wave antennae against a double broadside of pairs of loop and vertical combinations showed an average improvement in favor of the loops of 2 db. The energy pick-up of the loop system over the old wave antenna shows an improvement of 4 db. It is customary to compare the signal-to-noise ratios of the antenna arrays against that of a single loop aerial and these improvement figures of 1929 are given, as follows:

Average improvement of triple broadside to 3 pairs of partial cardioids over one large loop antenna........................	20.2 db.
Average improvement of triple broadside of 3 pairs of cardioids over one pair of cardioids....................................	5.8 db.

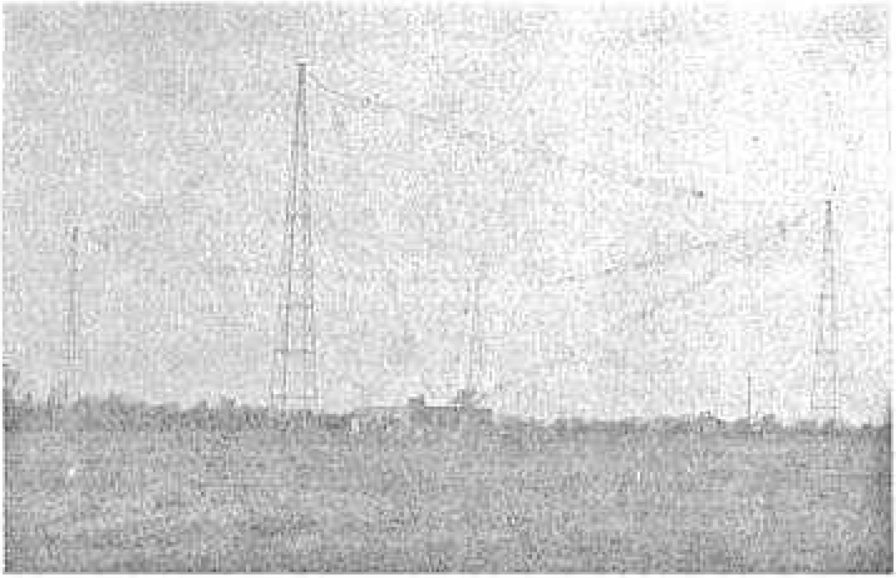


Fig. 92

The Masts and Transmitting Building at Croydon.
The four masts each 180 feet high support four cage aerials of the inverted "L" type. The masts are located at the corners of a 250-foot square.

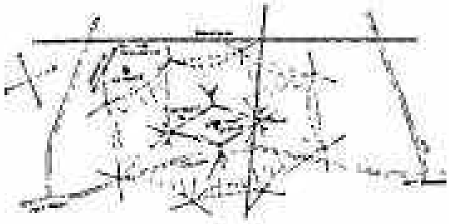


Fig. 93
Transmitting Antenna Layout, Nauen, Germany.

Average improvement of double broadside of 2 pairs of cardioids over one pair of cardioids..........................	3.9 db.
Average improvement of triple over double broadside...........	1.8 db.

It is proposed in the near future to add two more loop systems, that is, converting the antenna system into a quadruple array. It is hoped by this means to narrow to a still greater degree the directive curve on reception from the front end although not much improvement is expected from the back end directions as the existing balances are very good.

For the short-wave channels reception is being concentrated at Baldock, about 40 miles from London and the arrays are situated around a central receiving station building, the outputs of the various antennae being led into the building by special transmission lines.

The site of this station is approximately 900 acres in extent, in order to

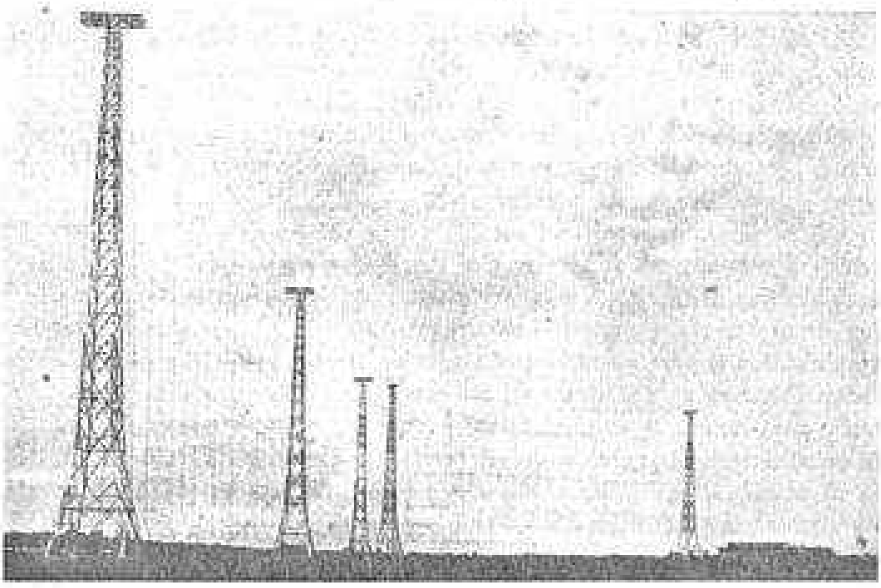


Fig. 94
Transmitting Antenna Systems at Nauen, Germany. Directional Type.

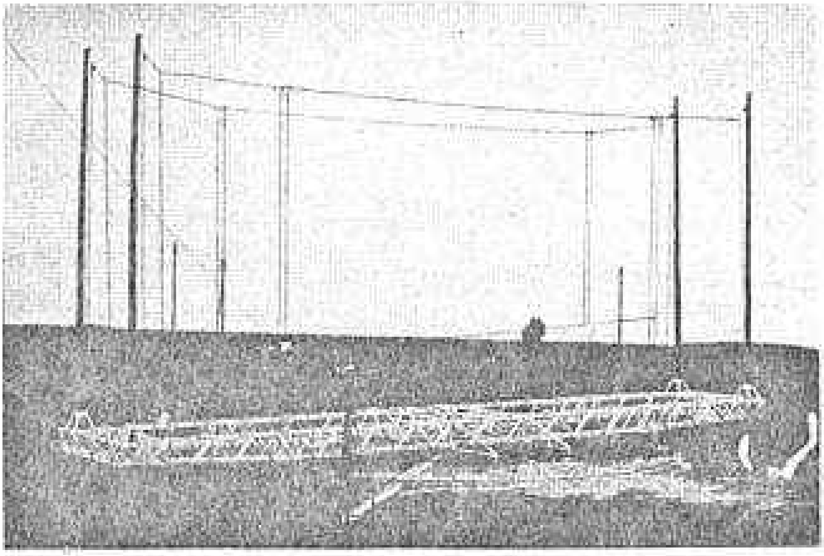


Fig. 91
Portishead Rotating Beam.

accommodate the multiplicity of short-wave arrays which will be required. The ultimate capacity of the station will depend largely on the number of aerial arrays which can be accommodated but it is anticipated that this will be at least 16 short-wave receivers and one long-wave receiver. On the short-wave bands fading of various types occurs. The receivers are therefore designed to have a large gain and are fitted with automatic gain control devices which keep the audio-frequency output sensibly constant although the signal input may be varying as much as 50 db.

A block diagram of the Post Office receiver is given in Fig. 91(d) from which it will be seen that there are two stages of push-pull high-frequency amplification, the first stage being in triplicate for connection to three receiving arrays working on different frequencies. The intermediate frequency amplification is performed by five stages of screened-grid tubes and the selectivity obtained by the intermediate frequency band-pass filter. The automatic gain control is obtained by means of a separate detector tube connected in parallel with the regular second detector. This tube has a high resistance in its anode circuit. The voltage drop across this resistance varies with the strength of the incoming carrier and is applied as a negative grid bias to the first tube of the main intermediate amplifier.

It should be pointed out that one of the duties of the high-frequency stages is to supply sufficient selectivity to differentiate between the two frequencies which are separated from the beat-oscillator frequency by an amount

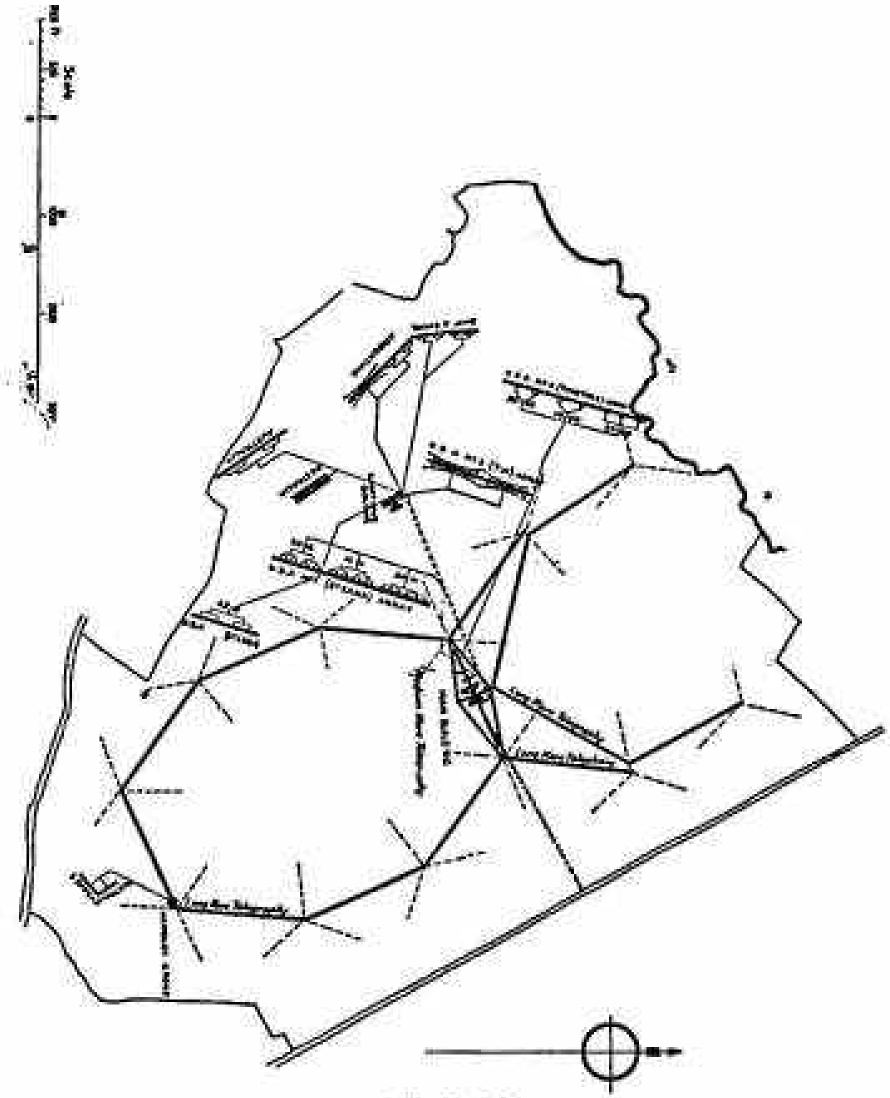


Fig. 91 (a)
Rugby Radio Station.

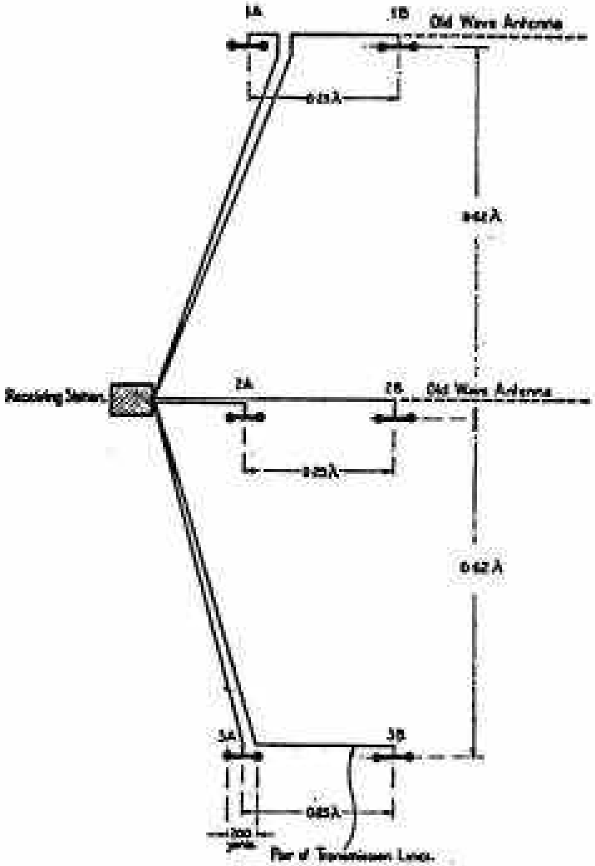


Fig. 91 (b)

Antenna System, Cupar. λ 5,000 meters. Staggering distance = 1,250 meters. Broadside distance = 3,100 meters.

equal to the intermediate frequency. In the Post Office receiver, this intermediate frequency is around 300 kc so these bands are separated by 600 kc and therefore the measured band width of the high-frequency circuits must be much less than 600 kc. The band width is usually measured at 6 db down from the maximum value on the frequency transmission characteristic and it will be seen that on the 30 meter wave-length the band width is only 52 kc. At 600 kc from the center of the band the attenuation is over 60 db. These stages give a gain of approximately 25 db on 30 meters and about 15 db on 15 meters.

The intermediate frequency filter has a loss of about 11 db in the band pass and therefore additional gain is supplied in the intermediate frequency amplifier to counteract this, and the over-all gain of this amplifier and filter is around 85 db, the band width being 9 kc.

The measurement of over-all gains of the order of 100 db and above is always difficult and is more so when the input frequency is 15 megacycles. Therefore in order to check the gains it is usual to connect a vertical antenna a half wavelength long to the receiver and to generate a field from an oscillator situated some distance from the receiver. The field strength at the same distance from the oscillator as the receiver is measured by means of a short wave field strength measuring set and a comparison between the different receivers can thus be made.

When using a vertical antenna a half wavelength long, a received signal of 0.4 μv per meter on 35 meters is capable of working the second detector up to the level at which the automatic gain control starts to operate.

It is the experience of the Post Office that for short-wave reception very much greater amplification can be used than in the case of long waves owing to the usual much lower noise level, and the full amplification provided on these receivers can at times be very usefully employed.

Both for radio telegraphy and radio telephony the British Post Office has built a large number of short-wave directive aerials of various types. The Sterba and Bruce types, well known to American engineers, are used for transmission and reception purposes respectively while the Dutch (Koomans) type, both in its vertical and horizontal form, is employed both for transmission and reception purposes. At Rugby and Baldock a modification of the Bruce aerial has been introduced with improved results over the original type. The single square pattern is retained but a second square inverted pattern has been added as shown in Fig. 91(e). Experiments have shown that the horizontal arrays having the same number of elements as vertical arrays and suspended from structures of the same height generally give a greater gain than the vertical type. From various types of aerial systems now in use on different services, both for transmission and reception, experience is being obtained and data coördinated as to the most effective types for the diversity of frequencies, distances, and conditions for which directive propagation is

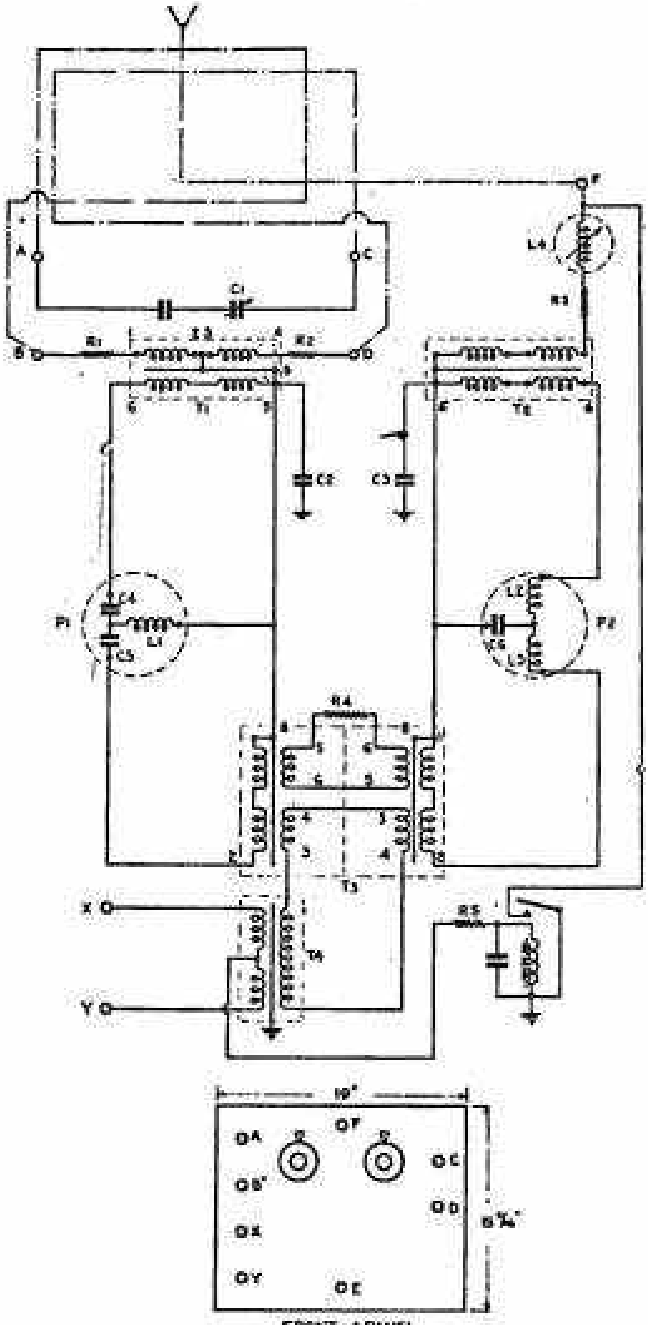


Fig. 91 (c)

Loop and Vertical Combining Apparatus.

adopted, but finality had not been reached. The most recent development utilizes the fact that appreciable gain can be obtained by building arrays in two curtains one behind the other. An example of an array of this type designed by T. Walmsley, which has been used successfully on the transatlantic telephone service is shown in Fig. 91(f). In effect, two curtains consisting of horizontal radiators spaced half a wavelength apart are erected one behind the other, the currents in the front curtain being 180 deg. different in phase from the currents in the back curtain. Good reflection action is produced if a reflector curtain consisting of an insulated half-wave element is fixed about a quarter of a wavelength behind the back of the excited curtain. For example

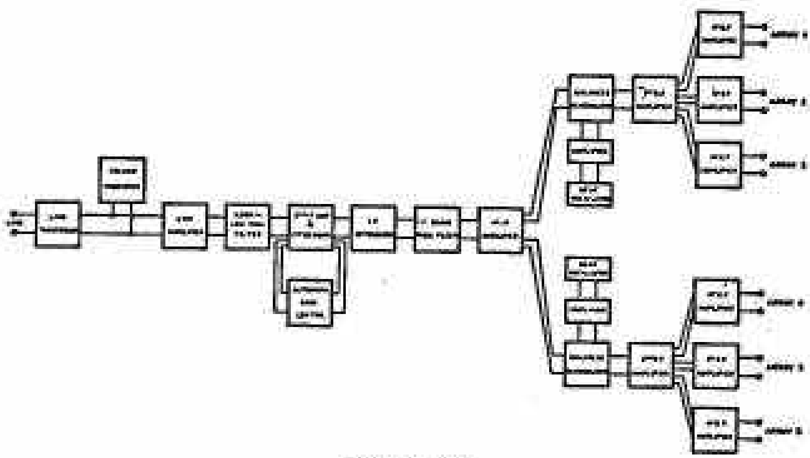


Fig. 91 (d)
Baldock Short-Wave Receiver.

in Fig. 91(g) in which the measured horizontal diagram of the vertical type of array is given, the front-to-back ratio of field strength is about 4.5 to 1 or 13 db. The array consists of 48 vertical directly energized radiators and 48 half-wave reflectors.

The development of radio-telephony service to ships from England has followed the same general lines as that of short wave point-to-point radio-telephony with such modifications as have been necessary to allow for the variability in the length of the path and divergence in the angles between the position of the ship and the land station.

The Rugby and Baldock stations are being employed for the transmission and reception and the control is centered on the London trunk exchange.

Tests between Rugby and the "R.M.S. *Olympic*" commenced in January, 1930. These tests gave such promising results that a commercial service was started in the following February and soon extended to four ships. The transmitter at Rugby on the marine service was built by the Standard Telephone &

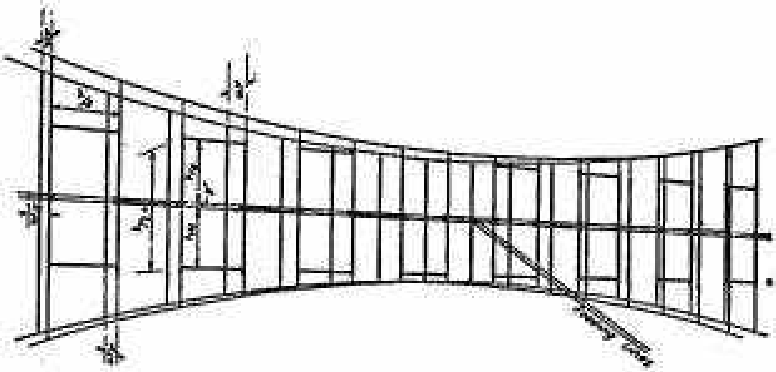


Fig. 91 (e)
Double Key Vertical Array with Reflector.

Cables Ltd., and is very similar to those used on the London-New York circuit. The final power amplifier, however, only employs two water-cooled tubes and the unmodulated carrier power in the antenna is 3-4½ kw.

It has been found necessary to utilize four different frequencies in order to span the Atlantic, and from the Rugby station these frequencies are as follows:

(a) 4975 kc (60.3 meters)
(b) 8375 kc (35.8 meters)
(c) 12780 kc (23.47 meters)
(d) 17080 kc (17.56 meters)

Of these (a) is used only to communicate with ships which are within

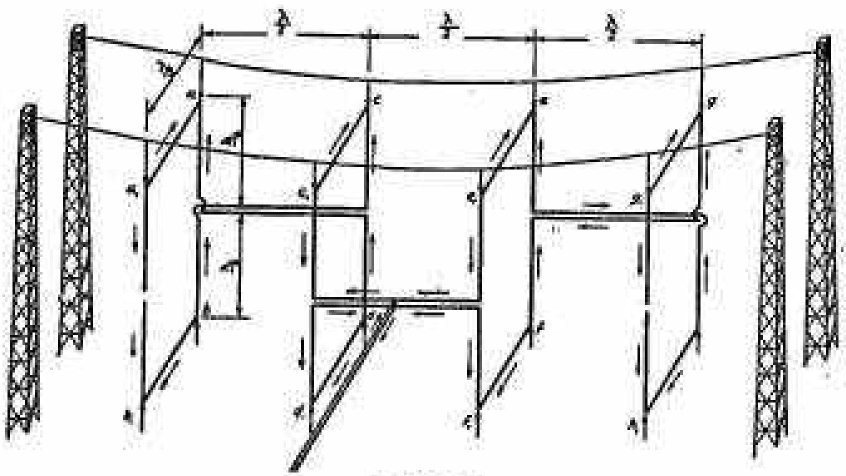


Fig. 91 (f)
"T. W." Short Wave Aerial (single-vertical unit).

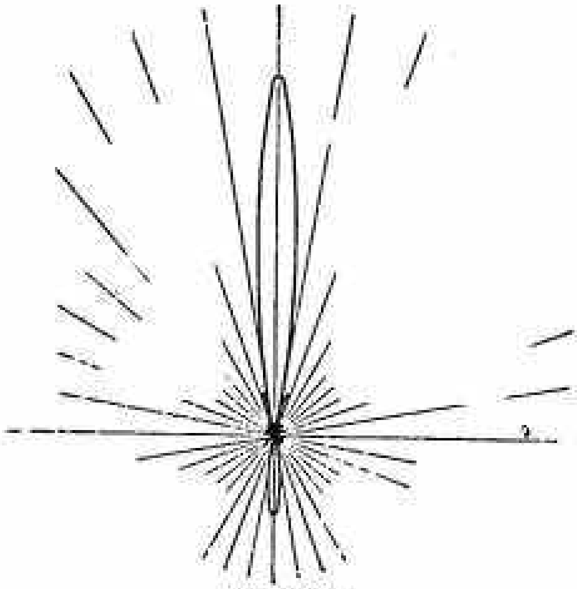


Fig. 91 (g)

Measured polar diagram in horizontal plane of "T. W." vertical 3-unit array. Span between end radiators 5½ wavelengths.

one day's run of Southampton; (b) is used by day during the second and part of the third day out, and for night transmissions; (c) is used by day when the ship is in Mid-Atlantic and during evening periods; while (d) is used for day transmission only as the ship nears New York.

Horizontal transmitting aerials are used on all frequencies and have been found to give distinctly superior results to those obtained with vertical aerials. On 17,080 kc an array of 32 half-wave dipoles is used, giving a fairly concentrated beam along a center line 15 deg. south of the Rugby-New York great circle. On 12,780 kc another horizontal array of 24 lipoles gives a rather wider beam directed along a line 25 deg. south of the London-New York great circle. Simple arrays are used on 8,373 and 4,975 kc owing to the wide angles which have to be covered when the ship is near England.

The chief difficulty in this communication was expected to be in establishing communication between Rugby and ships close in to Southampton. The difficulty, however, seems to have been almost entirely overcome by the use of the 4,975 kc frequency in conjunction with a simple horizontal array of four doublets, giving high angle radiation, and directed 20 deg. west of Southampton; and ordinarily, a ship can be worked right up to the English Channel into Southampton docks.

The receiver at Baldock is similar to the transatlantic telephone receivers. Arrays having directional effects similar to those at Rugby are used.

The operation of the service presents several difficulties due to (a) the number of different frequencies employed, (b) the increasing divergence between ship and Greenwich mean time as the ship steams west and (c) the fact that each ship has to work both to America and to England. Naturally these difficulties increase as the number of ships fitted with radio-telephony equipment increase.

The following method of operation as arranged between the American Telephone and Telegraph Co. and the British Post Office is at present in use and is giving satisfactory results for the number of ships at present in commission. Each ship is provided with two sets of frequencies for each band, one set working to New York and the other one for working to London. For convenience, the Atlantic is divided into "European" and "American" zones, the dividing line being the meridian 37 deg. 30 min. west of Greenwich. Each day is also divided into periods, usually each of three hours duration, and operating schedules are so arranged that when London is working with ships in the American zone, New York works ships in the European zone, and vice versa.

Each day the approximate position of the ship and the expected days run are plotted on a special chart, both at the land terminal and on the ship. Reference to this chart then shows to the operator at either end (a) the time during which the ship should communicate with London or with New York and (b) the best wavelength to use on either service. (In cases where, during any period, the ship leaves one zone and enters another, the zone in which it will lie at the end of the period counts as the appropriate zone.) The ship at the commencement of each period tunes in its receiver and transmitter to the appropriate wavelength, and listens for the land station. The land station in the meantime calls up any ship for which it has outgoing traffic and disposes of this immediately if possible. It then calls up any other ship which is in the zone listening on the same wavelength, and from it receives any incoming calls. Then if reference to the chart shows that other ships are in the same zone but should be worked on another frequency, the land station changes over to that frequency, calls up the ships and receives any traffic which may be waiting.

The technical operators turn over the circuit to traffic without a formal line-up if it is evident that the circuit is commercial, and noise measurements, etc., are made during actual traffic. A period of five minutes only is allowed for establishing contact and generally this has been found to be quite sufficient.

In general the operation is simplified by the fact that the ship and shore stations before losing contact during any period usually make arrangements with regard to frequency and time of work during the next period.

Directional Antennas—Practical Problems

Each short-wave transmitting station produces a certain electric field strength at the various locations where the signals are received. In the case of ship-to-shore work this is a variable amount; in the case of point-to-point work a certain definite figure can be decided upon. For transatlantic work it has been found that a value of approximately 10 μv per m is generally satis-

Fig. 91 (h)

Illustration of a Setup for the Measurement of Electrical Field Strengths at the Receiving Point.

factory. On some days telephone communication can be established when the radio noise is low with a value considerably less than 1 μv per m while on other days of extremely bad noise and fading 100 μv per m may not be sufficient. The low signal level or low signal-to-noise ratio is only one of the many problems connected with the effectiveness of the telephone circuit. Fading which at the same time usually gives bad quality is an equally important factor. These factors cannot be separated easily as they usually occur at the same time. The low signal-to-noise ratio occurs alone more often than does fading.

One of the most important and difficult problems is the maintenance of service on days during magnetic storms (solar conditions). Observations have indicated that these difficulties are more pronounced in high latitudes than in the case of transmission across the Equator. In actual practice this magnetic effect has been so disturbing that transatlantic signals are so attenuated that even the carrier cannot be detected as a beat note. Such extreme conditions in order to be overcome would require an increase in signal-to-noise ratio of more than 30 db over the values now used. It will, of course, be difficult to secure an improvement of this value and furthermore, there is no definite assurance that the gain required may be in excess of this value. In any event the various improvements made from time to time will materially reduce the time during which the circuits are made "uncommercial" by these unusual conditions.

As previously explained long distance short-wave systems require several wavelengths for twenty-four-hour operation throughout the year. This applies both the point-to-point work and for ship-to-shore communication. In recent practice transmission during the daylight period for the transatlantic work has been carried on at frequencies of approximately 17 to 19 megacycles. It has been noted that on winter days somewhat better results are obtained through the use of lower frequencies. Observations show that in different years the results obtained in order to secure the best daylight frequency have varied widely. During 1926-1927 on the transatlantic system a frequency of 13 megacycles was useful over a longer period than in any winter since.

During the winter night there is another extreme in that a frequency as low as 6 to 7 megacycles was found desirable. These limits of frequency represented by the summer day and winter night create a condition where intermediate frequencies must be selected to secure the desired results. The actual number of frequencies required depends upon the importance of service when part of the space between the receiver and transmitter is in daylight and the balance in darkness.

One of the most difficult times of the year is in the winter afternoon. The sun has set in England but it is still daylight in America. During this period the optimum frequency varies gradually from the morning frequency of 18 megacycles to a value one-half of this amount at 6 p. m. Eastern Standard time.

The additional fact that the conditions change considerably from day to day makes the selection of operating wavelengths still more difficult. As time passes there will be a relatively large number of channels in operation between the point-to-point systems. By making a change in frequency in one of them the desired information peculiar to that particular day can be readily obtained. This observation will be a guide to deciding the proper time to change frequencies in the remaining channels.

In the transatlantic channels provision is made to operate at frequencies of 19 megacycles (16 m) 14 megacycles (21 m) and 9 megacyclees (31 m).

In addition one channel is equipped to use 6.7 megacycles (45 m), this frequency being provided to cover the winter night satisfactorily.

Very little changes in frequency are required during the long summer days.

The usefulness of the 18 megacycle band does not deteriorate with sunset but continues on into the night. In some case it may be used even later than midnight but in each case it always fails during the hours preceding sunrise in America. The summary is, therefore, that short-wave transmission is

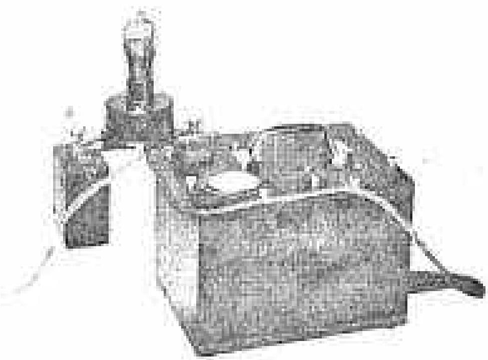


Fig. 91(i)

Precision Wavemeter With Oscillating Tube Inserted Between the Inductances and Variable Condenser of the Measuring Circuit.

at its best during the summer. Fortunately, this is most desirable in view of the fact that long-wave transmission is most difficult under the same circumstances.

Field-strength tests and measurements have been made over an extended period, most of the measurements having been made at the English end of the transatlantic system. Observations have been made on frequencies varying from 2.7 to 27 megacycles. Some measurements have been made at higher frequencies.

Sufficient data is not available to summarize results completely but some of the conclusions will be indicated.

During June, 1926, the field strengths reported were at a minimum during the daylight period due to the daylight absorption of the lower frequencies in the short-wave region. These same frequencies gave excellent results at night. This is typical of mid-summer results in these particular latitudes and the small period of satisfactory night-time reception is due to the short time the whole path is in darkness. On the other hand, considering the winter quarter the period of satisfactory low frequency transmission is greatly increased on account of the longer nights. These observations made in England were from the transmitting station located in Deal, New Jersey. It is likely that if the transmitter was located farther North the summer night-time peak at 9 megacycles would have been reduced or even eliminated. This is due to the fact that conditions in the upper atmosphere might have been approximately the same as those of daytime all along the path. In a like manner an opposite change might have been observed if the receiver had been movd to a point south of England equal to the latitude of New York.

Similar results have been obtained and observations made from Buenos Aires on the same Deal Beach transmitting station. The general characteristics are the same as those already given. On account of the greater distance the frequencies required are higher and the seasonal variations are much less pronounced since the opposite seasons are encountered at the two ends of the path.

In addition to the field strength measurements intelligibility tests have also been made. These are determined by the percentage of words understood. On this basis it is possible by extrapolation to attain a good idea of the communication to be expected with facilities which are better or poorer than those actually available. Of course, these estimates are not wholly reliable but are valuable in determining certain tendencies which are of interest.

It is, of course, interesting to determine the average percentage of the day that a transatlantic short-wave circuit is satisfactory and this data is being accumulated from regular observations. A dependable estimate of commercial reliability cannot be made in advance of actual use under practical conditions. The data given is, therefore, confined to experimental data and the methods used in estimating the effects of increasing or decreasing the signal-to-noise ratio. Each individual observation is supposed to indicate whether the experimental intelligibility was greater than that assumed to represent the line between a "commercial" and "uncommercial" circuit. The understanding of 60% of a list of unconnected words was arbitrarily taken as the criterion. In addition the field strength is known. At the receiving station there was used an elementary antenna with three "reflectors." The observations were collected in groups according to field strength—for example: the groups may be 5 db wide—and the percentage of each group which is commercial is recorded and may be plotted on a graph. Such a curve will indicate the fact that as the field strength is increased the probability of the circuits being satisfactory also increases, eventually reaching a value which may be somewhat less than 100%. In making extrapolations the assumption is made that while intelligibility is affected by fading, the differences in intelligibility at different levels are caused by differences in signal strength only. While this assumption seems evident it may not be entirely above question but probably is not far from wrong. Other observations indicate that with a power of 5 kilowatts used over transatlantic distances with simple transmitting and receiving antennas it may be possible to obtain a reliability in the order of 20% to 30%. In view of this a small gain in the system would result in considerable improvement. Under these circumstances and due to the fact that for short waves directivity provides an economical manner of obtaining a considerable signal increase makes it greatly advisable to use at least elementary directive antennas at both ends of the point-to-point radio links.

Depending upon the importance attached to the maintenance of continuous communication and the economic feature determines the extent to which these improvements can be made. Under certain conditions remarkable success can be obtained with simple apparatus and at other times the results obtained are of little consequence. These variations correspond to a power ratio of 1,000 to 10,000 times. It must be remembered that for slow-speed telegraphy a much weaker signal can be employed successfully than in telephony or in high-speed telegraph. This gives a good idea why commercial services require so much more elaborate facilities than amateur work. Additional measurements indicate the fact that one kilowatt radiated at frequencies below 50 kc gave stronger signal fields than at very high frequencies. This is also true during night conditions. There is some uncertainty as to the behavior of intermediate frequencies. These observations clearly indicate the fact that solely from the viewpoint of transmission very long waves—for example: 20,000 meters—are for transatlantic distances somewhat superior to very short waves—for example: 15 meters. One kilowatt gives about 20 μv per m at 20,000 m and only 3 or 4 at 15 m.

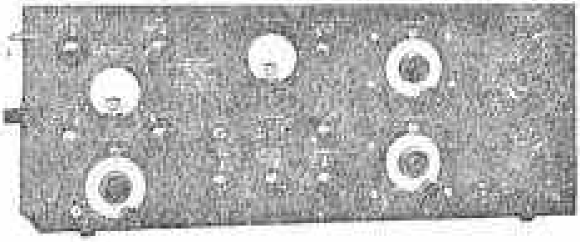


Fig. 91(j)

Special Antenna Measuring Instrument Built for U. S. Coast Guard Enabling the Direct Measurement of All the Various Characteristics of an Antenna.

This is, however, only one angle of the comparison. It is by far much more expensive to radiate 1 kw with long waves than to radiate the same power with short waves and furthermore, it is out of the question in a long-wave transmitting antenna to obtain the degree of efficiency which is possible in a short-wave directive array. This difference is not definite in the case of the receiver. Substantial gain in signal-to-noise ratio can be obtained through the use of directional reception with both short and long waves. An additional consideration is the fact that it is not customary to use as high a power with short waves as with long. A still further and important consideration in the comparison is the amount of noise encountered in the two frequency ranges. In some cases this difference has been over-estimated but generally static is less in the case of short waves. The summary of the comparison is that the larger power at low frequencies together with the smaller amount of time lost due to magnetic storms and fading sometimes offsets the advantages of high frequencies resulting from the improved antenna efficiency and reduced static.

There are several considerations entering into the design of a suitable transmitting antenna pending upon the requirements and limitations. The directional properties of the medium must be considered to meet the conditions specified. In this design it is also important to consider the distribution of the currents both in regard to the phase and spacial arrangement in order to satisfy the original conditions. This circuit must be determined which will provide these currents.

The term "broadside" is usually applied to antenna arrays where the elements are located along a horizontal line perpendicular to the line of transmission and excited in the same phase. A large number of antennas of this sort have been constructed and tested by transmission to England. These arrays have varied in length from 1 to 9 wavelengths. Up to 6 wavelengths the gain calculated has been actually obtained within reasonable limits using a wavelength of 16 meters and with daylight conditions. In some cases longer antennas have also given the calculated gain. In the case of the antenna six wavelengths long there was a major lobe whose width from minimum to minimum was 19 degrees and it appears that the range of useful bearing was less than one-half of this value. Under actual testing conditions the direction of the most important component for the signal did not deviate from the geographical bearing by more than ± 5 degrees. During these experiments in one instance two receivers were employed. One was located in London which was on the great circle normal to the antenna length and the other located in Scotland on the great circle about three degrees difference. With these conditions relative signal strength was measured for the two directivities of the system. These readings were taken over a period of several hours of daylight transmission of 16 m. This antenna having a major lobe of 9½ degrees width from maximum to minimum would be expected to give decidedly different signals under the two conditions. As a matter of fact this was found to be the case and the observer found that on the average the difference numerically checked with the assumption the maximum signals clustered closely about the great circle paths. These measurements were so accurate that they would have served with good accuracy to determine the bearing of the receivers. This brings out the fact that these very short wavelengths may prove useful for beacon service. Time did not permit determining how short a measurement period might be made without loss of accuracy. Further information was obtained by consideration of the well-known phenomenon that near a receiver fading differs at two points which are a few wavelengths apart. For example: if there is simultaneously present in the received wave two components from somewhat different directions and if they add in phase at one of these locations, they will be out of phase at a second point provided it is sufficiently distant.

The existence of this fading phenomenon, conversely, is always caused by the existence of two or more components traveling in different directions. Under the circumstances it is desirable to consider the directivity of antennas from this point of view.

It should be remembered that when conditions are such that the wave clusters about a direction different from the great circle bearing it will be necessary, in order to obtain the greatest efficiency, either to shift the direc-

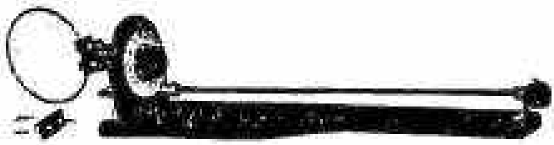


Fig. 91(k)
Short Wave Wavemeter. Note Extension on Adjustment Handle to Avoid "Capacity Effects"

tion of maximum signal correspondingly or to increase the angular width of the main lobe. The first consideration is possible in suitably designed arrays and has been accomplished in an experimental manner. It seems that operating difficulties would be simplified by avoiding too sharp a "beam."

In the present transatlantic telephone links three wavelengths in the range of 16 m, 22 m and 32 m are used while one employs a fourth at 45 m. In each case the antennas at the American transmitting terminal located at Lawrenceville, N. J., are broadside with respect to the great circle and employ "reflectors."

These antenna lengths vary and in some cases are 4, 6, and 8 wavelengths. In addition to the factors already discussed there are other considerations which influence this choice. It might be mentioned the desirability in a row of towers of maintaining uniform spaces.

There is no question that high angle radiation exists but low angle waves are more dependable in the 15 m range. This conclusion is taken from the fact that antennas designed to narrow down the vertical polar characteristics to moderately small angles in an experimental manner give nearly the gain which is anticipated on the assumption that the maximum signal could be obtained in a nearly horizontal direction. In actual practice this advantage can be over-done, particularly at the longer waves. At Lawrenceville the antennas employ a single "tier" (a "two tier" antenna array is one having two half-wave elements, one above the other. The larger number of tiers the sharper directivity of the vertical plane). At 45 m, two at 22 and 32 m and three at 16 m.

The arbitrary standard usually employed in a comparison of short-wave antennas is the half-wave vertical antenna. In decibels the gain over the standard is 20 log E/E_0, E and E_0 referring to the field strengths at the receiving points for equal power inputs to the two antennas.

The result of calculations of two types of array namely the broadside and end-fire indicate that there is an increase in gain with an increase of the number of elements. In the case of 20 elements the gain with the broadside type is approximately 14.5 compared with 10.3 for the end-fire type. In these cases it is assumed that the antenna is erected above a perfectly conducting ground and that the doublets are one-quarter wavelength. These are arranged along a horizontal straight line with a spacing of $\frac{\lambda}{2}$. The phases are the same in the first case. In the second case there is a progressive phase shift of 180 degrees per element so that the maximum signal is transmitted in the direction of the line of the array. Curves plotted from these observations indicate that for a given size of structure the broadside system is more efficient than the end-fire type.

Results cannot be accurately anticipated unless account is taken of the actual properties of the earth which, unfortunately, is not a perfect conductor.

While the effectiveness of the antennas may be generally estimated these calculations are centered around ideal conditions of transmission. These estimated gains are not always obtained in actual practice. In the 15 m range gains of 18 or 20 db are secured over a sufficient portion of the time to justify the use of antennas of this relatively large size. At Lawrenceville the theoretical gains of the antennas vary approximately from 20 db at 15 meters to 13 db at 45 meters.

CHAPTER VI

Television

General Considerations

At the present time there are widely separated views in regard to the commercial possibilities of television. Some firms are spending considerable time and money with a view to presenting equipment suitable for home use. Others contend that the activities should be confined to laboratory experiments until the problem has been solved to a higher degree. There is no question but that the wonderful possibility of this new development has

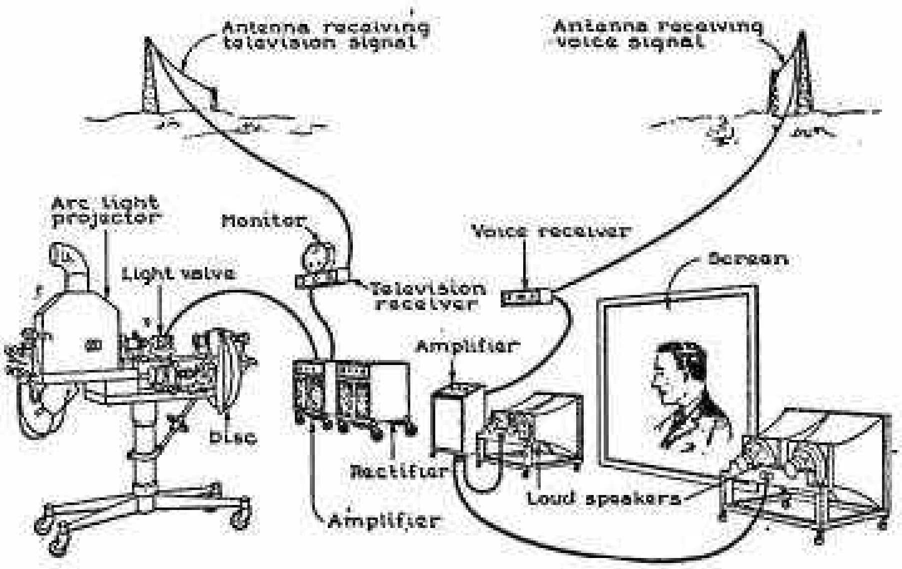


Fig. 95

Block Diagram Showing General Electric Television System.

caught the fancy of the public and it is regretful that the preliminary information when released did not include an outline of the problems involved. The laboratory demonstrations given so far have been a great success. When television is introduced on a commercial basis many new problems must be solved. There is a consideration of the matter of suitable programs. There is no question but that this will be an ideal method of direct advertising and for that reason will bring sufficient revenue to guarantee its support. However, the same as the present broadcasting system, the advertising value will depend upon the interest factor of the program. As far as the artists will be concerned the problem will be similar to the motion picture industry where in selecting the performers, appearance and vocal ability will be the main requirements. Probably one of the great difficulties will be the available channels for television transmission. At the present time there are only a few channels and it must be remembered that one television station requires approximately three times the amount of space on the air as an ordinary broadcasting station. This may be overcome through technical improvements. To supplement the present broadcast programs with television will involve the erection of costly transmitting stations and probably this will be financed in a similar manner in which the original broadcast stations were. That is, although the operation at first may be at a loss there is no question in regard to the future and eventually the whole project will be a great success.

The development of radio has been exactly opposite to that of motion pictures in the entertainment field. In radio, sound was the first development and the visual accompaniment followed; in motion pictures, the visual development was used for a good many years before the sound accompaniment was added. It is quite possible that within the next few years talking moving picture service will be given over television transmitters as in regular service in private homes. Looking further ahead, it is possible that this talking motion picture service will be given direct to motion picture theatres throughout the country and throughout the world rather than through the distribution of films.

The development work with television in continental Europe is quite interesting inasmuch as they have certain limitations not found in this country. They have shown good judgment in standardizing the scanning arrangement. Three leading German companies have decided upon clockwise scanning as seen by the observer from top to bottom a ratio of four units of breadth to three in height for the image, a 30 line image reproduced at the rate of 12½ frames a second or 750 a minute. Each line of the image has to be scanned at the same time, that is, the holes of the disc are spaced at equal angles between the radii. This solution is necessitated by the fact that broadcast waves used for television under the present European channel allotment are confined to 9 kilocycles and the modulated frequency is thereby limited which in turn, of course, limits the detail of the image. This 9 kilocycle limitation can be compared with the 30 kilocycle limitation in this country. It seems that the progress of television would be increased more rapidly through the application of shorter wave lengths. This would enable using a wider band giving a more detailed image. Possibly still better results will be obtained through the use of ultra-short waves especially when they are sufficiently understood. Of the three German companies manufacturing television equipment, one is not offering the apparatus to the public as yet. The Telefunken in retaining the mirror wheel system offers the greatest possibilities of development and almost unlimited illumination. The present drawback is the matter of price. As the channel limitations in continental Europe are fixed for the next two years, it is doubted whether any great progress will be made. On the other hand, due to these limitations it is possible that new systems will be developed to overcome obstacles which probably under other circumstances would not be developed so rapidly. The development of colored motion picture film has led to the suggestion of similar application to television. At the present time colored television necessitates either a special wave length for each color employed or, on the other hand, modulating the

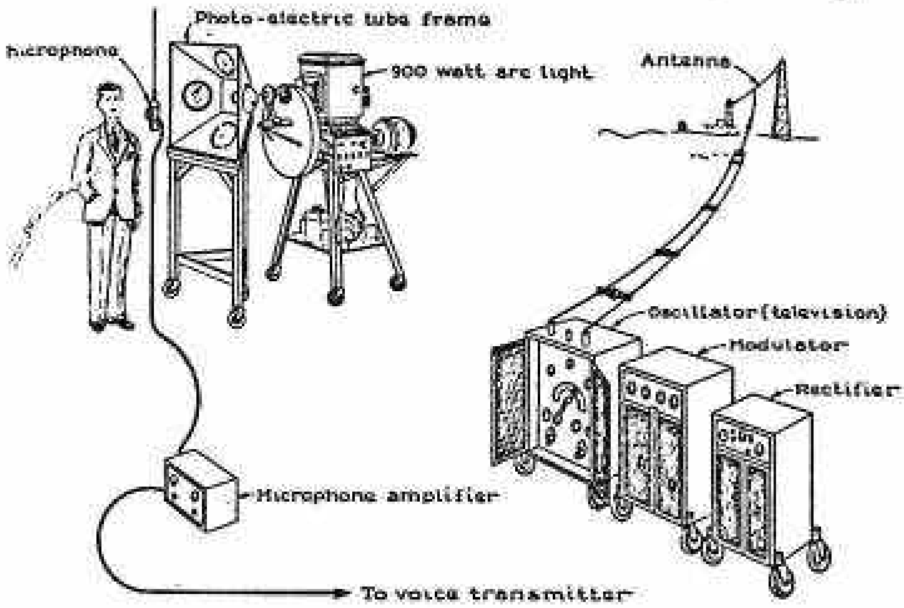


Fig. 96
Television Transmitter Arrangement, G. E. System.

transmission at twice or three times the normal image frequency. Under present circumstances, either method widens the wave band channel to an extent which is considered prohibitive. Even so, the super position of two or three pictures, each in a different color, does not give an accurate natural effect because the spectrum of visible light is much more complex. The details of colored television systems heretofore disclosed are in actuality exactly like those used in the black and white reproduction. The different image points varying in illumination are converted into corresponding electrical impulses at the transmitter. They must be faithfully and exactly reproduced at the receiver to have the correct picture. In attempting to carry out transmission on short waves fading is encountered causing faulty reception in the form of interruptions of reception and suppressing part of the transmission corresponding to certain frequencies. Fading is overcome to some extent in telegraphic reception with automatic volume control systems, the sensitivity of the receiver being so high that even the weaker signals are regulated to a workable value. This can be accomplished in radio telephony but is unsuited to television due to the necessity of reproducing different light values. If a process of scanning could be adopted in which pictorial points of the same intensity are always selected, then fading could be readily overcome. Ahron Hein has proposed a system which would overcome the above

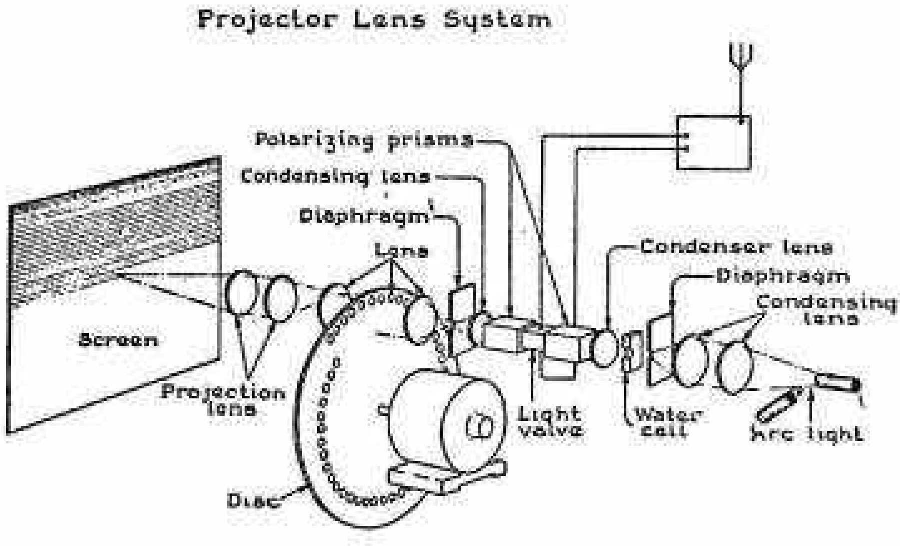


Fig. 97
Scanning Mechanism, G. E. System.

difficulties without winding the wave band and without fading and with greatest fidelity to nature. This system is based upon using 12 colored discs assuming that the colored image points show in different intensities of light or different color tones. The dark red and light red are not merely reds of different intensity but actually different colors. This method of scanning the image is the same as in previous systems, the difference lying in filtering the light before it enters the photo-cell governed by its place in the spectrum. The visible spectrum contains many graduations of color but this system undertakes to reproduce it with 12. Assuming the revolving disc is arranged with colored glass sectors through which the light must pass, from the scanning apparatus to the photo-cell the ray of light can only penetrate the appropriate filtered colors. It is, of course, necessary that the filter disc revolve at high speed to compensate for the fact that the light ray penetrates only one of its sectors at each revolution. Likewise at the receiving end a similar system of scanning is used to build up the image also with a glass filter with 12 sectors placed between the source of light and the observer's eye. When the two discs are synchronous the picture corresponds exactly to the image at the transmitter. The photo-cell interprets just as many impulses as with the black and white transmission; therefore, the modulating frequency required is not greater for color television, and when the transparency of the filter is properly regulated, the image impulses at the start of the transmitter

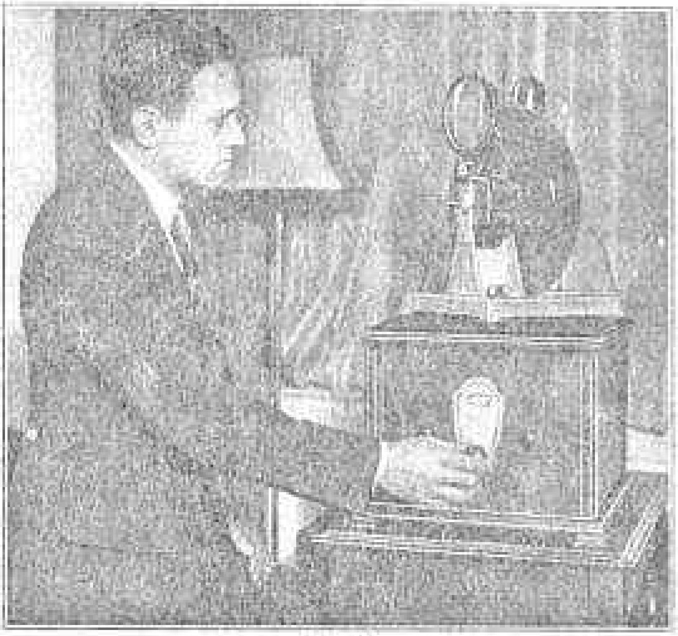


Fig. 98
Jenkins Scanner and Television Receiver.

and the signals actually sent out are of uniform intensity. The same scientist proposes not to use a mechanical filter system but to utilize a prism; this latter device, as we know, decomposes white light into its constituent colors. The whole spectrum will reproduce only when light has been directed into the prism; single colors will emerge unchanged. Light rays will be disbursed at different angles according to their wave lengths and 12 photo-electric cells could be arranged side by side behind the prism so that one would receive all the dark red light which enters the prism, another all the light blue, etc. In actual practice, however, only one cell need be used because of the scanning device when the color corresponding to the image point reproduced will be conveyed to the cell. With this system colored motion pictures could be reproduced satisfactorily. As was mentioned before, the German transmission of television is made at the rate of 750 thirty-line frames per minute, framed at the top of the disc, the image being about one-third wider than it is high.

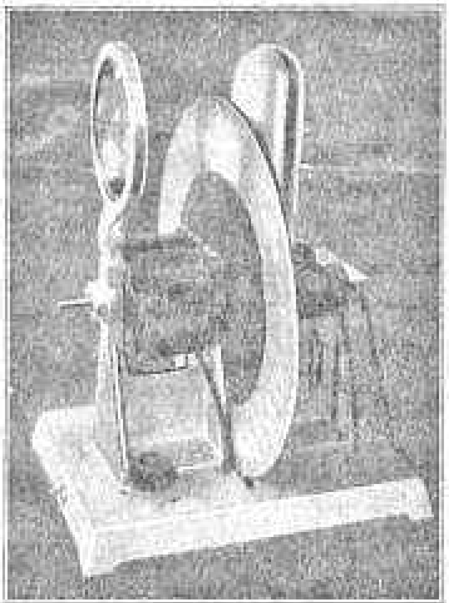


Fig. 99
Scanner with Synchronous Motor.

The English (Baird) system, the number of lines and rate of speed are the same, the image is viewed at the side of the disc and it is higher than it is wide. Here again the matter of standardization is realized so that the receiving equipment can be adapted to all types of transmitters. The necessity of changing the disc motor speed, etc., involves considerable annoyance and should be overcome.

Television has interested scientists much earlier than is commonly supposed. Probably one of the first television patents issued was that to P. Nipkow (English patent) January, 1884, which discloses a mechanical system for television. It describes a method of scanning the object and picture using the familiar perforated disc, practically the same as used in present day television system. Nipkow's invention and the subsequent progress was retarded through the lack of photo cells and electrical amplifiers, the latter being comparatively recent improvements. The rotating disc method of television is at present giving excellent results but of course will be subject to many further improvements. The application of the cathode ray for scanning purposes was believed to have been proposed for the first time by B.

Rosing in 1907 at Petrograd, (English patent), December, 1907. A successful dev[...]ent of Rosing's patent was also retarded by the lack of photo [...]trical amplification. Other scientists using the cathode ray sys[...] experiments included Belin and Holwick (France), Deauvillier (France) and Takayanagi (Japan). In 1929 the subject of television was given an unusual amount of publicity. As a matter of fact it was given too much publicity for the good of the industry. Radio engineers and scientists were working on the problem in all parts of this country as well as European countries. The initial experiments were very encouraging. However, upon trying to apply the theories to a practical and commercial proposition, it was found that considerable additional development work remained to be accomplished. Many individuals dropped the subject on account of the considerable expense involved. The progress of television has now settled down to a more stable status and good progress is being made continually. The Jenkins organization has accomplished considerable pioneer work having two television transmitting stations in operation—one at Jersey City, W2XER, and the other one in Maryland just outside of Washington, D. C., W3XK.

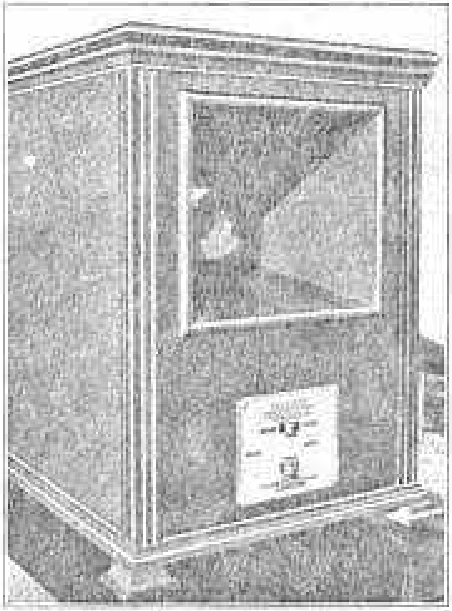


Fig. 100
Scanner in Enclosed Cabinet.

These stations are licensed for maximum output up to 5 kilowatts. This television transmission is accomplished on a band between 100 and 150 meters and due to the efficiency of short waves, the service covers quite an area. The Jersey City station broadcasts on 107 meters. A regular daily schedule is maintained from both of these stations, details of which are announced from time to time. The station broadcasts using maximum power. T . . . er of program is a problem just as it is for broadcasting. The usua! . to have vocal announcements explaining the picture to follow anu. as to the adjustment of the receiving apparatus. As far as the transn..tter is concerned, the amount of detail which can be received depends on the percentage of modulation and the carrier wave band. Using 100% modulation over the entire 30 kilocycle side band width enables providing a good degree of detail for the image transmission. The transmitter is usually fed the result obtained from a reel of standard motion picture film with half-tone and detail. Of course, this is not received as clearly as animated cartoons in most cases probably due to limitations of the receiving ecquipment. For example: a receiver operating with a high degree of regeneration would have a frequency cut off of approximately 3000 cycles. As the full band width is

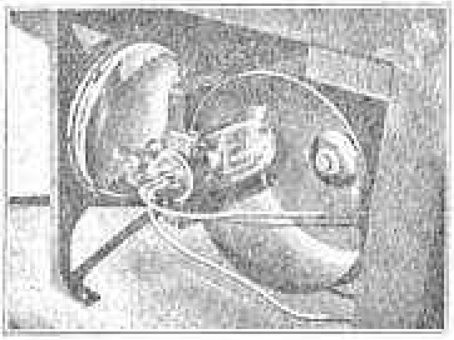


Fig. 101

Drum Type Scanner for Console Installation.

30 kilocycles, it is immediately apparent that the receiving efficiency as far as the picture is concerned is only 30%. By using a tuned radio frequency set free from regeneration, one which tunes broad and which will cover a 30-cycle band, much greater detail can be received. At the transmitting end it is, of course, desirable to have the apparatus so that wave propagation is taken care of in all directions and of equal field strength. At the Jenkins' Jersey City station the aerial consists of a copper mast 110 feet high located on the roof of the building. This mast is constructed of sections of corrugated copper tubing properly re-enforced and jointed. This vertical antenna is, of course, guyed and the bottom rests on an insulated platform, connection being made at this point of the mast. Instead of a ground, a counterpoise is used consisting of a system of radial wires branching out from the bottom of the mast. The result is a non-directional antenna giving equal service in all directions. Satisfactory reception has been reported from this transmitter at points in Chicago.

One of the serious considerations in television is the matter of inductive interference. This interference shows up in forms of streaks and smears ... To eliminate this difficulty it is necessary to have a very elab- ...g system. Accordingly, the component parts of the various ...nclosed in copper shields as well as the entire units and even in-

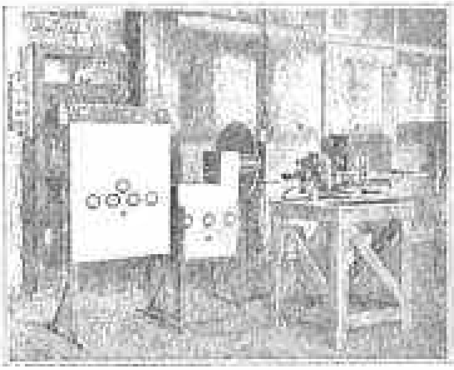


Fig. 102
Television Transmitting Apparatus

cluding the operator in a copper mesh cage. Connecting leads which might cause interference of this type are enclosed in shields. A fair number of television transmitters are now operating in various parts of the country and there is an increasing demand for the necessary apparatus for the receiving end. Unfortunately, the various transmitting systems vary in technical requirements which makes the receiving instrument requirements more elab-

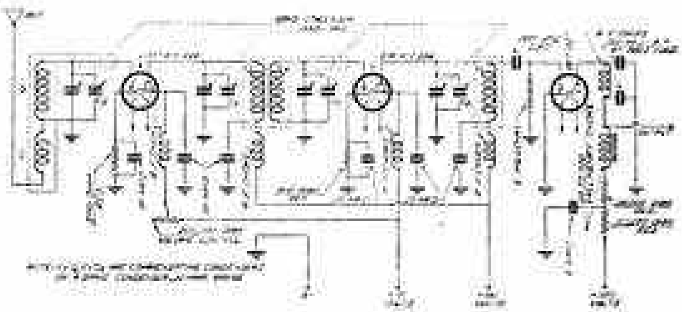


Fig. 103
Schematic Wiring Diagram Television Radio Receiver, Radio Frequency Amplifier and Detector.

orate. It is believed that in due time there will be more standardization along these lines. Most television signals are on a 48-line system although some broadcast 60-line and others 24-line pictures. The 48-line system is in favor at present although better detail is obtained with 60 line. The degree of detail obtained with 24-line pictures is relatively poor and probably will not be used in the future unless other improvements are made to c[illegible] this. Some of the television stations now arrange for the simultaneou[illegible] of pictures and sound, what has been termed "radio talkies".

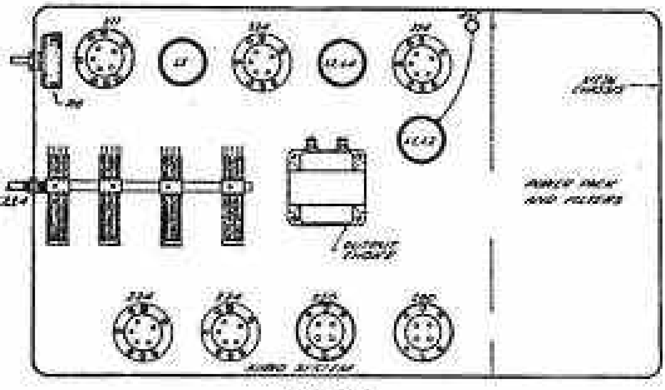


Fig. 104

Television Receiver, Suggested Layout.

course, accomplished on two different wavelengths. In the case of station W2XER, the accompanying sound transmission is taken care of through the DeForest transmitter W2XED on 187 meters. Of course, two radio receivers are required, one for television and one for the audio accompaniment. The combined program originates at the Jenkins studio, the television component being sent to the television transmitter on the roof and the sound

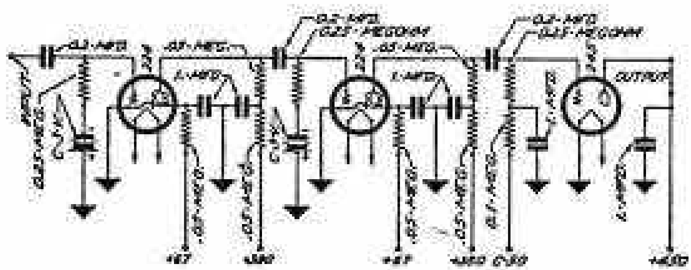


Fig. 105

Television Radio Receiver, Schematic Diagram of Audio Amplifier.

signals picked up from the disc record are amplified and forwarded over telephone lines to the DeForest radio transmitter at Passaic. Using an output of 5 kilowatts for television transmission, the service range is estimated at approximately 100 miles. Reports have been received at a greater distance which is obvious that the range also depends on the sensitivity of the receiving equipment at the receiving end. There are three distinct sections to a television receiver—first, the radio frequency short-wave receiver which must co[illegible] to 150 meters, the present television band, a suitable audio and power amplifier designed to meet the technical requirements of television and a suitable scanning device to convert the audio signals into corresponding visual detail.• Even on this band a loud speaker should be included which sim-

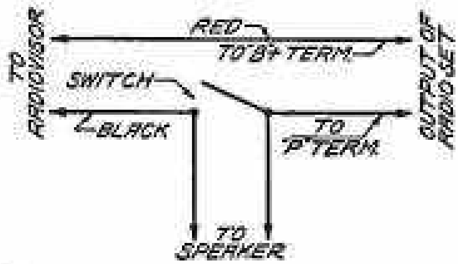


Fig. 106
Television Receiver Switch for Changing From Loud Speaker to Scanner.

plifies picking up the signals in the first place. Listening to a television signal with a loud speaker the note received is a continuous series of dots. The receiver can then be adjusted to tune in this signal in the best possible manner and the output then switched to the scanning device. Considerable power is required to operate the scanning lamp to a degree where the picture reproduction is satisfactory. Accordingly, the receiver should be powerful and adjusted to give the maximum possible output. At the same time it must be remembered that a television signal is subject to static interference exactly the same as a broadcast receiver. In this consideration it is true that the interference is of greater consideration as static and background noises will cause blurs and troublesome patterns. It is then realized that even with a sensitive receiver good reception will not be obtained unless the transmitter has sufficient strength to place a strong signal at the receiving end. While any short-wave receiver may be used for this work, it was previously mentioned that the presence of regeneration detracts from the detail of the reproduction. The accompanying diagrams illustrate a typical short-wave receiver designed especially for television work inasmuch as it is practically free from regeneration, tunes broadly and has a high degree of amplification. The matter of passing the frequencies of from 50 to 30,000 cycles both in the radio frequency and audio frequency amplifier is satisfactorily accomplished. A satisfactory experimental short wave receiver can be constructed by following the diagrams and the details of the component parts given, Figs. 103, 4, 5 and 6. Of course, high-grade parts should be used to insure good results. The receiver as designed was intended to give a band pass effect in the radio frequency amplifier covering a width of approximately 60 kc. The volume is controlled through a series resistor in the screen grid of the first radio frequency amplifier which regulates the sensitivity. Shielding should be carried out along approved methods so that the operation will be stable and free from oscillation. With careful shielding it is believed that the receiver will give a sensitivity of approximately 10 microvolts per meter which would be satisfactory for reception up to approximately 500 miles from the transmitter. Either a 224-or 227-tube can be used for the detector, the latter having the advantage of greater stability. The 224 has the advantage of high amplification less

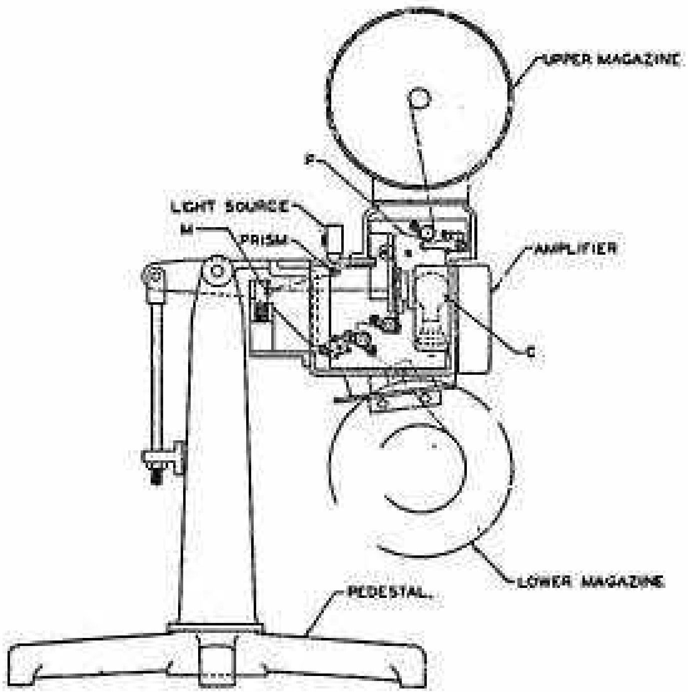


Fig. 107
Cathode Ray Tube Television Transmitter

AC hum and less microphonic. In arranging the parts in the receiver, tuning coils should either be placed in compartments or surrounded with copper cans. It would be well to have the gang condensers completely shielded. All the plate supply leads should be equipped with a filter choke and by-pass condenser individually on each radio frequency stage. The control leads should be shielded. Referring to the tuning coils, the antenna is closely coupled to the first tuned circuit. Band-pass filter coils, L 3 and L 4, are rather loosely coupled, about one-half inch between their nearest ends on a one-inch diameter tube. The component parts of each stage consist of coil

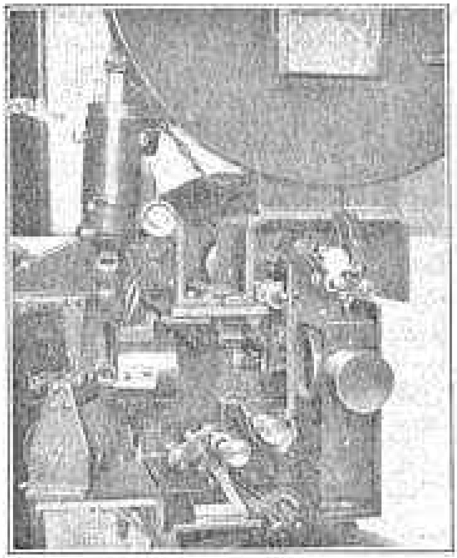


Fig. 108
Film Mechanism
Cathode Ray System.

tube and condenser to be so arranged that they are as close as possible to each other providing short connections and eliminating the possibility of feed-back coupling to the antenna or from the detector. The power requirement from the various tubes is of a relatively high order and batteries would not provide economical operation. The power pack used should be of ample

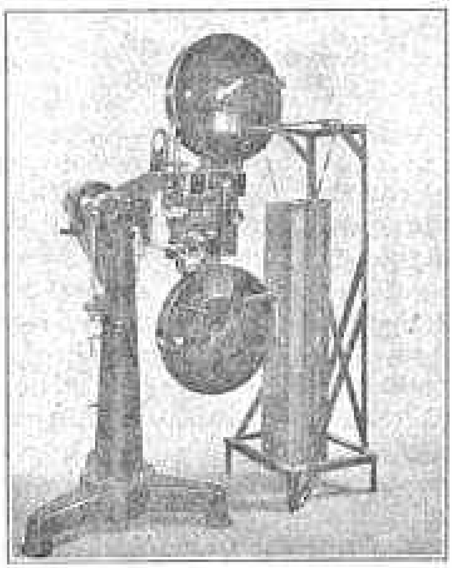


Fig. 109
Cathode Ray Tube
Television Transmitter.

capacity so as to prevent any overloading. It will be noted that the recommended audio amplifier is the resistance coupled type obviously to pass all the frequencies used for television transmission, for example: 15 up to 30,000 cycles. Even though a high-grade broadcasting receiver covers 50 to 5000 cycles it is obvious that it would not be suitable for reproduction of extreme detail although it would give fairly satisfactory results. Experimenting with a resistance coupled amplifier one should not be guided by fixed values but should feel free to experiment and determine the best values when used under individual circumstances. The television lamp is of the neon type and for satisfactory excitation the output of a 45 type tube is essential. The television lamp requires approximately 1.5 watts of undistorted output for good

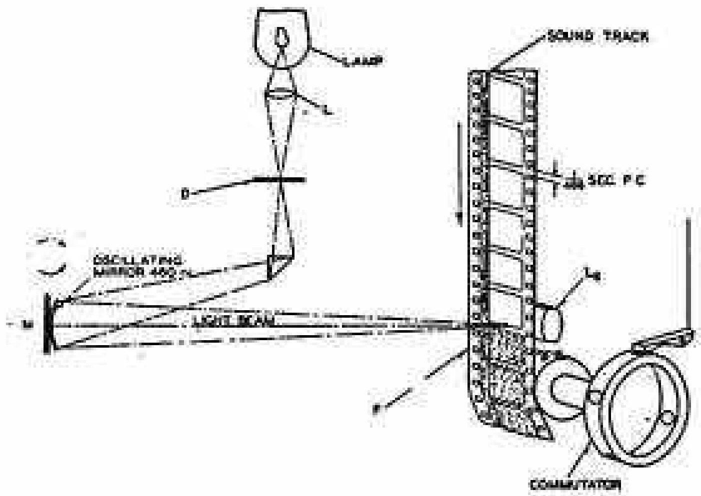


Fig. 110
Showing Combined Oscillating Mirror and Downward Motion of Film.

detail reproduction. In view of this the output voltage of the lamp circuit should be around 200 volts DC with an AC signal of about 50 volts R.M.S. on the neon lamp itself. The characteristic of the resistance coupled amplifier illustrated is said to be 100 to 10,000 cycles in a straight line and decreasing from that maximum upon reaching 15,000 to 30,000 cycles. This decrease does not seriously impair the quality of the television image. It is suggested that in constructing a receiver of this type the radio frequency coils and transformers be of the interchangeable type. This would enable having more than one set of transformers in order to cover different ranges. One set of transformers could be used exclusively for television and the second set to cover the lower half of the broadcast band. Experiments could then be carried on with the receiver on the lower half of the broadcast band where plenty of test signals are available and the circuit components could then be adjusted and altered to obtain maximum efficiency. Whether the radio or audio amplifier is passing all the frequencies desired could be determined by the quality of the reproduction from the transmitting station. On the other hand, another method of testing the audio frequency amplifier alone would be with an electric phonograph pickup feeding the output of such a pickup to the input of the audio amplifier the circuit components could be adjusted in a similar manner to that mentioned above. Screen grid tubes are shown in the radio frequency amplifier due to the high voltage gain obtainable from these tubes. This is not the most suitable arrangement but will be best if the adjustments are made so that the operation is not eratic. Summarizing the above it will be remembered that in the television receiver itself the radio

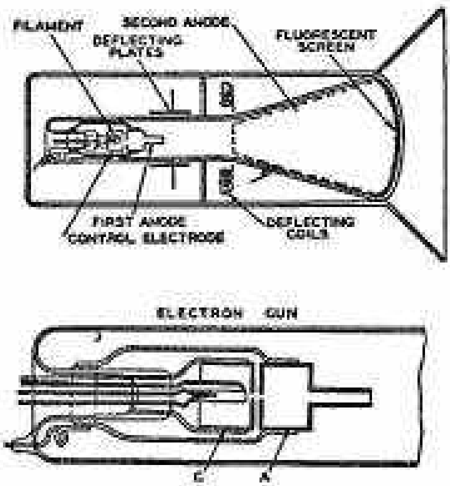


Fig. 111

Cathode Ray Tube Internal Construction.

frequency end must be free from regeneration, tune a wide band width and the audio amplifier give a high gain corresponding to a strong signal and that the neon tube circuit be provided with a –45 power tube to give the proper illumination. The next consideration is the conversion of the audio signals to a visual response. The design of the scanning disc is an important consideration. For example; if the holes in the disc are not carefully laid out, in proper position, correctly drilled and the disc perfectly true, there will be distortion created. This feature of the disc can be tested by connecting the television lamp to unmodulated direct current, for example, from batteries. Rotating the disc at proper speed and provided the disc is true, there will appear a solid glowing pattern. On the other hand, inaccuracy will be noticeable by the appearance of black streaks.

It is, of course, essential in actual operation that the receiving disc (Fig. 99) operate at the same speed and be in synchronism with the scanner

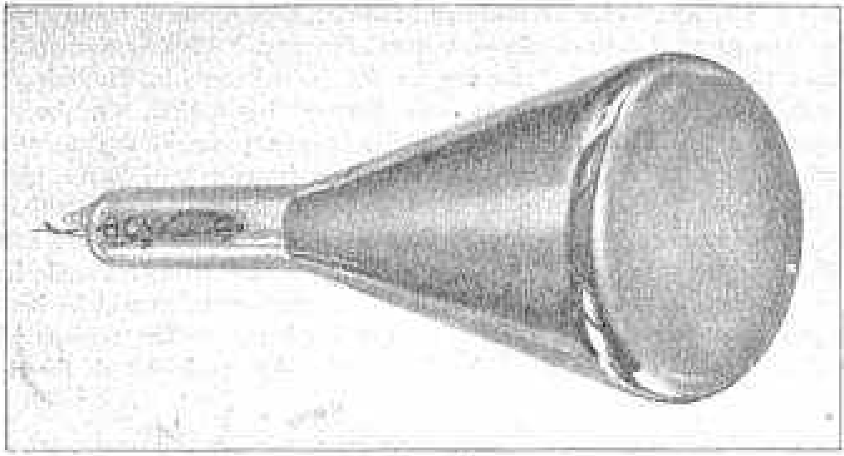


Fig. 112

Cathode Ray Tube, Special Design for Television.

at the transmitter. Variable speed motors have been used for this purpose with an adjustment to control the speed. Systems have been proposed to keep these variable speed motors in exact synchronism with the transmitter. Obviously the synchronous motor operating on the same 110-volt alternating current as the transmitter is a more satisfactory solution. This would be a similar arrangement to the method of using 110 volts alternating current power supplies for the control of electric clocks. Where the receiving station is

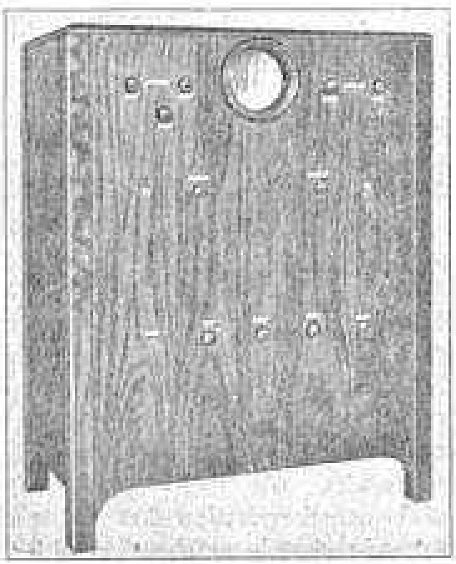


Fig. 113

Television Receiver.

at a point beyond the power system which feeds the transmitter, it is only necessary to make an initial adjustment to bring the scanner into synchronism with the transmitter. Any slight variation can be taken care of with the manual regulator which is a part of the scanner equipment. There are ad-

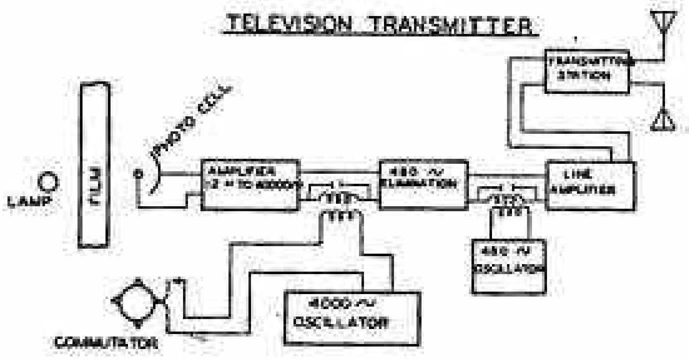


Fig. 114

Cathode Ray Tube Television System, Transmitter.

justments to be made so that the picture is properly framed both in the vertical and horizontal planes. The necessity of vertical framing is noticed when two pictures appear, one above the other, and is corrected by turning off and on the motor switch one or more times and if not corrected one can try shifting the aperture of the light source. The horizontal framing is regulated by shifting the motor frame or aperture of the light source. Figures

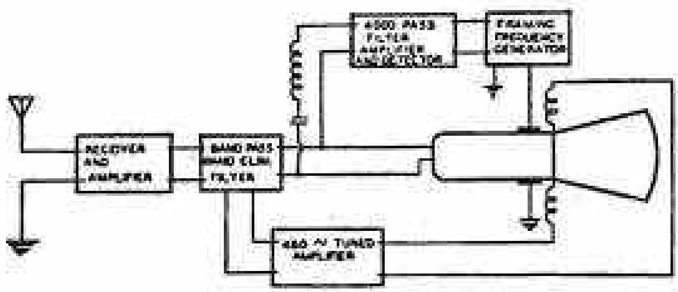


Fig. 114 (a)

Cathode Ray Tube Television System, Receiver.

98 and 99 illustrate the Jenkins scanning disc complete with synchronous motor, lamp, magnifying glass, etc. This equipment has been designed for the layman and especially for experimental work. The motor is of individual design inasmuch as two distinct motor elements are used. The first motor

of the eddy-current type similar to the well-known watt hour meter brings the disc up to speed and secondly, a small synchronous motor which maintains the desired steady speed of 900 r.p.m. After the full speed is attained the only function of the eddy-current motor is to compensate for friction and wind resistance. Incidentally, the shaft rotating the scanning disc as well as the eddy-current disc and rotor is mounted on ball bearings. The operation is quite silent. A regulating device enables bringing the motor up to speed and to make slight adjustments in its speed. Although the pictures are small they are, under proper circumstances, exceedingly sharp and shown in good

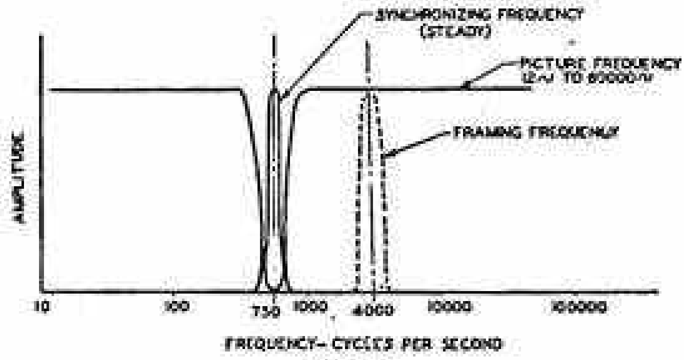


Fig. 115

Cathode Ray Tube Television System, Showing Component Frequencies.

detail. The television lamp is mounted in a metal housing and is adjustable. There is an oblong opening towards the disc of the proper size for a complete picture frame. The lamp housing is adjustable vertically or horizontally to enable framing.

A complete television receiver, console style, has also been introduced by Jenkins and shown in figures 100 and 101. It will be noted in this case that the usual disc is replaced with a scanning drum together with the lamp, magnifying glass, etc. The procedure in operating a television receiving equipment is as follows: (assuming the equipment consists of the apparatus previously described or similar thereto and including a change-over switch enabling either audible or visible response) preliminary tuning would be accomplished with the switch in the loud speaker position and the short wave signal tuned in. As mentioned before, this is recognized as a series of rapid dots and with varying pitch. Adjustment should be made to get the loudest possible response at the loud speaker and the switch then thrown to the scanning position. Starting the scanning disc motor it will be noted that at first with the scanning disc at rest a single dot of light will be noticed. As the speed of the disc increases the single dot of light extends to the line, then to several lines and eventually a glowing screen. Assuming the disc is out of synchronism a regular pattern will be noticed in the field of vision. Necessary adjustments are then made to the scanning disc speed and step until the image is received in a satisfactory manner. With anything but a synchronous motor this requires an unusual amount of manipulation. On the other hand, with a synchronous motor specially operating on a common power system as the transmitter, the process of manipulation is simplified. Besides regulating the motor with the adjustment provided, the speed and step can sometimes be adjusted by using one's thumb as a brake on the smooth end of the shaft. When the picture drifts to the right it indicates that the power through the eddy-current motor is too great and the rheostat should be retarded. On the other hand, if the picture travels to the left it indicates that the frictional load of the motor is too great and the power to the eddy-current motor should be increased to compensate for this. Even when the synchronous motor has reached full speed there will be noticed a phenomena known as "hunting" which is an oscillating motion due to the disc trying to find its synchronous speed. This can be corrected by slight pressure on the rotating shaft or if left alone this condition will correct itself. After synchronization has been obtained it will possibly be noticed that the picture may appear out of frame either horizontally or vertically. The television lamp cover is then adjusted

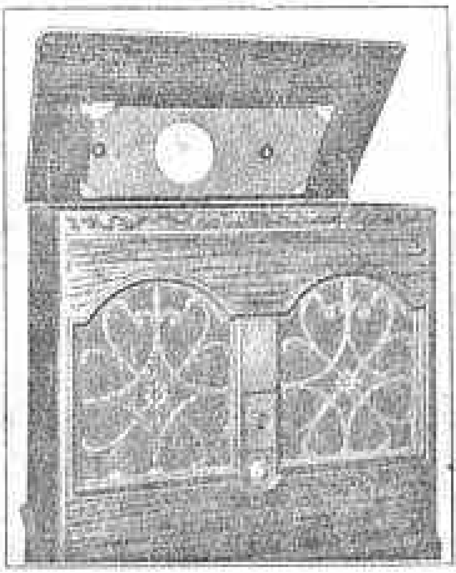


Fig. 116
Television Receiver.

and shifted to the correct position so as to center the image properly. The experimental scanner illustrated is so arranged that it can be conveniently dismantled and the discs with different numbers of apertures can be used. Different elements can be supplied for the motor to give a speed of 1,200 r.p.m. for 20 pictures-per-second signals. A device is being developed which can be attached to this scanning motor which will provide automatic synchronization, this apparatus being actuated from the radio vision signal itself. This will give automatic synchronization between the transmitter and receiver

Fig. 117

Artist's Booth, G. E. System. Note Microphone as Well as Light Cells.

regardless of whether they are operating off a common AC power system or not.

The General Electric System

In May, 1930, the General Electric Company's consulting engineer, Dr. E. F. W. Alexanderson, gave a very interesting demonstration of television as illustrated in the accompanying photographs and diagrams. In this instance the images of the performers were reproduced on a screen six feet square and readily visible by all those seated in the theater. The performers appeared before the television camera in à temporary studio at the General Electric plant. The light impulses converted into electrical impulses for radio signals were sent out on the transmitter in the laboratory on a wave length of 140 meters. A microphone close to the artist picked up the audible part of the entertainment, converted the sound into electrical impulses which were carried by wire to a short wave transmitter at South Schenectady from which point they went on the air on a wave length of 92 meters. At the receiver an engineer operating a television receiver transferred the electrical impulses received to the light valve at which point the light was broken up to produce an image corresponding in every detail to the subject at the studio. The second radio receiver picked up the sound signals from the 92 meter transmitter and these were fed into a suitable loud speaker which converted the electromagnetic waves into sound. It will be remembered that the first demonstration given by Dr. Alexanderson covering one of his early systems was shown at the Madison Square Garden in New York in 1929. At that time the picture projected was an image 14 inches square. The improvement showing an image six feet square is a distinct advance and in addition the image was not simply black and white but showed gray shades between black and white registering every shadow and shape of the features and giving depth and detail to the image. The difference in operation between the two transmitters is that in the radio broadcast of the voice, the frequency of speech and music modulate the current radiated by the antenna. On the other hand, in television the antenna radiation is modulated by a succession of light impulses. In the television studio the subject to be transmitted stands before an incandescent lamp. Placed between the subject and the light is a metal disc approximately three feet in diameter and having 48 holes. This revolving disc covers the complete subject twenty times per second, that is, there are twenty complete pictures made up of light and shade. A large square frame contains four photo-electric tubes sensitive to light. These tubes respond 40,000 times per second to impulses reflected back from the subject. At the receiving end the electrical impulses are passed to a light valve, a new invention of Dr. A. Karolus. This light valve is the middle of an intricate lens system in front of a high intensity arc lamp similar to that used for motion picture projection. The operation of the light valve is delicate and accurate and permits the passage of light corresponding to the impulses received from the television transmitter. In due course these light emissions are passed on through a system of lenses to a disc corresponding in size and number of holes, rate of rotation, to the disc at the camera or transmitting point. Additional lenses pass the light forward to the screen where these light impulses at the rate of 40,000 per second become the active image of the subject. This arc lamp lens system, light valve and the rest of the equipment are placed 17 feet back of the screen. A tunnel made of heavy black cloth is constructed from the screen to the projector eliminating the possibility of interference from stray light. The apparatus has beeen constructed as portable equipment possibly so that it can be readily moved to different parts of the country for demonstration.

Cathode Ray Tube Television

A number of distinct advantages for television reception are available through the use of the cathode ray tube system. It will be noted from the diagrams and photographs of this type apparatus that there is an absence of

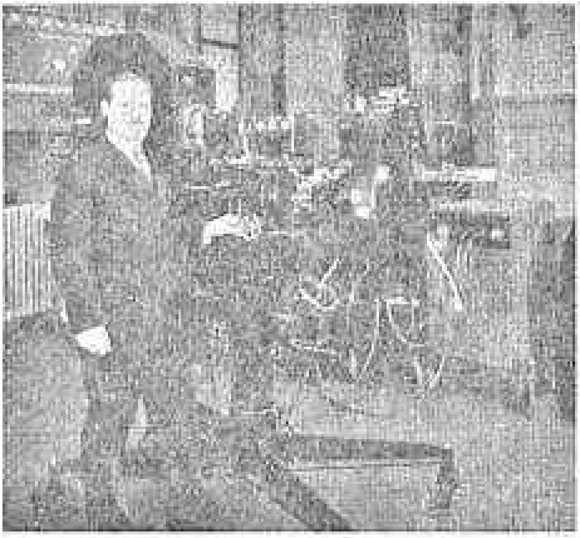


Fig. 118

E. F. W. Alexanderson with G. E. Television Apparatus.

moving mechanical parts which provides quiet operation. The matter of synchronization is simplified allowing operation even over a single carrier channel. More light can be passed giving plain visibility. An outstanding feature of the cathode ray tube in this application to television is the persistence of fluorescence of the screen which acts together with persistence of vision to the eye. On account of this fact a number of pictures per second can be reduced without noticeable flickering. A greater number of lines and therefore better details of the picture can be obtained due to this optical phenomena without increasing the width of the frequency band. The cathode ray apparatus described in this chapter was developed in the Westinghouse Research Laboratories under the direction of V. Zworykin. It was developed under the assumption that if eventually the receiver was to be produced in a form suitable for private homes, it should be free from any mechanical moving parts. Furthermore, the equipment should not require any great skill in order to secure satisfactory reception. This consideration, of course, does not apply to the transmitter at which point the necessary trained and skilled operators can be readily employed. The transmitter was constructed from a standard motion picture projector. The light source optical system and intermittent motion devices are removed. The film is arranged to move downward at a constant speed, this motion providing the vertical components of scanning. The construction of the transmitter is outlined in Figure 107. Following this picture it will be noted that the light source is indicated and at this point an ordinary 6-volt lamp is used. The light is focused by the condensing lens at L in turn upon a diaphragm D with a small orifice. The beam of light after leaving the orifice is reflected from a vibrating mirror M and in turn focused in a sharply defined slot on the moving film F. The mirror vibrates at a frequency of 480 cycles about the vertical axis causing the light spot to sweep the film horizontally. The vibration of the mirror combined with the downward movement of the film allows the light spot to cover the entire surface of the pictures as shown in Fig. 100. After passing through the film the light enters a photo-electric cell C, the variations of

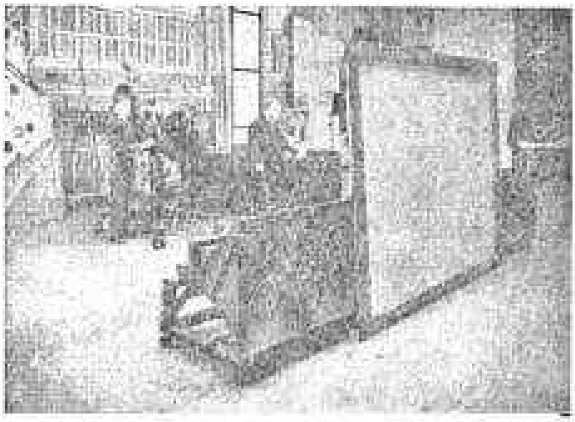


Fig. 119

Method of Projection, G. E. Television System.

optical density in the film being then changed into a variable electric current. Fig. 110 shows the vibrating mirror. It is constructed of a small steel rod with a vane placed between the poles of an electromagnet. The poles are U shaped and each leg is provided with a coil. An oscillating current is fed to the coils and having the same frequency as the natural frequency of the rod, this causing the mirror to oscillate about the axis of the rod. It is not necessary to rely upon the uniformity of the sensitivity from the cathode ray of the photo-cell due to an additional lens L. 2 situated between the film and the photo-cell. In locating this lens the mirror and sensitive surface are at conjugate foci. The scanning beam is, therefore, always focused upon a stationary spot in the cell. The velocity of the beam across the picture is not uniform due to the fact that the horizontal scanning is obtained by a sinusodial current. Actually the velocity in the center is about 50% higher than that of a spot scanning at uniform rate of a picture of the same width. Before actual tests it was thought that this feature would be objectionable and would probably have to be corrected by an optical filter. In actual transmission, however, this was not found to be detrimental and no precautions were used. The transmitter is illustrated in figure 137.

In the receiver a special cathode ray tube is used. An ordinary tube of this type cannot be used for picture reception due to the fact that while they have scanning arrangement in two dimensions there is no means for varying the intensity of the picture. Therefore, the usual type of oscillograph cathode ray is not suited for television work. The high potential type oscillograph tube is always operated in connection with a vacuum pump of course impractical for a private home television receiver. The low potential type of oscillograph does not require the pump but the amount of light available from the screen is insufficient. To obtain enough brilliancy for a picture 5 inches square the tube should operate at least 3,000 volts. Much higher voltages are required for larger pictures the degree of brightness increasing with the oscillatory voltage. To meet the above requirements a new type of cathode ray tube was developed and is shown in figures 111 and 112. The oxide-coated filament is located within the control electrode. The cathode beam emerges through a small hole in the front part of the controlling element and again passes through the hole in the first anode A. The electrons are accelerated to a velocity of 300 to 400 volts by a second anode consisting of a metallic coating on the inside of the glass bulb. At this voltage the velocity of the electrons is about .1 that of light. The second anode also assists in focusing the beam electrostatically into a sharp spot on the screen. The bulb's target wall is approximately 7 inches in diameter covered with a fluorescent material such as willimite making it slightly conductive. This conductivity is necessary to remove the electric charges from the screen caused by the electron beam. This tube is usually referred to as the kinescope. Either an electrostatic or electromagnetic field can be used to move the beam of electrons across the screen in which case leaves a bright fluorescent line as it passes. To accomplish this a set of deflection plates and another set of deflecting coils are mounted on the neck of the kinescope outside the tube. These deflectors are adjusted on the same plane to give vertical or horizontal deflection at right angles to each other. As the deflecting elements are located between the first and second anodes the deflecting field acts upon comparatively slow moving electrons. Due to this fact, the field strength required is considerably less than that required to deflect the beam under the high acceleration of the electrons from the second anode voltage. The negative bias on the controlling element regulates the brightness of the line and consequently the intensity of the lights and shadows super-imposes on this mean intensity. Therefore, it is apparent that we apply to this controlling electrode the amplified impulses from the transmitter and at the same time deflect the beam in synchronism with the motion of the light beam across the picture on the film; the picture will be reproduced on the fluorescent screen. The matter of synchronization is greatly

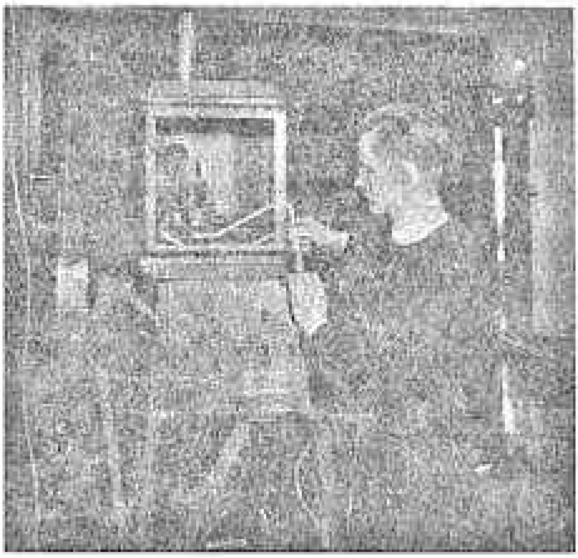


Fig. 120
Television Projector.

simplified if two separate channels are available, that is, the synchronization between the transmitter and the receiver. As far as horizontal scanning is concerned, it is simply necessary to transmit the scanning frequency operating the mirror at a sinusodal voltage and to impress it upon the deflecting coils of the kinescope. In this case the cathode beam will exactly follow the movement of the light beam across the film. Regarding the framing or picture frequency, the voltage is generated at the receiving end and merely controlled by signals from the transmitter. Through a current limiting device (for example: a two-electrode tube) a condenser is charged at constant current, so that the voltage at the condenser rises linearly. By connecting the deflecting plates of the kinescope in parallel to this condenser, the cathode beam is deflected gradually from the bottom to the top of the fluorescent beam when the condenser is charged. This speed is governed by the temperature of the filament of the charging tube to duplicate motion of the downward film. The impulse sent out by the transmitter between pictures discharges the condenser and quickly returns the beam to the bottom position ready to start upward and ready to reproduce the next picture. For the entire system of transmission three separate signals are required: picture signals, horizontal scanning frequency and impulses for framing. Experiments show that it is possible to combine all these sets of signals into one channel. This is accomplished by having the photo-electric cell voltage of the transmitter first amplified to a sufficiently high level for transmission. The other regulating impulses are a series of high audio frequency characteristics lasting a few cycles only and occurring when the light beam passes between the pictures, therefore not interfering with the picture itself. In the transmitting signal the picture frequencies and framing frequencies are directed through a band eliminating filter which in turn removes the picture component of the same frequency as that of horizontal scanning. In turn a portion of the voltage which energizes the transmitter vibrator is impressed upon the signals directed through the filter and the entire spectrum is used to modulate the radio frequency carrier. See Fig. 114. On the other hand, at the receiving end the output of the equipment is amplified and divided by a band pass band eliminating filter into two parts: first, the synchronizing frequency and second, the picture frequency plus the framing frequency. The first mentioned synchronizing frequency is further amplified by a tuned amplifier which supplies the necessary current to the deflecting coils of the kinescope. See Fig. 114a. Both the picture and framing frequencies are fed directly to the kinescope control electrode. The voltage which modulates the light is also impressed upon a band pass filter and in turn is tuned to the frequency of the AC voltage used for the framing impulses. The output from this filter is amplified, rectified and in turn is used to unbias a discharging triode (normally biassed to 0 plate current) and which takes its plate voltage from the condenser which provides the vertical scanning voltage. From the above it will be seen that the picture synchronizing frequencies and framing frequencies are all transmitted on one channel and that the synchronization is fully automatic. The technical considerations of amplification do not differ widely from that for mechanical television of the same picture frequency. It should be noted that the frequency band of the amplifier can be constructed to a much lower value for the same number of lines due to the fact that a smaller number of pictures per second is used. In actual operation it will be noted at the receiving end that there are quite a few differences in reproduction as compared with the conventional scanning disc type of television. In the first place, the picture is green rather than red (using a neon glow tube for the disc). A fairly large number of people can observe the picture at once as magnifying lens are not necessary. No moving parts being used, consequently there is no noise. As the picture is framed automatically it does not require adjustment and furthermore, there is sufficient brilliancy so that the picture can be seen in a moderately lighted room. There are many additional advantages including the fact that the high frequency motor for synchronization and its associated power amplifier are not required. The actual power required to operate the kinescope grid is not more than that necessary for a simple vacuum tube.

Latest Developments of German Television Methods

To obtain standard television apparatus, the following specifications have been adopted by the three German companies which are working in its development: clockwise scanning, as seen by the observer, from top to bottom; a ratio of 4 units of breadth to 3 in height for the image; a 30-line image reproduced at the rate of 12½ "frames" a second, or 750 a minute. In addition, each line of the image is to be scanned in the same time, that is, the holes in the disc are to be spaced at equal angles, between the radii.

It is noteworthy that this does not correspond to the system of scanning used in the English transmission (*or the American*). Its selection is dictated by the fact that broadcast waves must be used for television, under the present European allotment of 9-kilocycle channels which cannot be changed for two years; and the modulating frequency is thereby automatically limited, which restricts the detail of the image.

The progress of television demands, primarily, low prices and easy operation of receivers which we cannot have with the short waves and which would permit the use of higher frequencies, giving more detailed pictures. In addition to this, short wave reception in the near neighborhood of the transmitter is subject to great fluctuations due to fading, echoing, etc. The ultra-short waves, according to Prof. Esau, the great authority on that subject, are not yet sufficiently understood for practical use.

While the technicians express the opinion that the pictorial quality of ordinary television, under these conditions, is too poor to satisfy the general public, we must make a start with what we have now.

For these technical reasons, however, the Telefunken Co. is not at present undertaking to make televisors for general use, and the Deutsche Fernsehgesellschaft ("German Television Company") hesitates to do so. The Telehor Company is the only one undertaking this on a production basis. The systems developed by these three are:

The Telefunken Co. will retain the mirror-wheel system which offers great possibilities of development and almost unlimited illumination. Yet its price cannot be lowered, below a certain figure.

The Deutsche Fernsehgesellschaft system includes the scanning disc,

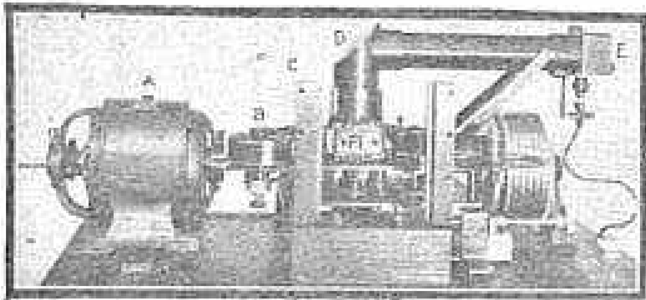


Fig. 120 (a) (Left)

A Moving-Picture Television Transmitter A, Motor; B, Film Reel; C, Frame; D, Mirror; E, Exciter Lamp; F1, Photo-Cell Housing.

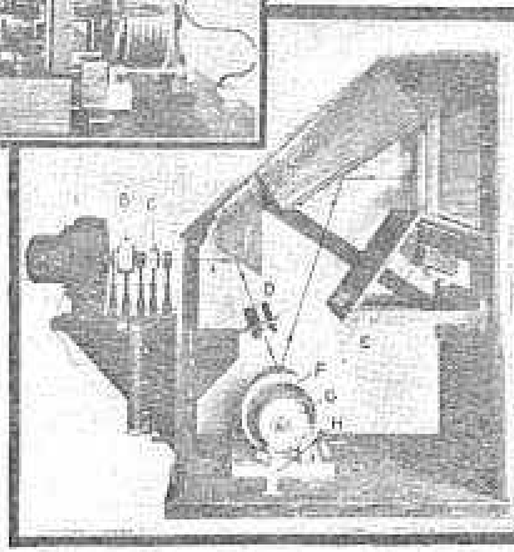


Fig. 120 (b) (Center)

Telefunken-Karolus Television Receiver: A, Arc Lamp; B, Cooling Cell; C, Kerr Cell; D, Lens; F, Mirror Scanning Wheel; G, Synchronizing Motor; H, Phase Control; E, Dynamic Speaker.

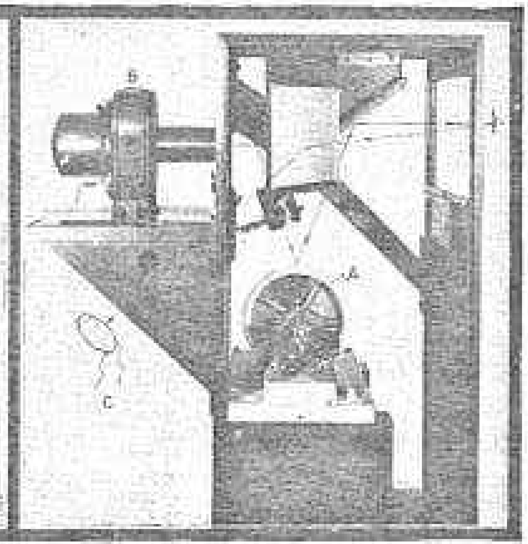


Fig. 120 (c) (Right)

The Corresponding Transmitter: B, Arc Lamp to illuminate subject; A, Mirror-Wheel, scanning subject with light spot. The illumination is reflected, as indicated by the dotted lines, to the Photo-Cell C, which is really in the triangular box.

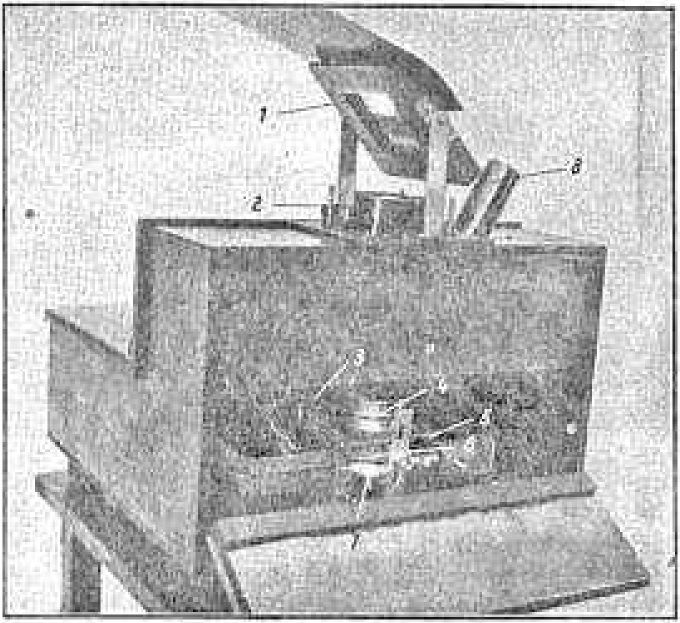


Fig. 126 (d)

The equipment shown here is a design of the Telehor Company, for the purpose of scanning images illuminated by daylight, to be broadcast through a portable transmitter. The mirror 1 reflects the rays from the object to be televised through the lens 2 which concentrates them on the scanning disc 3. The lens 4, screen 5 and lens 6 pass on the ray to the Photo-Cell 7, which is connected to an amplifier. The tube 8 contains a magnifying glass through which the scanned image may be observed.

which is most familiar in England and America. An image-frequency (normally 375 cycles) is used to obtain synchronization.

The Mihaly Methods

The Telehor Company also uses a scanning disc with a glow-lamp, a driving motor and synchronizing wheel; the motor is connected by a belt to the axle of the synchronizing motor and, consequently, to that of the scanning disc also. Phasing is effected by turning the frame of the synchronizing motor around its axis while it is in operation. To produce the necessary voltage for the glow lamp, a special battery or power unit will be required.

In a larger type, to be used as a universal television receiver, there is also a small vacuum tube oscillator generating a local synchronizing frequency of 375 cycles to which it is tuned by a small rotary condenser; an ordinary receiving tube will serve. This current is amplified and conducted to the synchronizing motor, which operates on 375 cycles; unlike that in the simpler model, which is designed for 50 cycles. The synchronizing motor and scanning disc are so delicately balanced that the output of the oscillator and its

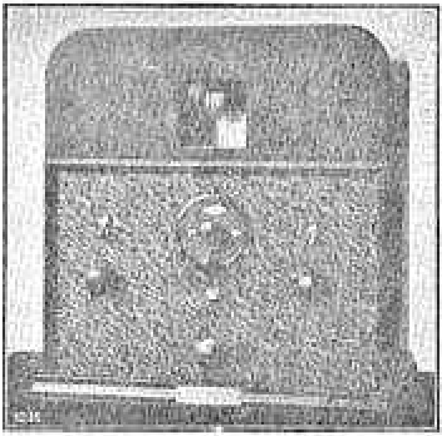


Fig. 120 (e)

The larger model of the Mihaly "Telehor, a German Televisor, now being marketed for reception of European television on broadcast wavelengths.

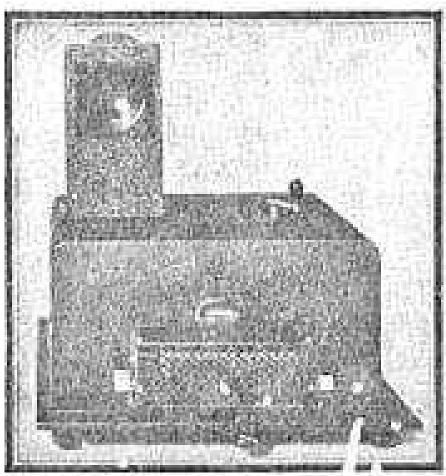
amplifier are sufficient to keep the apparatus operating at the proper speed. To maintain perfect synchronism between the transmitted image frequency and the locally-generated 375-cycle current, the Telehor circuit conducts the A.C. plate potential of the receiver's tube to the oscillator. The oscillator-frequency is thus restored to the normal value if it should vary; a very slight amplitude of the image-frequency will suffice. Only when the received image-frequency is completely lost, through fading, can the receiver get out of synchronism; and this cannot last.

If the image is improperly framed in the "window" of the receiver—say, with the bottom half at the top—this can be corrected by turning the mounting of the synchronizing motor, as already explained.

The possibility of using a tuning-fork instead of the tube oscillator to obtain the local synchronizing frequency has been considered; but the tuning

Fig. 120 (f)

A commercial German Televisor, on the Mihaly System, as produced by the Telehor Company.



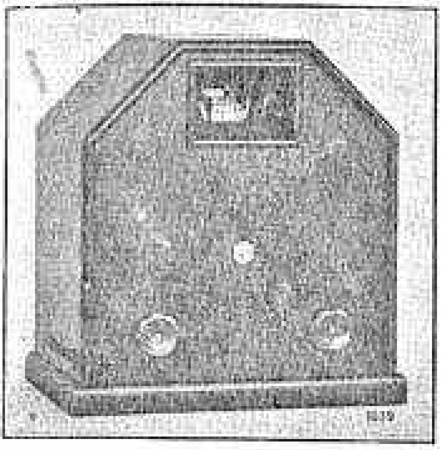


Fig. 120 (g)
A receiver model of the Deutsche Fernseh-A.G.

fork, although it has been successfully employed in transmitting photographs by radio, must be carefully protected against changes of temperature or its note will vary. So the use of the tube is simpler and cheaper; however, its construction entails some practical difficulties if exact frequency-regulation is to be required. As the frequency decreases, resistance will cause a lessened peak of the curve of frequency-response.

With the Telehor, the television receiver is connected to the loud-speaker terminals of the radio receiver, and the speaker across the terminals provided on the television apparatus; a switch permits immediate change over from sound to images, and vice versa. To provide the necessary voltages, a power unit will probably be built into the receivers; the televisor will then have only two cords, one to the receiver output and one to the house socket, with terminals for the speaker, as stated.

The designs so far made are only for alternating-current operation; direct-current house supply does not give a voltage sufficiently high. It is not impossible that a battery-operated model may be provided for those who have D.C. receivers.

The German Reichspost (post office department, with control of wire and radio communications) is making test broadcasts for the benefit of experimenters in Germany from which others will also benefit. The Berlin transmitters are used, and perhaps others, such as Stuttgart, will be used later. This will permit of determining the practical value of the television apparatus, and the suitability of different radio receivers for operating them, before official programs are regularly undertaken.

In my opinion, this is a little too paternal, for these things should be left to the radio trade which will adapt its apparatus to the condition it meets. However, this is the way things are done in Germany.

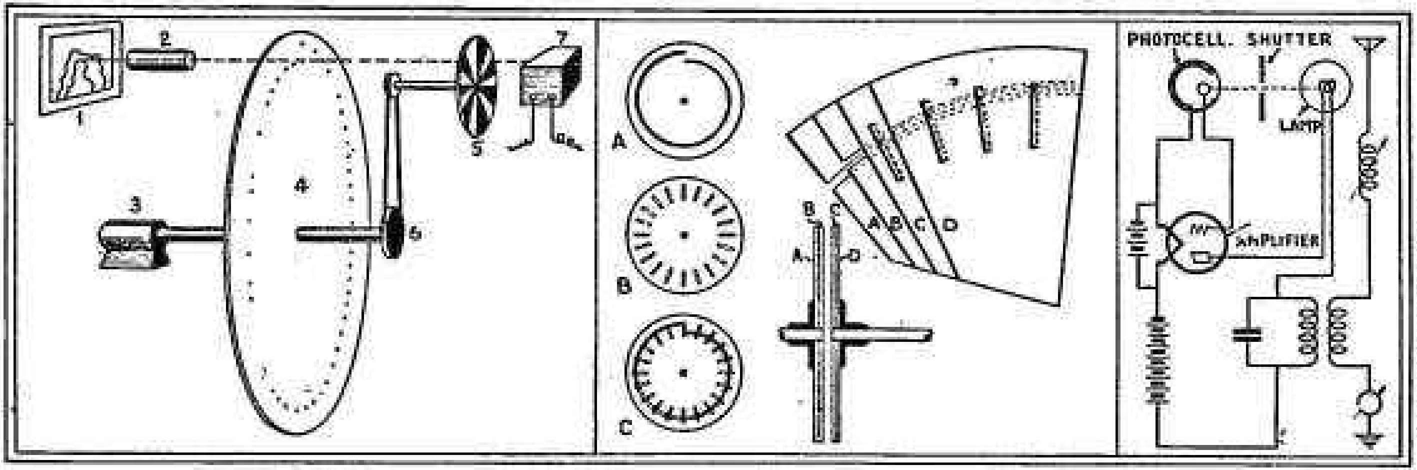


Fig. 120 (i)

Television in Twelve Colors. (Left) Fundamental principle of the Ahronheim System: Light from the image 1 is concentrated by lenses 2 on the scanning disc 3; but reaches the photo-cell 7 only when the proper filter is presented by the disc 5, which is geared (6) to revolve faster than the scanner. (Center) The Fries Universal Scanner: It will be seen, at the left, that A and B combined as at C give a spiral of square holes. Four discs, two spiral (A-B) and two slotted (C-D), at the right give any desired "grain" to the image; and revolving them on two shafts as shown below gives any desired scanning rate. (Right) Optical regeneration is produced by flashing the impulses of the photo-cell back into it from the lamp.

CHAPTER VII

Aircraft Equipment

..'rivate firms have made considerable progress in the development of radio receivers for aircraft service. In the case of a ship at sea mechanical failures or ignorance of position do not always mean disaster. On the other hand, safe transportation by air is intimately connected with knowledge of three directions as well as advanced knowledge of weather conditions. In view of this it is certain that the development of radio instruments to fulfill the severe requirements of aircraft navigation will rapidly advance. In addition to the work of private concerns, the Bureau of Standards in co-

Fig. 121
Flying Laboratory for the Development of Short Wave Radio Receivers.

operation with the Signal Corps Aircraft Laboratories have designed apparatus along this line. One of the first developments was a directive radio beacon which subsequently proved valuable for the guidance of airplanes along Federal airway mail routes. The universal acceptance of this system was retarded by the lack of suitable radio receiving equipment which, of course, should be practically automatic, light weight, simple in control and of extreme sensitivity. In operation it should not detract the pilot or interfere with the operation of the airport. One of the successful designs developed was first introduced by the Radio Frequency Laboratories in 1928. It is now considered a standard receiver of its class for the reception of beacon and weather signals. Adapting a powerful radio receiver to aircraft operation brought up many new physical and psychological factors of importance. It is acknowledged that radio in an aeroplane presents a total new point of view to the engineer operator who was previously trained on the ground. It was realized that research would be worthless without continual practical application and facilities were made available to enable test flights with the radio equipment. In this case it included an associated flying field, radio laboratory, work shop, quarters, etc., besides special aeroplanes. The main plane used for these experiments had space for two pilots, baggage compartment which provided room for batteries, apparatus, etc. The cabin had an operating table, two operators' chairs and a bench for observers. Electrical power was obtained from batteries and from an engine-driven generator. Aerial equipment included a vertical rod for beacon work and a horizontal wing antenna for use with altimeters and other devices and a horizontal fusilage antenna for short-wave communication. This plane was used as a general flying laboratory. The second plane had a single pilot's

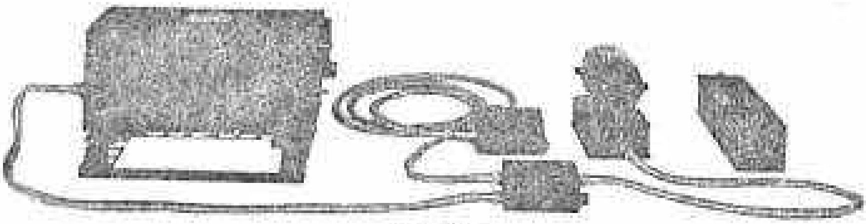


Fig. 122
Type D. Aircraft Radio Receiver, Complete Assembly.

cockpit and a two passenger cockpit of the conventional type. It was equipped with a vertical rod antenna and a horizontal wing antenna, Fig. 121. Tests could be made from this plane to simulate conditions of air mail service or small privately owned planes. Of course, the ignition systems of both planes are thoroughly shielded and experiments are continually being made to improve and simplify this shielding without sacrificing its effectiveness. In designing a set for aircraft work it is first necessary to consider the electrical requirements such as sensitivity, selectivity, over-all characteristics and necessary terminal equipment while other details such as size, weight, power supplies and controls are usually specified in advance. Mechanical design is given first consideration and is followed by the electrical design. The various single elements are first tested and measured and later over-all measurements made of the entire set. The final models are then installed on a plane and actually tested in flight observing the results under actual conditions, making further alterations, followed by tests, until the final model is accepted by the contractor prior to actual production. In the development of receivers for beacon weather service the current practice in radio receiver design is not closely followed. For example, features unjustified in the case of broadcast receivers might be highly useful for aircraft reception. One of the first considerations is high sensitivity and obtaining same with a minimum number of tubes and small power supply. This can be best obtained through the use of new screen grid tubes and the so-called "Hi-Mu" single grid tubes.

Usually only a limited wavelength range is required for each receiver. The special problem of over-loading in the radio detector was encountered in the operation of visual beacon indicators. This was readily solved and this particular research found one practical application which had not even been conceived the time investigation started. The type D aircraft receiver described here in (Figs. 122 to 126) is a development over early receivers of a similar system. The primary wavelengths required are, for beacon and weather service work including the band of 790 to 1,070. The receiver is now constructed to include the interchangeable radio frequency transmitter feature and by changing these transformers it will cover a wavelength range of 235 to 15,000 kilocycles corresponding to approximately 20 meters to 1,235 meters. Remote tuning control mechanism is furnished on special order to fit particular types of installations. The main material used in the

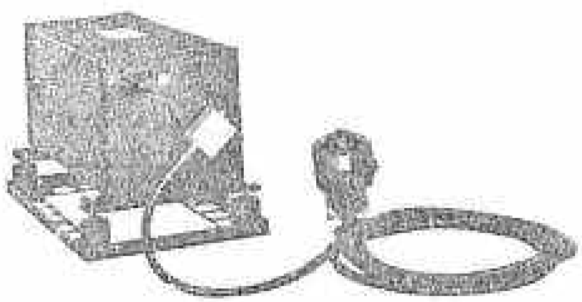


Fig. 123
Type D. Aircraft Radio Receiver, Showing Remote Control Tuning Arrangement.

construction is aluminum and bakelite. Special attention in design has been given to shock proofing, dust proofing and the permanence of the soldered and welded joints as well as other details which became apparent after actual flights in the aeroplane. The receiver is single tuned type and the tuning control dial is engraved and calibrated directly in frequencies, Fig. 123. The second control is provided to adjust the signal intensity. These two controls are usually mounted on the instrument board of the plane together with an "on" and "off" switch and the necessary terminals for checking the condition of the batteries. When following a beacon course the pilot need not readjust the tuning control at all and merely keeps the intensity control adjusted in accordance with his distance from the beacon. The pilot well experienced along beacon courses can tell roughly by the intensity position of the receiver his approximate distance from the beacon itself. The receiver proper, Fig. 124, is very compact measuring 15 by 9 by 7 inches and weighing approximately 12 pounds. The receiver together with all the necessary accessories weighs approximately 31 pounds.

The sensitivity of the receiver is so high that the range is usually only limited by external factors such as the power of the transmitter, completeness of the ignition shielding and intensity of the static. Using this receiver it is not uncommon to report useful beacon service at night in the winter

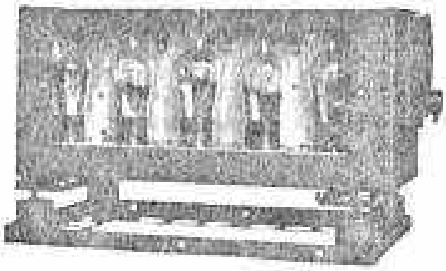


Fig. 124
Type D. Radio Aircraft Receiver, Tube Compartment.

covering a range of 250 miles from a 2 kilowatt beacon. A more conservative range under the same circumstances would be 150 miles from land. In connection with the development of the receiver itself it has been necessary to spend considerable time to develop complete shielding for the electric ignition systems both for the radial and water-cooled engines. The design of the receiver also led into the design of an associated self-supporting rigid antenna for use in reception of weather and beacon signals, also the design of an electrical altimeter. This latter instrument works on the principal whereby the distance of an object or surface in the path of the train of electrical waves can be determined by the use of the interference phenomena between the direct wave and wave reflected from the obstacles. This system has an outstanding advantage inasmuch as it indicates the absolute height of the instrument above ground, water or obstacles to landing over which the aircraft may be flying instead of indicating the height above sea level or above the predetermined point which is all the ordinary aneroid altimeter will show. The apparatus for such an electrical wave altimeter is relatively simple and practical instruments of this type are now available.

A radio receiver capable of high sensitivity imposes severe demands on the degree of ignition shielding. In the early days the radio receivers for aircraft were of low sensitivity and they used a trailing wire antenna. Accordingly, the use of ignition shielding was unjustified. The present plans call for a rigid vertical antenna necessary for the successful use of radio beacon which also eliminates physical hazards. To operate from such a small aerial the receiver must have high sensitivity and accordingly, the ignition system must be completely shielded. The degree to which it is shielded determines the actual distance from which reception can be accomplished. Of course, no radio signal can be received and promptly interpreted in an aeroplane unless it is strong enough to produce greater currents in the receiving antenna than is set up by the electrical discharges of the electrical ignition system. In a like manner it follows that the smaller the ignition

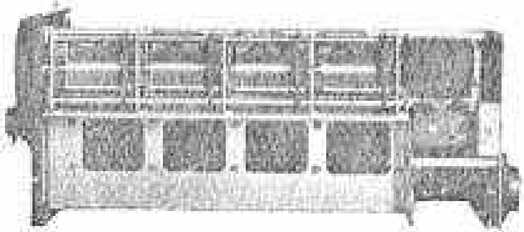


Fig. 125
Type D. Aircraft Receiver, Multiple Tuning Condenser.

interference the weaker the radio signal that can be received and the range extended.

In the case of water-cooled engine the metal cowling often provides a satisfactory enclosure for the high tension system and it is only necessary to shield the low tension wiring which enters the cockpit. On aeroplanes using air-cooled radial engines without the stream line cowling it is necessary to add the following shielding elements:

1. Metal covering over the magneto terminal box; 2. Metal covering over the high tension harness; 3. Either shielded spark plugs or metal housing over the standard plugs; 4. Metal housing on the low tension circuits including the magneto switch box.

Fig. 126
Type D. Aircraft Receiver, Interchangeable Radio Frequency Transformers.

It should be pointed out that the use of shielded spark plugs or shielded covers reduces the interference to such a large extent that a receiver can be used having 30 to 40 times the sensitivity as may be used with unshielded plugs. Shielded plugs of an improved design are now available commercially. As a matter of fact some manufacturers of air-cooled engines can supply a completely shielded ignition system on regular order. The schematic wiring diagram of the Type D receiver developed by the Aircraft Radio Corporation is shown in Fig. 127. Fig. 122 gives a general view of the receiver showing the flexible control for remote installation. It will be noted that the tuning dial is calibrated directly. Fig. 124 shows the tube arrangement and also the provision made for shock proofing. It will be noted that there are three screen-grid radio frequency stages, a screen-grid detector of the plate rectification type to prevent over-loading and one audio stage using a 227. Although the set is operated from a generator battery it will be noted that AC type tubes are used. There are several advantages including freedom from microphonic disturbances and the high amplification obtained from this type tube. Fig. 122 shows a completely assembled receiver, junction box, control box generator and case for extra radio frequency transformers.

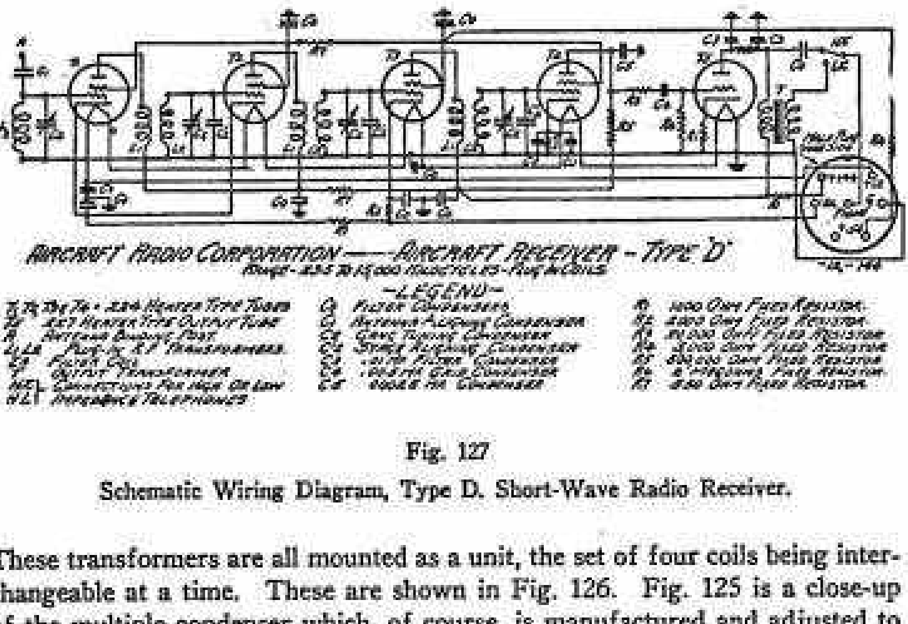


Fig. 127

Schematic Wiring Diagram, Type D. Short-Wave Radio Receiver.

These transformers are all mounted as a unit, the set of four coils being interchangeable at a time. These are shown in Fig. 126. Fig. 125 is a close-up of the multiple condenser which, of course, is manufactured and adjusted to a very high degree of accuracy. One of the test planes is shown in Fig. 121 showing the vertical antenna and also the wind generator mounted in one of the right hand struts. There are a few additional features of the receiver design which are interesting. The use of screen-grid tubes in the radio frequency amplifier provides a radio gain of approximately 50 per stage compared with a gain of 10 or at the most 15 per stage ordinarily obtainable with regular tubes. This increase in gain is highly desirable due to the limitations of space and weight. This type tube is not so acceptable for the detector on account of microphonic noises.

It is absolutely essential that the detector be arranged to prevent overloading and this is accomplished by plate rectification with automatic bias. This feature is particularly important when using the receiver with the visual type of beacon indicator. The pilot when approaching the beacon may neglect to keep his reed amplitude down to the proper level by an adjustment of the volume control. Under such conditions the detector may be so overloaded as to cause the reed amplitude to pass through a maximum and then fall to normal levels. This might create a situation where the indicated course would be reversed, i.e., the reed of lesser amplitude would indicate the side in which the aeroplane was out of course. With plate rectification a somewhat higher output may be obtained than with grid rectification or overloading. In either case, however, reversal or lack of course indications may result if the input circuit is increased abnormally. Plate detection with automatic grid bias has other advantages. It is commonly supposed that grid rectification results in greater sensitivity than plate rectification. As a matter of fact, the micro-volt sensitivity of this particular receiver is twice as great with plate rectification as with grid detection although the small signal detection factor for the latter is about three times as great as for the former. Plate detection exceeds grid rectification in this case because it leaves unaffected the radio gain of the preceding stage whereas due to electronic conductance grid detection reduces this gain by a factor greater than 2 to 1. In a like manner the sensitivity is considered greater with plate rectification than with grid rectification. The high output impedance resulting from plate detection does not impair the uniform transmission of low modulation frequencies required for the visual beacon provided, of course, the coupling between the detector and the audio amplifier is properly designed. It will be noted that the detector is coupled to the first audio stage by the resistance method which has the advantage of saving in weight, economy of battery drain and uniform transmission of the required modulation frequencies.

The Western Electric Company produces a similar aircraft receiver, exterior view shown in Fig. 131 and the same equipment with the cover removed in Fig. V. It will be noted that screen grid tubes are used for the radio frequency stages, that the radio frequency transformers are of the interchangeable type and that the tubes are of the AC heater type. The radio frequency transformers are contained in a shielded case and perforated screen shielding is provided for the screen grid tubes. Fig. 132 is the top view of the same receiver and Fig. 133 is the bottom view with the base removed showing the whole case with the various tube and coil sockets, choke coils, by pass condensers, etc.

This particular receiver weighs approximately 16 pounds and is arranged so that it may be located in any part of the fusilage where space is available. This means that it must be remotely controlled and a suitable flexible mechanical device is provided. The tube arrangement consists of three stages of radio frequency amplification using screen grid tubes, a space charge grid detector and one stage of resistance—capacity coupled audio frequency—all tubes are of the equi-potential cathode type simplifying the operation in as far as the noisy source of power supply is concerned. The use of three tuned circuits gives a high degree of selectivity and no interference between stations operating on adjacent bands from the signal desired. A band pass filter is included in the antenna circuit preventing interference from low frequency broadcast stations. While it is possible to operate the receiver from B batteries a less troublesome power supply is desirable. This can be accomplished in two ways—one using a motor generator from a 15 volt aeroplane battery or using a double voltage wind-driven generator. The

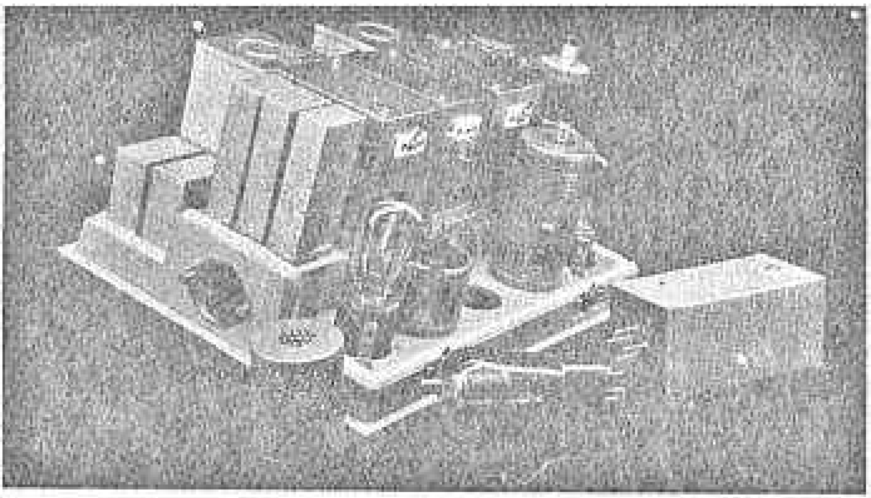


Fig. 128
Western Electric Aircraft Radio Receiver, Cover Removed, Note Tube Shields and Removable Shielded Radio Frequency Transformers.

latter unit is most desirable especially on small planes not having any battery. The wind-driven generator is driven by a self-regulating propeller which maintains a constant speed of 6,500 r.p.m. for all flying speeds of the plane. At this speed the generator gives 13 and 230 volts for the A and B supplies respectively. A ballast lamp takes care of variations in the filament circuit. This unit can be seen in the right-hand corner of Fig. 128. On a plane not of all metal construction, all metallic parts of it must be closely bonded together. This includes all hinges, variable control surfaces or other joints of any description and they must be by-passed by a metal bonding around the movable surface. This is a very important feature to insure freedom from interference of the radio receiver and, if possible, this should preferably be taken care of while the plane is under the course of construction. Fig. 128 shows the general assembly with the cover removed. The schematic wiring diagram of the receiver (tuned radio frequency type) is given in Fig. 129. The transmitter to match, is built along the system shown in the schematic wiring diagram, Fig. 130.

Short Wave System for Blind Landing of Aircraft

One of the first attempts to develop a radio system for the blind landing of aircraft was started by the Aeronautics Branch of the Bureau of Standards in the latter part of 1928. The idea was to develop a simple and effective radio system which could be used in combination with the regular aircraft navigating instruments to permit the safe landing of aircraft at airports under conditions where the visibility was extremely poor.

A successful system of this nature must indicate to the pilot the position of the aircraft in three directions as it approaches and reaches the moment of landing. Following the practice used for radio course indicators it was decided to use the simplest possible equipment on board the aeroplane and have the complicated bulky apparatus on land.

The apparatus developed fulfills all the various requirements, is very simple in operation and the pilot receives all the desired information with little effort on his part. The necessary radio apparatus on board the plane is very simple not having any variable adjustments and weighs only approximately 15 pounds.

A radio beam has been used to aid point-to-point flying for the past two years and the service given by this radio range beacon system on Federal airways has been very practical. This system enables the pilot to keep accurately on his course, know approximately the points over which he is flying and proceed directly to his destination. The flying can then be kept closer to schedule and under many conditions flights can be made which under ordinary conditions could not be made without the aid of these radio direction facilities. It is apparent, however, that the simple course direction system is not sufficient if the landing fields lie in an area of poor visibility. The improvements secured by the development of instrument flying and radio navigation apparatus are nullified unless there are suitable means to provide a safe landing at the desired destination. The system of radio aids to blind flying described herein should serve to insure the regular maintenance of schedule flying whether by day or by night.

The idea of using a local field radio beacon was suggested by the success of similar apparatus for the point-to-point flying. In addition to the main beacon used for guiding an aeroplane to a given landing field it was decided that a lower power beacon with simple loop antennae could be employed for marking out the major or any desirable axis of the landing field. The lower power marker beacons could then be used to define a hazard free approach to the field along the axis or runway selected and for indicating the longitudinal aircraft course along the runway. Two outstanding advantages are secured. The same receptive equipment on the aeroplane as required for the fixed airways was satisfactory for the reception of signals from the local beacon and marker beacons. Secondly, the ground equipment was simple and inexpensive, a moderate power transmitter for the runway localizing beacon being satisfactory for marking out a course for a distance range of approximately ten miles. The marker beacon power requirements

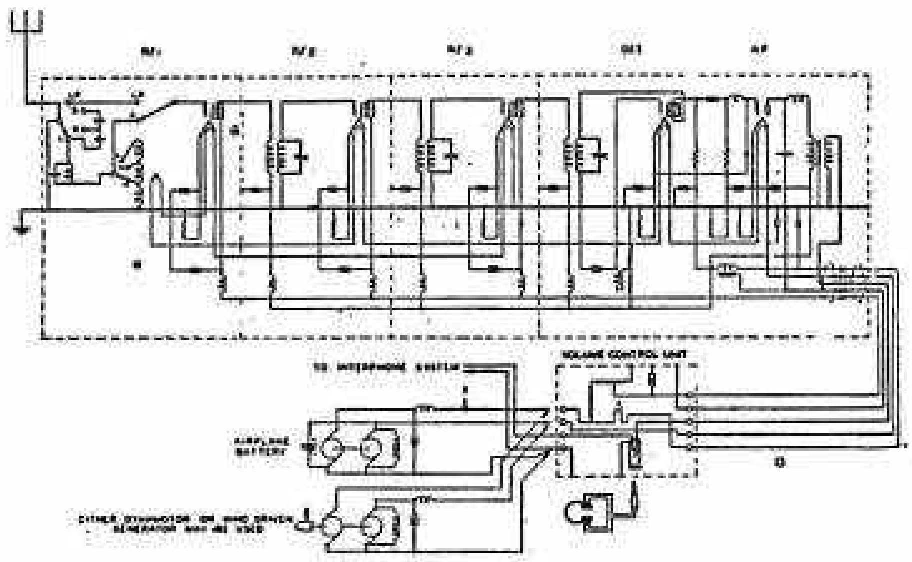


Fig. 129

Schematic Wiring Diagram. W. E. Aircraft Receiver, Note A. C. Heater Type Tubes Are Used.

are also small. All the apparatus could be located conveniently within the limits of the airport.

A system of this type was first tried out at College Park, Maryland, in November, 1928. The test flights demonstrated that as far as landing field localization was concerned it was perfectly feasible, but the problem of altitude indication was not solved. Further experiments were made leading to a landing beam and the first successful flights using this transmitter were made in July, 1929. Fig. 134 illustrates the landing beam transmitter itself as installed in the airport. It operates on an ultra high frequency of the order of 10,000 kilocycles. The beam is directed at a small angle above the horizontal and is arranged to provide a convenient gliding path for the landing aeroplane starting at from 500 to 5000 feet altitude and approximately two to five miles distant from the landing field. Referring to the photograph of the beam transmitter again, it will be apparent that the construction is very simple. The directive antenna system consists of the doublet horizontal antenna shown running perpendicular to the main supporting structure. The angle of the landing beam above the horizontal is determined by tilting this horizontal structure about the vertical support shown. Fig. 140 gives a plan view of the airport ground transmitting equipment for field localization. The main radio beacon for point-to-point flying on the Federal airways is located at A, a 2 kilowatt instrument. This beacon serves to direct an incoming aeroplane to the vicinity of the airport. It is usually located out-

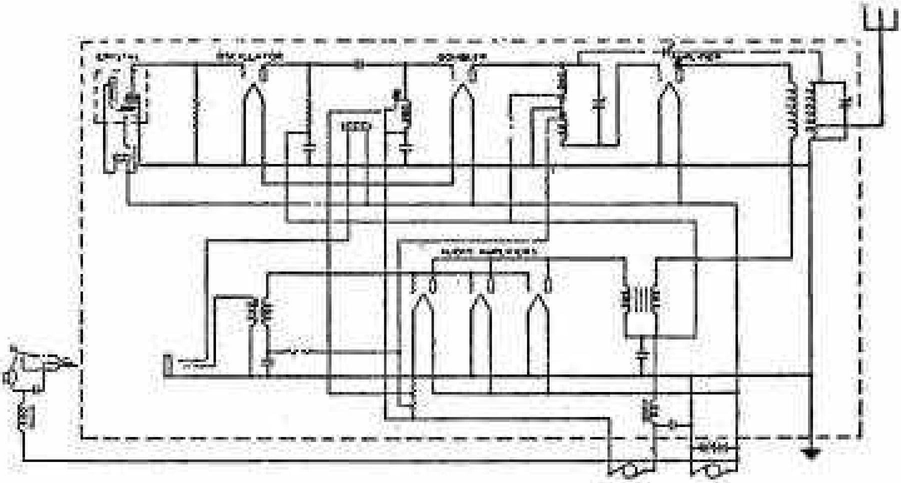


Fig. 130

Schematic Wiring Diagram, W. E. Aircraft Transmitter.

side the actual flying field so that the loop antenna does not constitute an obstruction to flying. The runway localizing beacon is shown at B and it is of 200 watts power. This is also located at one edge of the landing field without constituting an obstruction and directs the course along the particular landing strip to be used. It operates at a radio frequency separated by 50 to 60 kilocycles from that of the main beacon A, thereby preventing interference from the main beacon. The landing beam transmitter shown at C and point D indicates where this first beam is picked up by the aircraft. The marker beacon E indicates the boundary of the landing field and operates on the same radio frequency as the runway localizing beacon. From the above it is apparent that a complete system indicates the main course by the means of radio range beacon A, landing field runway direction by means of the landing field beacon B, altitude indication by means of the landing beam C and longitudinal position (approach) along the runway by means of the boundary beacon D. Installed on the aeroplane a simple medium frequency receiving set and a vertical mast antenna receive all these indications except the landing beam signals. A special high frequency receiving set is provided for the latter and works in connection with a horizontal doublet antenna about five feet long. Figs. C and D illustrate the action of the altitude indicating instrument. The medium frequency set is equipped with a visual range beacon reed indicator. An automatic volume

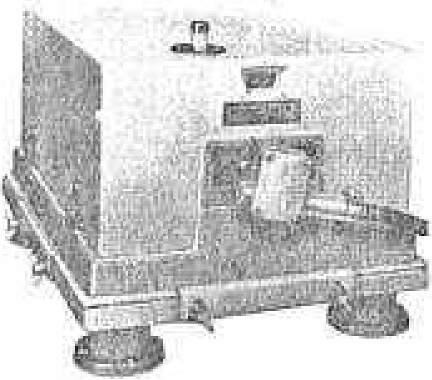


Fig. 131
W. E. Aircraft Radio Receiver.

control may be used to receive the beams from the main radio range beacon and also the runway localizing beacons. Through the use of a special filter circuit reception of the aural boundary marker beacon is permitted while the leads on the visual beacon indicator are functioning. The distance away from the transmitter can be approximated and is determined by the rough distance indicator. This is in reality an adaptation of the conventional tuning meter on the sets provided with automatic volume control. Both the main beacon A and the localizing beacon B are of the visual type. The essential difference between the two lies in the power ratings, the number of beacon courses radiated and dimensions of the loop antennas. The two loop antennas cross at 90 degrees carrying currents of the same carrier frequency but modulated to different low frequencies, in this case 65 and 86.7 cycles respectively. The visual indicating instrument on the aeroplane consists of two vibrating reeds mechanically tuned to these two low frequencies and excited by small electromagnets connected in the output circuit of the receiver. When the beacon signals are received the two reeds vibrate and the comparison of their relative amplitudes of vibration serves to indicate the relative amount of signal received from the two improved antennas. When the aeroplane is exactly along the line bisecting the angle between the two antennas the reed vibration amplitudes are equal. Off the course they are

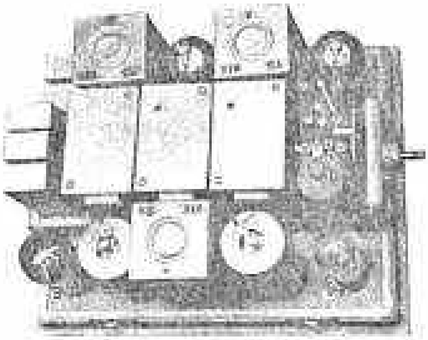


Fig. 132

W. E. Aircraft Receiver, Top View.

unequal and if the aeroplane deviates to one side the reed on that side will vibrate with a greater amplitude than the one on the opposite side.

The time phase displacement between the carrier current and the two loop antennas can be adjusted to provide either two or four courses from the beacon. The four course arrangement is often used for the fixed airways while the two course arrangement is more desirable for the localizing beacon. First going in for landing the presence of the course at right angles to the runways might be confusing. The 50 watt transmitter feeding a loop antenna is used for the boundary beacon. This modulated wave is fixed at 1,000 cycles per second and is obtained automatically by supplying the transmitting tube with an alternating voltage of that frequency. At the receiving end ear phones connected in series with the main course indicator are employed with the special filter circuit. The boundary line is defined by a 0 signal zone two or three degrees wide. In flight the pilot observes an increase in the marker beacon signal as he approaches the edge of the landing field, a decrease to 0 as he passes over the boundary line and then again an increase in signal as he comes in the landing field area. On the aeroplane the signal

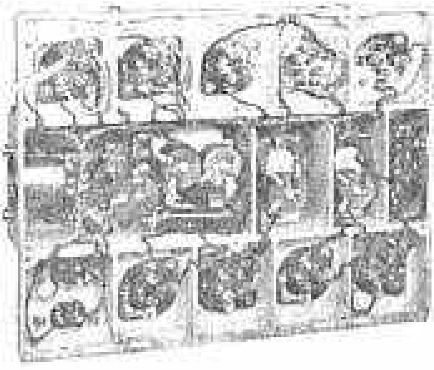


Fig. 133

W. E. Aircraft Receiver, View of the Bottom Wiring.

current in the output circuit of the special high frequency receiving set used exclusively for the landing beam is rectified and passed to a landing beam indicator, Fig. E, which is mounted on the instrument board. The aeroplane does not fly on the axis of the beam but on a curved part directly under the beam, the curvature diminishing as the ground is approached. The path is the line of equal intensity of the received signal below the axis of the beam. The decrease of intensity as the aeroplane drops below the beam axis is compensated for by the increase of intensity due to approaching the beam transmitter. Therefore, flying the aeroplane along such a path as to keep the reflection of the landing beam indicator constant, the pilot comes down to the ground on a curved line suitable for landing.

The obvious advantages are that the pilot following the landing path is automatically kept above obstructions and does not need a thorough knowledge of the terrain in order to effect a safe landing. Secondly, the landing path may be adjusted to suit different landing fields which is particularly important in getting safe landings into a small landing field. A further advantage lies in the fact that in following the landing path the pilot automatically levels off, therefore facilitating a normal landing. In following the landing path prior to receiving the boundary marker beacon 0 signal zone the pilot maintains an air speed somewhat above the landing speed of the plane having the craft under complete control with some margin to spare. Upon receiving the marker indication that he is passing over the boundary of the field the aeroplane speed may be adjusted to slightly over the landing speed. The landing is therefore at a speed approaching the normal landing speed of the aeroplane landing under normal visibility. The still further advantage is that the landing glide may be started at any desired altitude of any range, for example, 500 to 5000 feet. The special high frequency receiver is illustrated in Fig. 139 and the installation of the same apparatus is shown in Fig. G upon the aeroplane. The circuit used for this special high frequency receiver is shown in Fig. 136 and the transmitting circuit in Fig. 138. The vacuum tube oscillator itself of the ultra high frequency type is shown in Fig. 135. All during these operations it is not necessary for the pilot to do any turning and furthermore, since the line of constant field intensity is followed, no volume control is necessary.

The operations necessary for the pilot to follow (see Fig. 141) in using this new system are given below. It is, of course, necessary that the associated flight instruments are available and installed on the plane to insure stability. When the medium radio frequency receiving set is tuned to the main radio range beacon (280 kc) and indications as to the correct course leading to the airport on the reed indicator, automatic volume control being provided the pilot need not bother about this feature. Fig. 141 gives you a prospective view of the aeroplane approaching the field along the radio range beacon. Of course an indication will be noted by the pilot as he passes exactly over the beacon. Information as to wind direction velocity will be transmitted to him by radiophone from the control tower of the airport provided this factor has to be taken into consideration. As this system is for schedule flying it is assumed that the pilot has a knowledge of the location of the airport with respect to the radio range beacon transmitter station.

The pilot will then make a wide circle of the field in a counter-clockwise direction. He will switch over his medium frequency receiving set to tune in the runway localizing beacon. Arriving in this beam he will then throw the switch which places the landing beam receiving set in operation and these are the only adjustments of the radio equipment required of the pilot during the entire landing manoeuvres. The reed indicator now serves to keep the pilot on the axis of the runway on which it is desired to land, the automatic volume control eliminating the necessity of any sensitivity adjustments in operating the transmitter. At the same time the rough distance indicator informs him of his approximate distance from the transmitter. As the plane comes within the field of the landing beam the landing beam indicator tells him whether he is flying above or below the normal gliding path. See Figs. 137 and 142. The altitude of the plane is then adjusted to hold this pointer on the midscale position, thus bringing the plane down along the gently curved path tangent to the surface of the runway at a predetermined distance from the landing beam transmitter. It is necessary for the pilot to keep accurately on the runway beacon course and at the same time following down on the landing beam path. This is facilitated by reducing the aeroplane engine speed so that the landing speed is just slightly above normal. This, of course, also helps the actual landing. The runway beacon course accuracy should be kept within ± 3 degrees. This is necessary in order that the landing beam may be encountered head-on; otherwise a landing path steeper than the one desired would be followed. It is not difficult to follow the course of the necessary accuracy since a variation of ± 1 degree may be observed on the reed indicator.

A certain distance from the landing field boundary line the pilot begins to hear the 1000 cycle signal through his head phones from the boundary marker beacon. This signal first increases gradually, reaches a maximum then decreases to 0 and begins again. The principal idea of this boundary marker is to establish a definite period after which the landing beam indications become of first importance. It is then possible to throttle down the engine to landing speed and manoeuvre the plane to follow the landing path accurately to the actual point of landing.

The above described system is, of course, limited to a given wind direction. However, there are unlimited possibilities of expansion to take care of this feature. It is unusual to have dense fog accompanied by a strong wind. However, blinding snowstorms, heavy rains and similar conditions often offer almost as great limitations to visibility as fog. The factor of wind direction cannot be neglected in the general problem of blind landing and developments are now in progress with a view to making possible blind landings into the wind regardless of wind direction. This will probably be readily accomplished by having the marking beacons and beam beacons on an adjustable device so that they can be regulated to suit the wind conditions. In this case it would probably be of great assistance if the pilot were perfectly familiar with the various landing fields following his route so that he would be prepared to pick up the beams in whatever direction they might be pointed.

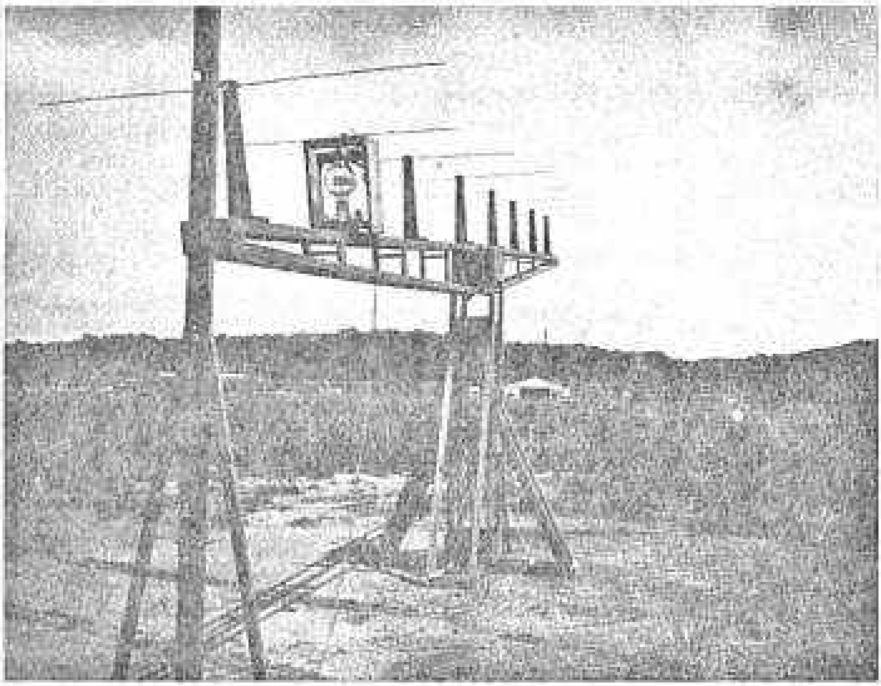


Fig. 134
Beam Transmitter for Guiding Aircraft (in relation to altitude).

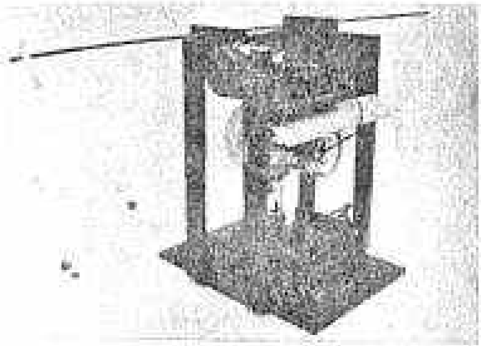


Fig. 135

Ultra High Frequency Oscillator for Airport Altitude Guiding Transmitter.

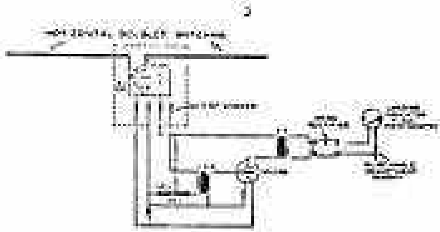


Fig. 136

Receiving Circuit as Used On the Airplane.

Fig. 137

Fog Landing Glidometer.

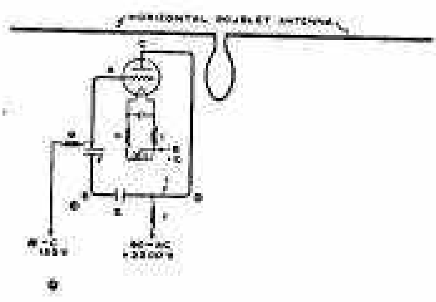


Fig. 138

Oscillator Circuit Used for the Land Transmitter.

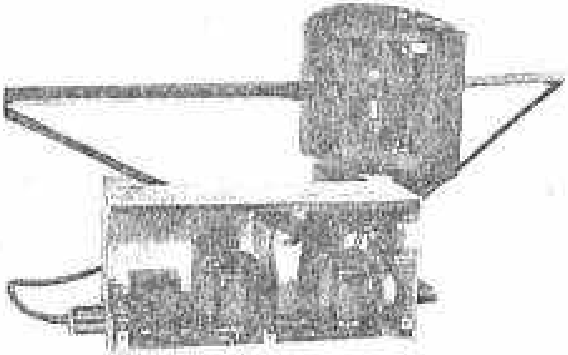


Fig. 139

Construction of the receiver as installed on the plane.

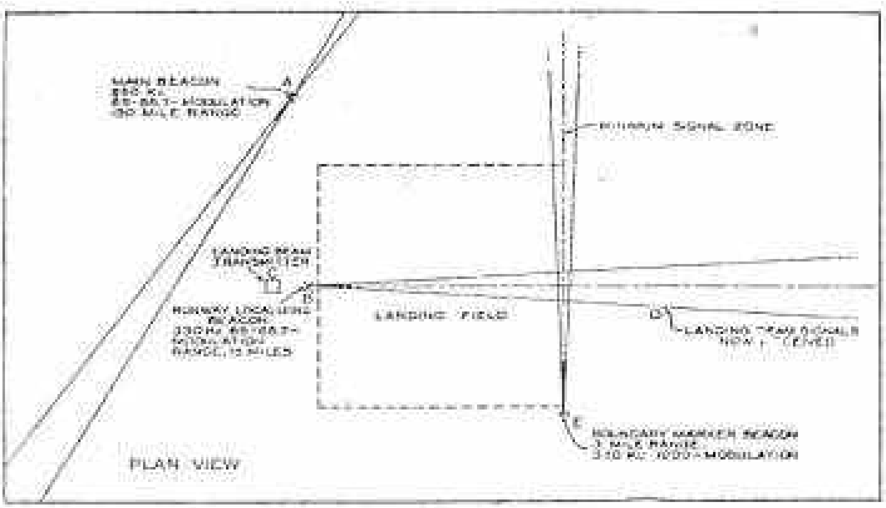


Fig. 140

Plan View of the Airport (typical), Showing Radio Beacons, Markers and Beam Signals.

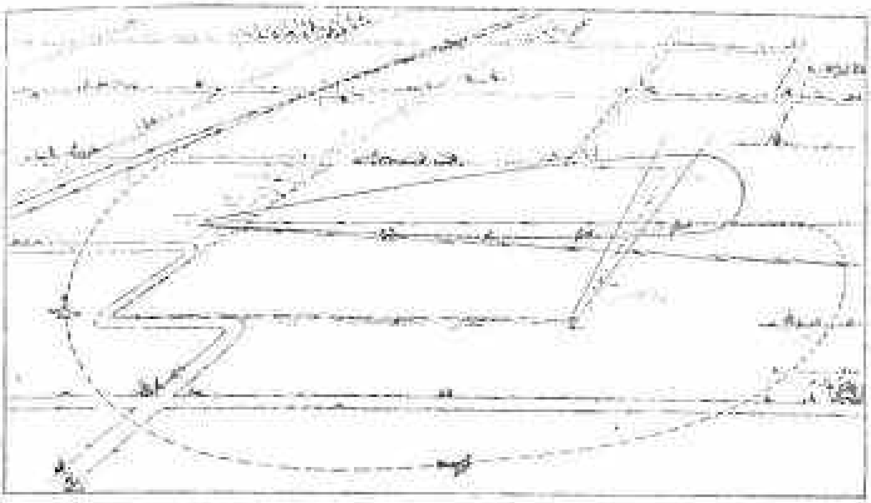


Fig. 141

Typical Airport with Radio Guiding Beacons and Showing Course Taken by Plane to Land in a Fog.

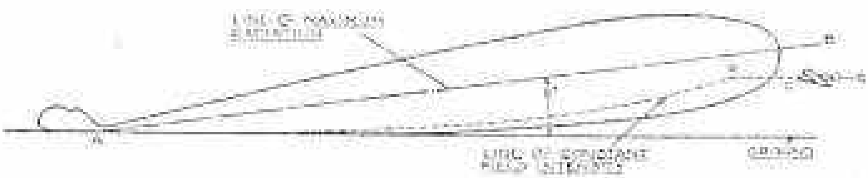


Fig. 142

Radiation from the Ultra Short Wave Guiding Transmitter.

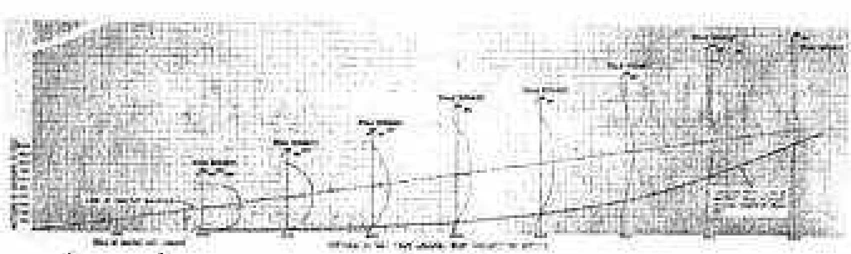


Fig. 143

Plotted Graph Showing Relation of Maximum Radiation to Constant Field Strength.

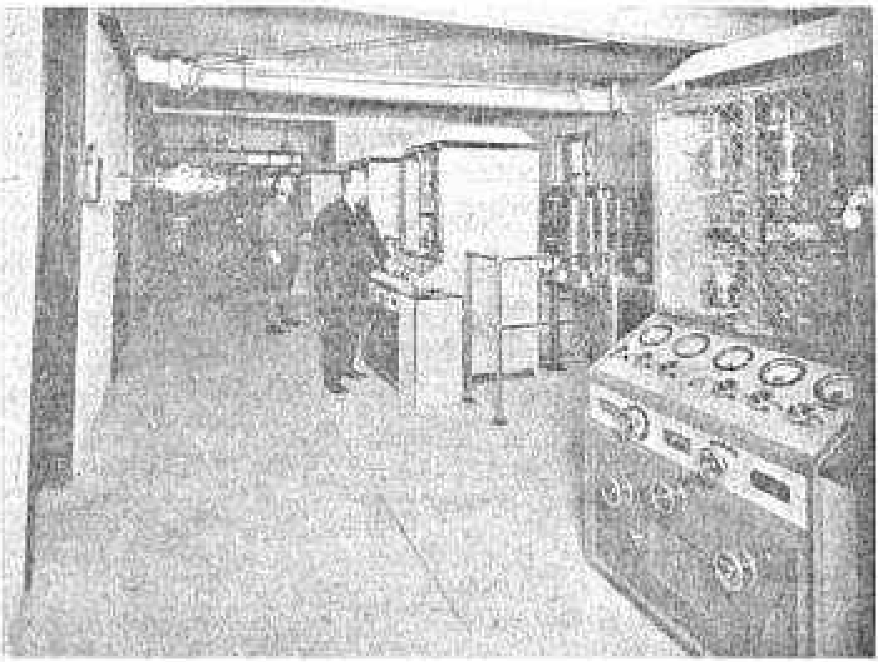


Fig. 144

The London Airport, Croydon, Interior View of the New Transmitting Equipment, Consisting of Four Marconi 3 KW Aerodrome Ground Transmitters, for either Telephony or Telegraphy.

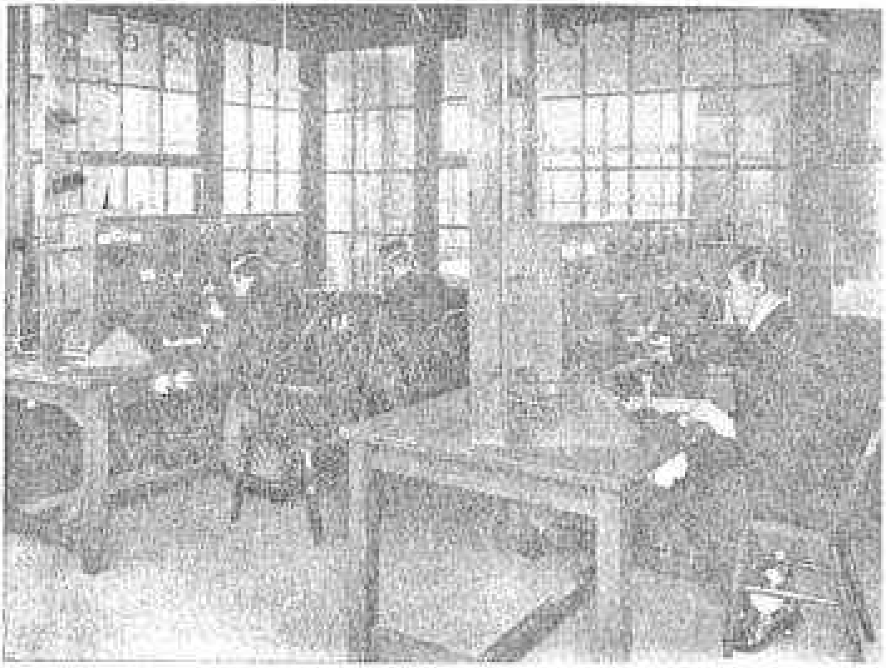


Fig. 145

Croydon Aerodrome, Interior of the Control Tower, Showing Operators receiving on Two Marconi Type RG 14 Directional Receivers, Which Enables Simultaneous Reception and Directional Finding of Two Different Transmitting Stations in the Air.

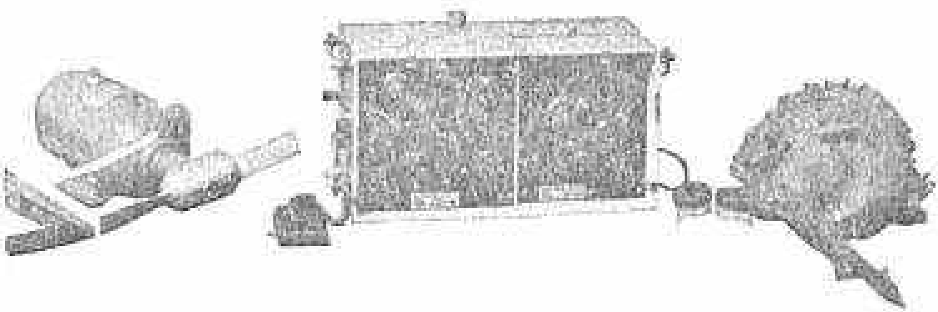


Fig. 146

Marconi Type A.D. 22 "Light Plane" Combined Radio Receiver and Transmitter. Total Weight approx. 80 lbs., Receiver size 20"x9"x8".

Ultra-Short Waves for Limited Range Communication

The following description covers a series of ultra-short-wave experiments conducted by W. J. Brown of Uxbridge, England. The idea was to investigate the possibility of using ultra-short waves on the order of two meters or lower, for communication purposes.

A fair amount of experimental work had already been carried out on methods of producing short-wave oscillations of limited power, and this had

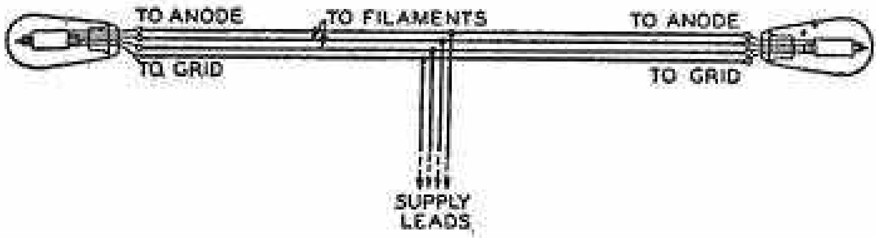


Fig. 134 (a)

shown an arrangement, comprising a pair of ordinary 5-watt tubes having their bases removed and their corresponding electrodes connected by straight parallel conductors, to be satisfactory. Two varieties of this kind of oscillator had been tried, as shown in Figs. 134(a) and 134(b). In the first of these, the tubes are located at the extremities of a perfectly straight system of conductors, while the leads for supplying energy to the system are connected to the mid-point of the straight-conductor assembly. In operation the straight-conductors form, together with the interelectrode capacities of the tube, an oscillatory circuit, and if the conductors are suitably arranged so as to obtain correct phasing of the anode and grid voltages, the tubes will generate oscillations at a wavelength depending upon the length of the system.

As the arrangement is symmetrical about the mid-point of the conductor system, this point is a potential node on the oscillatory circuit and provided the power supply leads are connected to this point and taken away roughly at right angles to the oscillatory circuits, no radio-frequency currents will flow in the supply leads and there will be no power loss on this account.

Since the length of the oscillatory circuit is a considerable fraction of a wavelength, a fairly high percentage of the radio-frequency energy produced will be radiated into space, and the transmitter thus forms, to a certain extent, its own antenna, though the radiation is improved by coupling to the transmitter circuit a regular half-wave antenna.

In the second type of oscillator shown in Fig. 134(b), high-frequency radiation is minimized by doubling the oscillatory circuit back upon itself so that the currents in the two halves of the circuit produce equal and opposite fields at a distance.

This type of oscillator was used in the earliest communication experiments. The radiating system comprised a half-wave antenna which was broken at its mid-point and connected so as to include a short length of the tube oscillator circuit (see Fig. 134(c)). By adjusting the points at which the two halves of the antenna are tapped on to the oscillatory circuit, the loading imposed on the oscillator by the antenna may be varied at will. The dimensions of a satisfactory arrangement, with reference to Fig. 134 (c), were as follows:

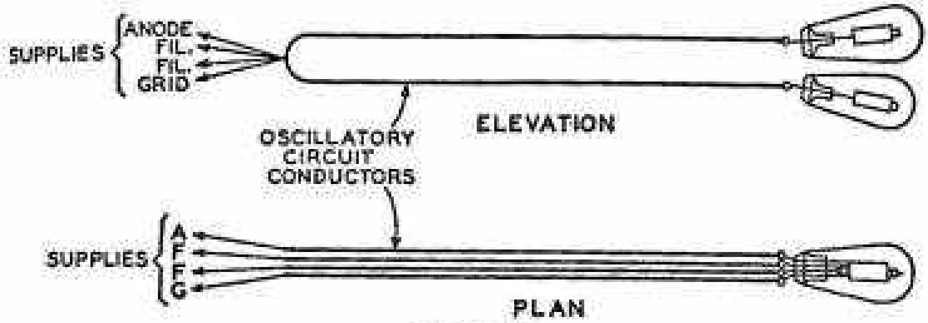


Fig. 134 (b)

total length of oscillatory circuit $(O\,A - O\,B)$	= 50 cm
total length of antenna $(U\,X - V\,Y)$	= 100 cm
length of common coupling circuit $(X\,O - O\,Y)$	= 5 cm
distance apart of parallel circuits $(X\,Y)$	= 1.25 cm
type of tube employed	Marconi LS5
wavelength	2.00 meters

The radiation was estimated by a small hot-wire ammeter located in the antenna circuit at X or Y. Typical results for the arrangement were

r.m.s. a-c voltage applied to anodes (500 cycles)	= 550 volts
average value of plate current	= 50 milliamperes
antenna ammeter reading	= 0.3 amperes

It should be noted that the antenna ammeter reading is useful for comparative purposes only, and its absolute value is subject to considerable error at such high frequencies.

Receiving Apparatus

The next question was to decide on the most suitable type of receiver. Heterodyne reception appeared at the time to be out of the question on account of the difficulty in maintaining the extreme constancy of frequency required (a constancy of the order of one in ten million), and greater sensi-

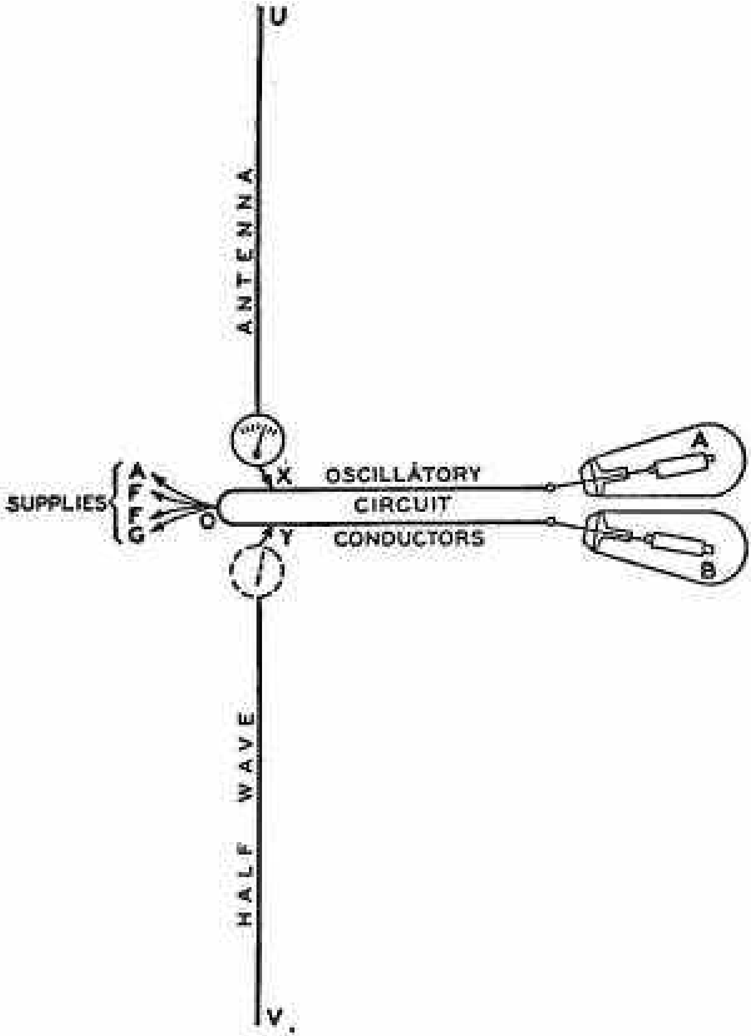


Fig. 134 (c)

tivity was required than could be obtained by using an a-c transmission and a regenerative receiver. The super-heterodyne again was considered too critical in its demands for constancy of frequency. The super-regenerative or periodic-trigger type of receiver appeared to be the most promising since this combines the qualities of extremely high sensitivity and flatness of tuning. Experience with this type of receiver at wavelengths of the order of 20 to 100 meters had already shown it to retain these properties at short wavelengths, and furthermore, they showed that at such wavelengths this type of receiver lost its objectionable uncontrollability and became in fact unusually easy to manipulate. The quenching frequency may be well above audibility so that the circuit does not have the objectionable high-pitched whistle that occurs with long-wave reception; for the two-meter receiver about to be described, a quench frequency of 300,000 cycles was employed.

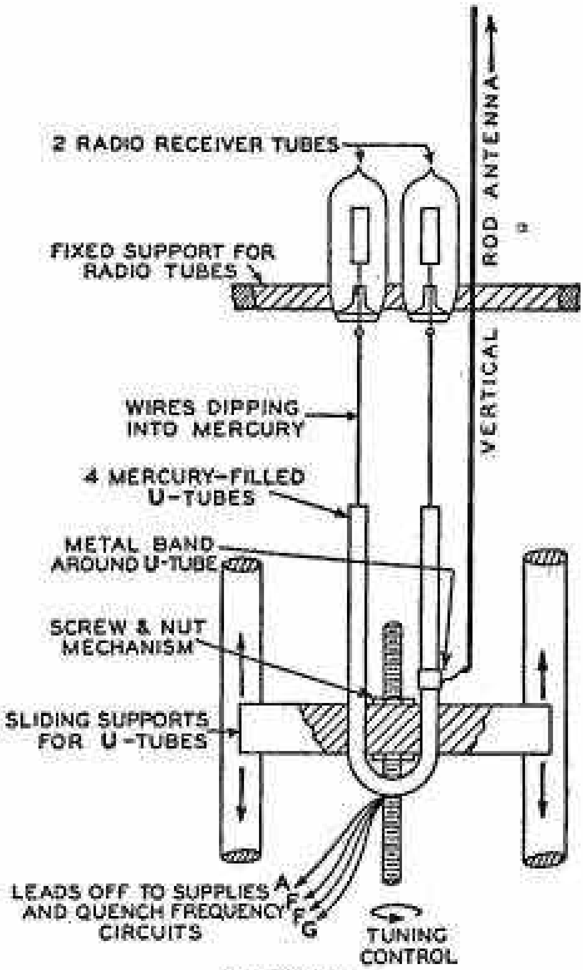


Fig. 134 (d)

The adjustment or control of the short-wave tuning of the receiver presented a new problem; it was considered inadvisable to employ a variable condenser, however small, for this purpose on account of the desirability of keeping the L/C ratio as high as possible. It was finally decided to employ a circuit similar to that used for the transmitter shown in Fig. 134(c), and to adjust the tuning by varying the length of the straight oscillatory circuits *OA*, *OB*. This was carried into effect by mounting the *U*-shaped oscillatory circuit in a vertical position and making the lower portion of it consist of a system of ebonite *U*-tubes filled with mercury, while the upper portion comprised a set of straight rods sliding in the *U*-tubes. Tuning was effected by raising or lowering the *U*-tubes, thus shortening or lengthening the circuit. The arrangement is shown diagramatically in Fig. 134(d). The antenna comprised a quarter-wave vertical type attached to a metal band encircling one limb of the *U*-tube connecting the grids of the radio tubes.

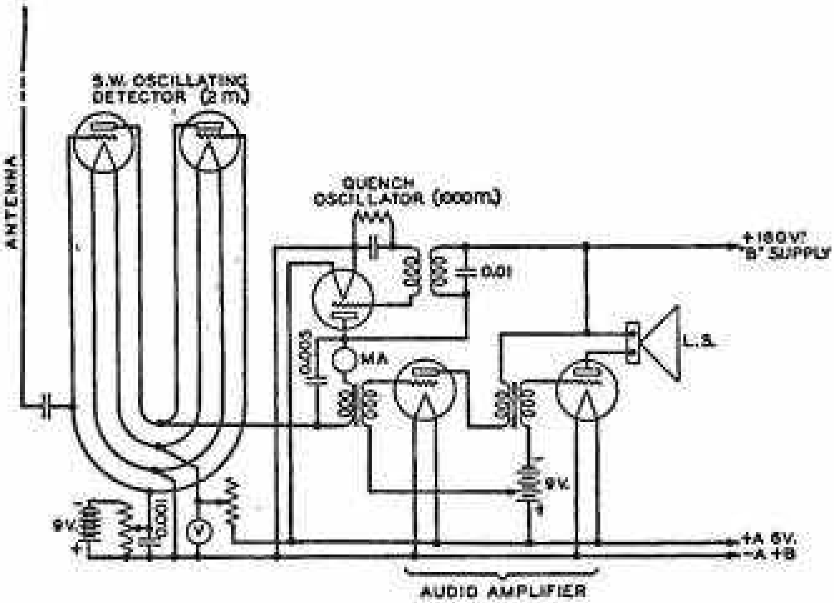


Fig. 134 (e)

The apparatus just described comprises the oscillatory detector unit of the short-wave super-regenerative receiver and its position in the circuit is indicated in the receiver diagram, Fig. 134(e). In the practical layout of the portable receiver employed for the tests, this oscillatory detector unit with its antenna was mounted on the top of a copper-lined wood box measuring roughly 24 in. long by 14 in. wide by 11 in. deep; this box contained the whole of the quenching-oscillator and audio-amplifier circuits as well as the batteries and loud speaker.

The only portions of the receiver which were external to the screening box were the oscillating detector and its antenna, the loud-speaker horn, and the controls. All the controls were mounted at one end of the copper-lined box, including the short-wave tuning control which operated through a bevel gear and a screw-and-nut movement to raise and lower the *U*-tubes.

In the tests, the transmitter referred to above and shown in Fig. 134(c), was supplied with alternating current at 500 cycles, and the receiver picked out this audio-modulation frequency.

Range Tests

Preliminary trials indicated that a range of the order of several miles was to be expected, and a series of tests was therefore carried out along the coast of North Wales, to make definite observations of the range. The North Wales coast was chosen for these experiments since it comprises a number of wide bays, across which signals could be transmitted without the intervention of land. Since the possible applications of the system are principally for maritime purposes, the above tests simulated the working conditions which would be encountered in practice.

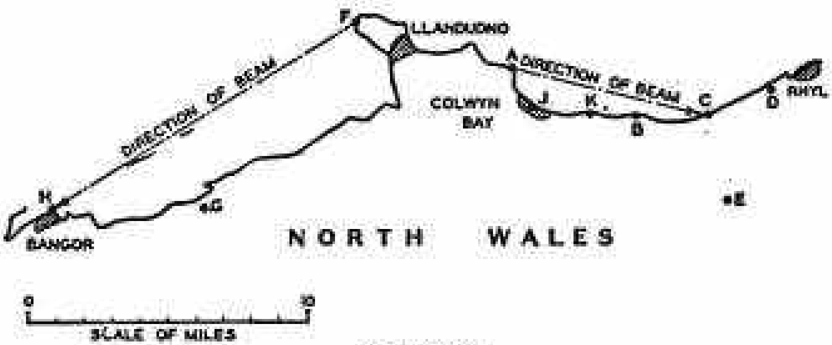


Fig. 134 (i)

For the purpose of the tests, the transmitter and antenna complete were mounted on a 7-ft. vertical ash pole and the necessary low-frequency power was supplied through a four-core flexible cable. It should be noted that this cable carried no high-frequency currents and that the transmitter is so small and light that it may be mounted together with its antenna in any convenient position, remote from the power source and from the keying position.

Anode power supply for the transmitter was taken from a generator mounted on an automobile, delivering 500 volts at 400 to 500 cycles, the average plate current being 50 milliamperes corresponding roughly to a power of 20 watts. A supply for the filaments (5 volts, 1½ amperes) was takon from the car starter battery and all control and keying operations were effected from a small control box mounted on the running board of the car. In operation an antenna ammeter reading of 0.3 was obtained.

The receiver was carried around in a second automobile and the procedure was to erect the transmitter at some convenient point on the coast and to explore the signal strength along the coast with the portable receiver. The results of some of these tests will now be given, and reference may be made to the map in Fig. 134(f) for the location of the transmitter and receiver during the tests.

Effect of Height on Signal Strength

It was quickly verified that signal strength varied considerably with variation in the average height of the line of transmission above the intervening country or the sea, as the case may be, and the following is an example of tests taken which will illustrate this point:

Transmission was carried out at point *A*, Fig. 134(f) from a position on the sea front 15 ft. above sea level, reception tests being made at point *B*, 4.2 miles distant. At point *B* a railroad embankment runs close to the sea; between the bank and the sea is a stretch of level shingle 100 yards wide and about 15 ft. above sea level. At the top of the railroad embankment (25 ft. above the shingle beach) signals were of strength *R7*. One-third of the way up the bank, on the sea side (9 ft. above the shingle beach) the strength was only *R3*—*R4*. On the shingle beach itself no signals were received.

In another interesting comparison, the signal strength when transmitting from point *A*, 15 ft. above sea level, was *R5* at 6½ miles (point *C*) and *R3* at 8½ miles (point *D*), the receiver being in each case at the top of a bridge over the railroad, about 20 ft. above the surrounding country, which itself was not more than 15 to 30 ft. above sea level. On the side of a hill (point *E*), at a distance of 8 miles from the transmitter, and at a point 815 ft. above sea level the strength was *R7*. In this case there were hills intervening between the transmitter and receiver which prevented a direct view from one to the other; on the other hand the "line of transmission" was well above the intervening country.

The transmitter was next moved to a part of the coast where high cliffs prevail and was installed at the top of the cliff at point *F*, about 400 ft. above sea level. Signals were now of great strength *R9* at points *G* and *H* which were 10½ and 12¼ miles distant, respectively, and about 25 ft. above sea level. Unfortunately time did not permit of the ultimate range being determined under these conditions.

Reflector Experiments

Tests were made with a portable parabolic reflector to determine the improvement in signal strength and also the degree to which the signal strength could be reduced in the unwanted directions. The reflector comprised 50 aluminum wires 18 gauge, each 1 meter in length, suspended vertically around the circumference of a parabola of focal length 50 cm, the "aperture" or greatest diameter of the parabola being 5 meters (i.e., 2½ wavelengths).

Transmission was carried out from point *A*, with the reflector directed towards point *C*. Transmissions were made alternately with and without reflector, and reception tests were made at various points in the immediate locality behind and to the side of the reflector and then at various points along the coast in front of the reflector. In all cases the receiver was purposely rendered insensitive by detuning the antenna, so that the louder of the two signals was of just comfortable strength, otherwise comparison would have been impossible. The results of these tests were as follows:

Receiver location	Deviation from center of beam	Strength with reflector	Strength without reflector
Local	160 deg.	R2	R5-R6
Local	128 deg.	R2	R9
J	80 deg.	R4	R9
K	21 deg.	R5	R2
L	8 deg.	R7	R3
C	0 deg.	R7	R2

The code of signal strength employed above is as follows:

R1 Signal just audible but unreadable
R4 Signal just-readable
R7 Signal of comfortable strength

Intermediate values estimated accordingly.

The tests of which the above are typical examples indicated that the range obtainable over sea at a wavelength of only two meters is quite a useful one for certain particular purposes which will be discussed later on. Meanwhile, other tests were made under conditions other than oversea conditions as a matter of general interest.

With the transmitter installed at ground level in an open courtyard near the center of a city, reception was carried out in an automobile in the city streets up to a distance of a mile. At this distance the signal strength varied greatly according to whether the street in which the receiver was located ran along or across the line of transmission, the greater strength being of course obtained in the streets running along the line of transmission. The overhead wires belonging to the street-car system did not have a very serious effect; sometimes they weakened and sometimes they strengthened the signal. Where the street, passed under a street railroad bridge, however, a distinct shadow was cast.

With the transmitter located on the roof of a 50-ft. building near the city center, reception could be obtained almost without interruption for a distance of two miles through the streets.

Tests made in the open country indicated that the range depended very largely on topographical conditions and varied from 4 to 15 or 20 miles. Good reception was obtained when the line joining transmitter and receiver averaged a good height above the intervening country and also when the ground at the receiver end sloped down towards the transmitter. Contrary to a popular belief, however, it was not necessary that the transmitter should be visible from the receiver; the average height of the line of transmission and the slope of the ground appeared to be the determining factors. Reception could be carried out even inside sheet-steel structures where it might be expected to be impossible on account of screening effect.

Limited-Range Feature

In "long-wave" radio communication a portion of the received signal is due to the direct or "ground" ray and a further portion is reflected or refracted down from the Heaviside layer. At short distances we receive chiefly the ground ray, but as the distance increases this becomes rapidly attenuated and we become more dependent on the reflected ray for reception.

At shorter wavelengths, between 10 and 20 meters, we do not begin to receive the reflected ray until we have gone some distance beyond the limiting range of the ground ray. The assumed reason for this "skip zone," in which no signals can be received, is that the 20-meter wave is incapable of reflection through such a sharp angle as are the longer wavelengths, so that it may not return to earth until a distance of 1,000 miles or so has been covered. As the wavelength is still further reduced, the "skip distance" increases and there is every reason to suppose that below a certain wavelength the reflected ray will never return to the earth at all. A. Hoyt Taylor has collected together a large amount of experimental data and has correlated this with the ray theory in an attempt to estimate the shortest wavelength at which long distance signals can be received.

The minimum wavelength for long distance reception appears to vary from about 25 meters on winter nights to something of the order of 7 meters under abnormal summer conditions. He suggests that possibly very occasional long-distance reception might be obtained at 5 meters. It would thus appear justifiable to assume that a wavelength of 2 meters will be immune from the possibility of long-distance pick-up under all conditions.

T. L. Eckersley has also discussed the "short-wave limit" and has given an alternative explanation on the "attenuation theory" as distinct from the "ray theory" as A. Hoyt Taylor and others. Eckersley places the short-wave limit at roughly 7 meters in darkness and 8 to 10 meters in daylight under normal conditions.

Assuming the above evidence to be correct, the all-important result follows that the two-meter system will have a *limited range* which can be *determined at will* since it will depend simply upon the ground attenuation, which is constant, at any rate over sea. For instance, if it is desired to signal over a distance of 10 miles, the transmitter power and height can be adjusted to suit this range when it can be safely predicted that the signal is incapable of being picked up outside a radius of say 20 or 30 miles at the same level. Such limitation of range has never been possible before, for however low the transmission power there has always been the possibility of "freak" reception at great distances owing to reflection from the Heaviside layer.

Directional Transmission

To produce a concentrated "beam" we must have a reflector which is several wavelengths in breadth and possibly in height. If the reflector size is limited, as it must be on a ship or aircraft, we realize that conversely in order to obtain a beam the wavelength must be short in comparison with the possible dimensions of the reflector. The two-meter system requires a reflector but a few yards in length, while still shorter wavelengths and smaller dimensions may perhaps be attained by using the special oscillator construction to be described later. It should be noted that the superficial area of the reflector will decrease as the square of the wavelength.

The "beam" feature in conjunction with the "limited range" feature might be expected to ensure that when sending to a point 10 miles distant the signal cannot be picked up outside a 3 or 4 mile radius in the wrong direction.

Radio-Frequency Modulation

By modulating the two-meter wave at a radio- instead of an audio-frequency we have a transmission which can be received under certain conditions by an ordinary super-regenerative receiver. It can only be received, however, if the quenching frequency is adjusted so as to give an audible beat note with the modulation frequency. Hence anyone attempting to intercept the transmission has to adjust his receiver to two independent frequencies simultaneously. Apart from the advantage of secrecy, the number of possible channels of communication is enormously increased, since a large number of independent transmissions may be made at the same short wavelength by using different modulation frequencies, e.g., 150, 175, 200, 225, 250, 275, 300, etc., kc.

The short wavelength may be fixed, or adjustable between narrow limits only, thus leaving the operator free to concentrate his attention on adjusting the long-wave tuning. We should visualize an ordinary 150- to 500-kc. transmitter at one end and a 150- to 500-kc. receiver at the remote end. The only difference between this and an ordinary long-wave system is that instead of supplying say, 300-kc. power to an ordinary long antenna, this power will be supplied to a small two-meter oscillator and antenna which will preferably be slung at the top of a mast, the same principle being adopted for reception. This is illustrated by Fig. 134(a).

It is of course realized that there is nothing new in modulating a radio transmitter at a lower radio frequency, but this becomes more practicable the shorter the wave on account of the greater difference between the carrier and modulation frequencies.

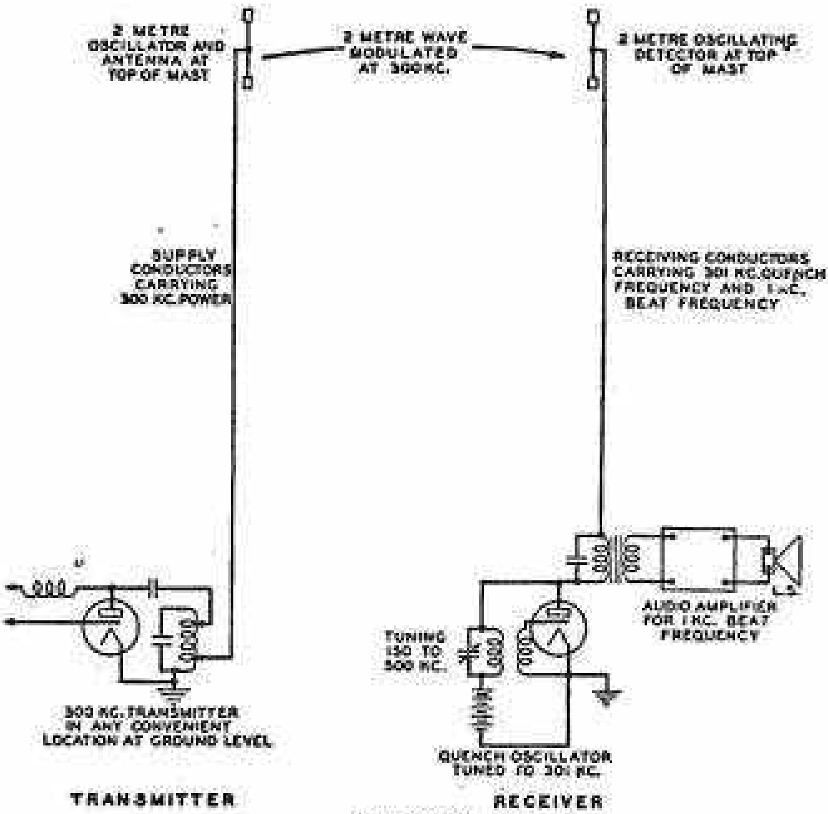


Fig. 134 (g)

Commercial Applications

The above characteristics immediately suggest a number of commercial and other applications such as the following:

(1) For signalling between neighboring ships, between ship and shore, or between aircraft and ground in case of fog. (2) For communication over short distances where absolute secrecy is required. (3) It has been suggested icebergs, etc., might be detected by such a short-wave beam, on the reflection principal. (4) The system might have some application to television transmission in that the shortness of the wave permits of an unusually high modulation frequency.

CHAPTER VIII

Short-Wave Broadcast Receivers

There are a number of short-wave broadcast receivers now on the American market all built more or less along the same lines. For comparative purposes illustrations and the schematic wiring diagrams will be given. Most of these sets are made both for battery operation and for AC operation. The AC sets have the advantage of greater amplification due to the high amplification obtainable with AC tubes. The battery operated sets have the advantage of greater stability and freedom from any electrical disturbances due to power pack operation.

Fig. 148 gives the schematic wiring diagram of a typical short-wave receiver. This set differs somewhat from the more simple short-wave receiver inasmuch as it has only one stage of tuned radio frequency (screen grid) ahead of the regenerator detector. In a short-wave circuit having only a regenerator detector ahead of the audio stages considerable skill and patience are required to obtain satisfactory results. This is particularly true in regard

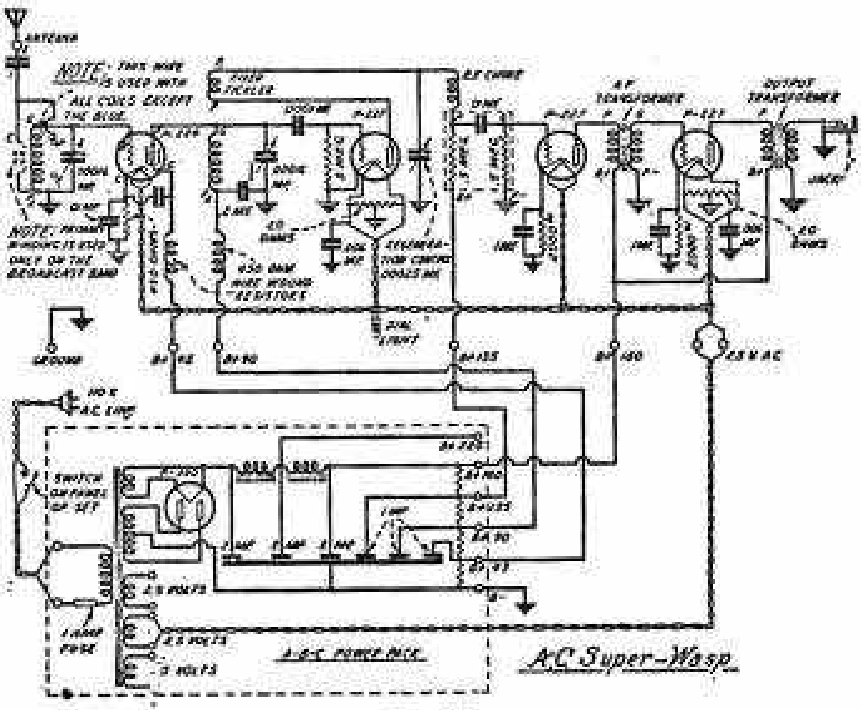


Fig. 147

Schematic Wiring Diagram, A. C. Short Wave Regenerative Receiver.

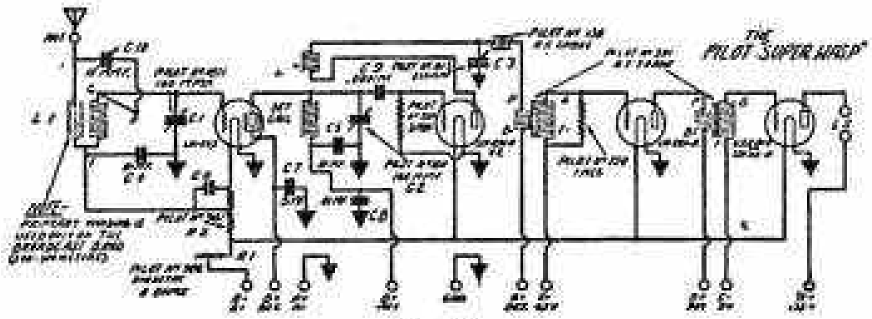


Fig. 148

Schematic Wiring Diagram, Short Wave Receiver Using Battery Type Tubes.

to tuning very weak signals. The addition of the radio frequency stage has the effect of adding sensitivity to the receiver making the tuning apparently broader and in consequence the matter of locating distant signals is facilitated. Coils are available extending the range above 200 meters to 500 meters for regular broadcast reception. The degree of selectivity obtained in this upper wavelength range would hardly be selective enough for operation in congested districts. It is not intended for this purpose and reception on the broadcast wavelengths is provided to enable reception with the receiver located at outlying portions of the country. From this schematic diagram in Fig. 147 of the AC model it will be noted that the tube arrangement is exactly the same with the exception of AC tubes being used. There is one stage of tuned radio frequency amplification, regenerator detector, first and second audio stages. The question of eliminating AC hum from the short-wave regenerative receiver involved considerable experimental and development work. This hum was particularly noticeable when the regenerator detector was working close to the oscillating point. One annoying hum was traced to the detector tube itself due to the method of construction of the heater cathode. In the regular 227 the heating element is not entirely surrounded by the cathode. A special type 227 tube was developed by Pilot having the heater element entirely surrounded by the cathode which reduced the residual hum to a negligible amount. The type 227 tube has been retained for the last audio stage in preference to a power tube due to the fact that the heater type tube is superior for head phone operation giving a minimum of hum disturbance. In an AC short-wave receiver the design must be carried out very carefully to eliminate sources of other hums caused by oscillating circuits consisting of the various components of the radio frequency chokes, condensers, etc. When the final receiver is put under its first tests these hums will be apparent and must be traced and eliminated by altering the components.

Another standard short-wave receiver is shown in Fig. 149. The tube arrangement consists of a 224 screen grid radio frequency stage, 227 detector, 227 first audio and two 245 push-pull for the power output amplifier. The power pack rectifier tube is a type 280. The antenna circuit in the radio frequency stage is not tuned. The detector is regenerative with a fixed tickler coupling. Four interchangeable coils cover a wavelength range of 16.6 to 195 meters. Two additional coils are also available to extend the range up to 592 meters. The receiver is claimed to be free from objectional AC hum throughout the broadcast and short-wave band, though under certain conditions for the range around 30 meters an objectional hum may be encountered due to peculiar line conditions. Fig. 151 illustrates the model "C" short-wave receiver which is probably the first one of this type to have two stages of radio frequency amplification ahead of the detector. The schematic wiring diagram is shown in Fig. 152. This design is far more elaborate than the regular short-wave designs previously available as the matter of cost and size has not been taken into consideration the first thought being to secure maximum results. Each radio frequency stage and the detector stage are built in a separate shielded compartment. The three audio stages are contained in a fourth compartment. It will be noted that there is considerable space between the radio frequency transformers and the shielding to insure minimum losses from absorption. The variable condensers are placed on the rear tube shelves close to the radio frequency transformers and tubes so that the length of the interconnecting leads is at a minimum. The mechanical control between the condenser and the front tuning dials is in the form of a cord. At the same time the reduction between the front panel and the condenser is 1:2 so that the front tuning dials can be moved very gradually for fine adjustments. This also provides a full 360-degree scale on the indicators which makes it possible to record the calibrations more accurately. The system of having independent shielding containers for the various stages has worked out very successfully in receivers for the broadcast band due to the fact that this double shielding reduces "skin effect" coupling to an absolute minimum. The push-pull power amplification was not used in the audio stage because it was believed that on weak signals there would not be sufficient over-all amplification to

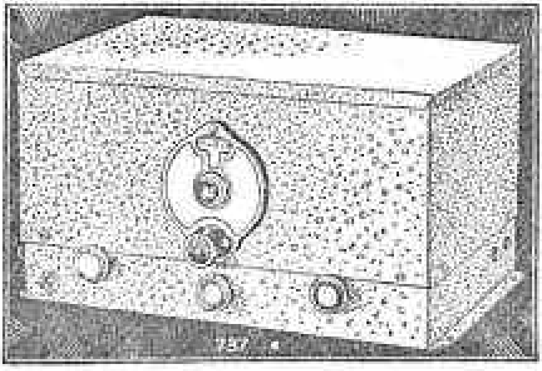


Fig. 149

Typical Short Wave Regenerative Radio Receiver, Exterior View.

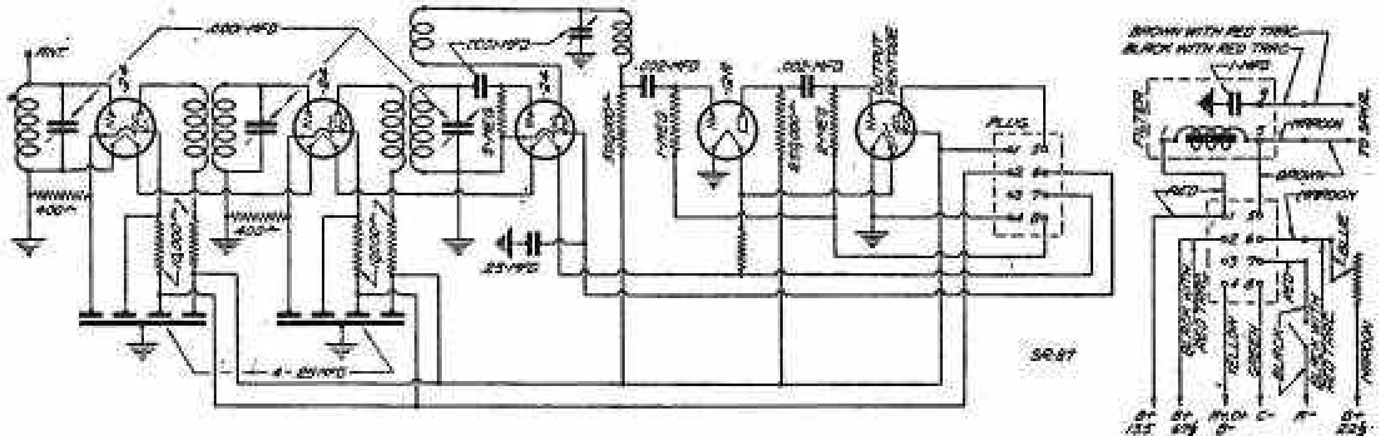


Fig. 150

Short Wave Receiver Schematic Wiring Diagram.

In this design there are two stages of tuned radio frequency amplification, a —24 screen grid detector, —12 first audio amplifier (resistance coupled) and a Pentode output tube. This receiver was designed for automobile installation, and therefore while three A/C tubes are used, they are operated from a battery. Using A/C tubes allows greater amplification per tube and freedom from microphonic disturbances. This combination of tubes gives the desired results with a minimum number of tubes.

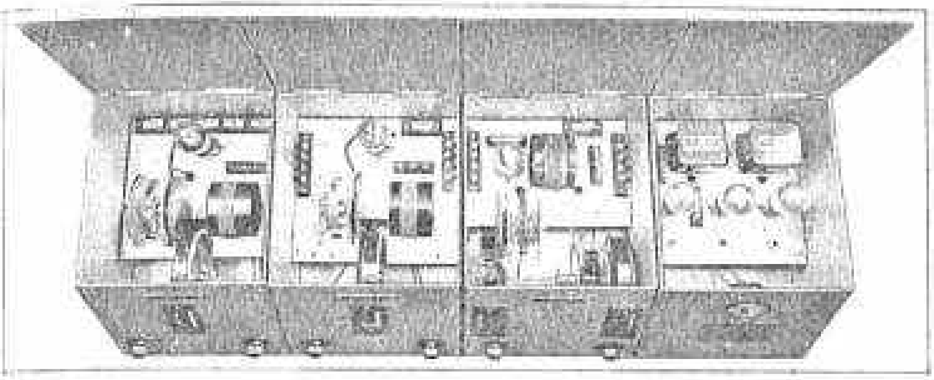


Fig. 151

Model C Tuned Radio Frequency Short Wave Receiver. The Radio and Detector Stages are in Separate Compartments to Allow 100% Shielding.

work such push-pull power tubes to full output. The method selected uses three progressive stages. With this arrangement even the weaker signals passed from the first detector to the audio amplifier can be built up to good volume for head phone or even loud speaker reception. The audio transformers used are of high quality and give excellent reproduction. Jacks are provided so that either phones or loud speakers can be used at any of the stages. The indicating meter is not permanently connected to any part of the set. Flexible leads are provided so that all the A, B, or C voltages can be read, the meter having two scales—0 to 8 and 0 to 200 volts. Flexible leads are used as permanent wiring would interfere with the working of the receiver.

Compared with ordinary short-wave sets using a minimum number of interchangeable coils, the model "L" has a total of six coils covering 15 to 200 meters with a reasonable overlap between coils. As maximum voltage amplification is obtained with a circuit having high inductance and low capacity the use of six coils gives a greater over-all efficiency than a circuit using a smaller number of coils. The mechanical shape of the coil to give best electrical results has been worked out very carefully. For example—the coil having a certain range might have one turn of wire 12 inches in diameter or 100 turns of wire on ¼-inch diameter. For radio frequency work neither of these two extremes would be satisfactory and it is obvious that the optimum shape and dimensions fall somewhere between these extremes. In this design these details have been worked out carefully and the various radio frequency and other inductances throughout the wavelength range give a high degree of uniform efficiency.

The antenna input circuit is arranged to accommodate different types of antennas. In addition to using a regular antenna the set can also use a dirig-

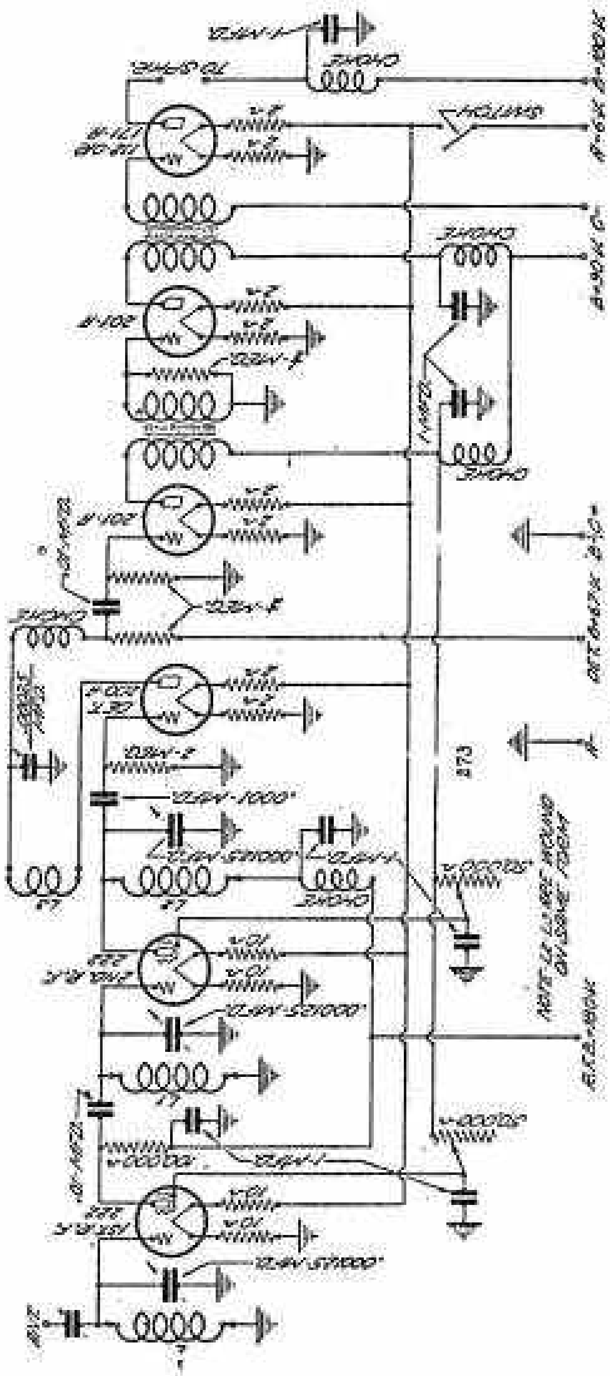


Fig. 152

Schematic Wiring Diagram, Model "C" Short Wave Receiver. Note First Radio Frequency Stage is Indirectly Resistance Coupled to Allow Operating that Tube at the Highest Possible Degree of Efficiency. Where Battery Drain is not Important, the Equivalent Tubes of the A/C Type Can be Used and with Increased Overall Sensitivity.

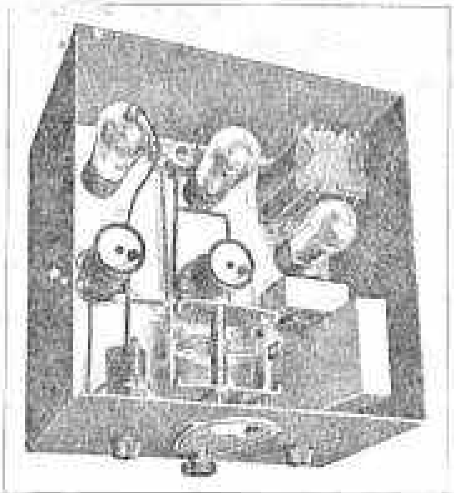


Fig. 153

Short Wave, Super-Heterodyne Adapter, Showing Interior Construction, Which Includes a Small Built-in Power Pack.

ible type or a wave antenna. It was previously mentioned that best results were obtained by using a very small condenser and a relatively large coil for the tuned circuits. This has the disadvantage of requiring a large number of coils. This disadvantage is further emphasized when it becomes desirable to tune wavelengths above 200 meters. For the range of 200 to 600 meters it would require either three or more sets of coils for the set. It is be-

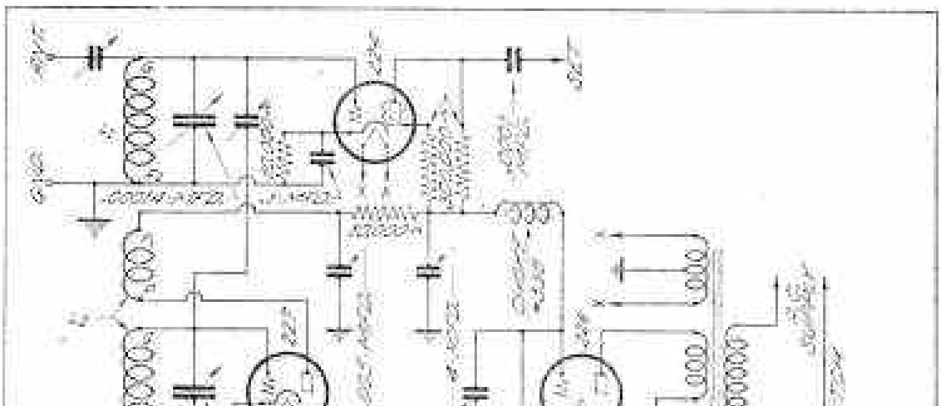


Fig. 154

Schematic Wiring Diagram, Short Wave, Super-Heterodyne Adapter.

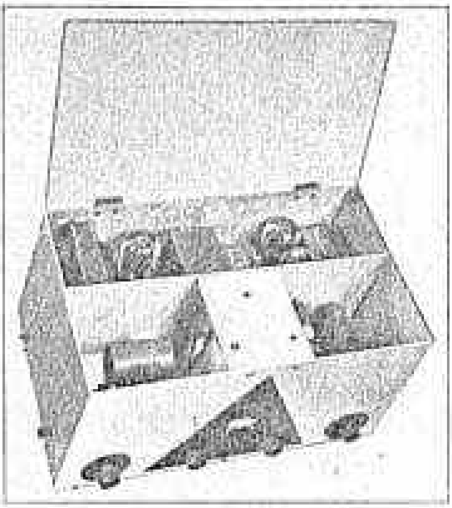


Fig. 155

Typical A. C. Short Wave Receiver Including Built-in Power Pack.

lieved, however, that the matter of short-wave design is a problem by itself and attempts should not be made to extend short-wave receivers into the broadcast band except for unusual conditions. Likewise for the reception of wavelengths below 15 to 20 meters the problem of design is again separate and distinct and requires another type of receiver. The Army, Navy, and commercial companies use special separate receivers to cover different bands

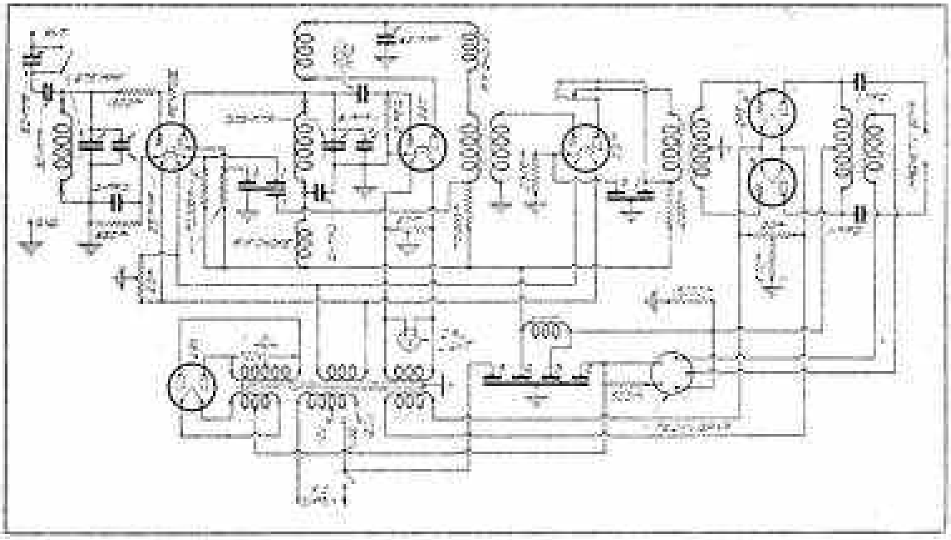


Fig. 156

Schematic Wiring Diagram of the A. C. Short Wave Receiver Shown in Fig. 155. Note a Pentode is Used in the First Radio Stage.

of wavelengths during their regular work. They do not make any attempt to design a receiver which covers a wide range of wavelengths because it is known that it will not be highly efficient.

The second radio frequency stage can be disconnected if desired, it only being necessary to remove this unit and then connect the antenna stage directly to the detector unit. In this unit the plate circuit is tuned which on account of using the screen grid tubes is the most satisfactory method. As small inductance in the plate circuits does not present an efficient arrangement for tuning, an ingenious method of indirect plate coupling is used with excellent results. This is shown in the schematic diagram. Vernier condenser adjustments are provided on the tuned stages. Individual voltage regulators are available so that each tube can be regulated to its maximum point of efficiency. The containing cases are constructed of aluminum and are at ground potentials thereby being free from body capacity effects. All the high frequency returns are blocked with radio frequency chokes, by pass condensers, etc., a very large number being used throughout the receiver.

The idea of using a variable inductance, usually in the form of a variometer, tuned by a variable condenser to obtain a wide wavelength range is not an efficient method. This system has been used in long-wave receivers years ago and discarded. Adjusting a variometer over its tuning scale it is found that with the inductance at a maximum, the coil is suitable for efficient tuning. However upon adjusting this type variable inductance toward its minimum value, the distributed capacity and losses encounted raise rapidly and the arrangement becomes more inefficient proportionally. Individuals offering designs involving this particular feature show a decided lack of radio receiver design experience and it is surprising the various radio editors accept the articles for publication as having any merit at all.

The ordinary broadcast receiver of the tuned radio frequency type especially one having high selectivity is suitable to be adapted into a Super-Heterodyne system for short-wave reception. In this case the radio frequency amplifier of the tuned radio frequency set is used as an intermediate frequency amplifier for the Super-Heterodyne. The regular detector is used as a second detector and the following audio amplifier is used in the regular manner. To complete the circuit into a Super-Heterodyne there is required a first detector and oscillator. In some systems one tube is used for both of these functions. A Super-Heterodyne adapter made along these lines which is illustrated in Figs. 153 and 154. As it is not convenient for the average layman to make the necessary connections to supply the adapter with filament plate and bias voltages, there is included a small power pack built in as a component part of the complete adapter. As the power requirements are small a 226 tube is large enough for the rectifier. A 227 is used for the oscillator and a 224 is used as the first detector. This idea of having a built-in power pack makes the adapter suitable to use with any receiver regardless of the type of tubes used or the voltages available. All that is necessary to do is to connect the antenna and ground to the adapter and connect the adapter to the input of the tuned radio frequency receiver. The receiver itself is then set at some frequency between 800 and 1,000 kilocycles depending somewhat upon local interference. The two-tube adapter is then tuned to cover the various short-wave bands. The center dial controls the beating oscillator and the small left hand dial controls the antenna tuning. A number of interchangeable coils are provided—usually four sets—covering the approximate range of 16 to 31

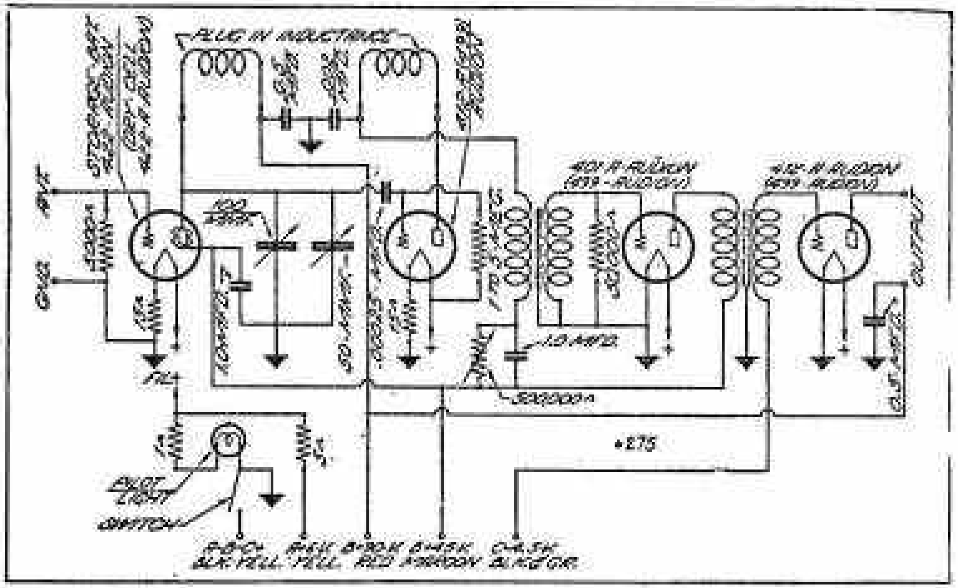


Fig. 155(a)

DeForest Short Wave Receiver, battery operated. Circuit consists of radio stage, detector and two Audio stages.

meters, 30 to 56 meters, 55 to 104 meters, 103 to 195 meters. Similar adapters to use with the high-power "Phantom" and "Silver Ghost" broadcast receivers were described in the 1928 edition of *Modern Radio Reception*. In using an adapter of this type in connection with a broadcast receiver it must be expected that interference will be received from stations of different wave-lengths. A high degree of selectivity is possible only by having a band pass filter tuned to the high frequencies and placed ahead of the first detector. It was also found that when using short-wave adapters and frequency changers in districts having a number of high-powered broadcasting stations in the vicinity, these stations will be received on harmonics, that is, a station operating on 560 kilocycles may be heard on 2,240 kilocycles, 4,480 kilocycles, 8,960 kilocycles, etc., depending upon the harmonic condition of the transmitter. In some cases high-powered transmitters have surrounding metallic objects such as steel towers, guy wires which absorb energy and re-radiate it at short wavelengths. These signals can also be picked up at short distances from such transmitters.

A SPECIAL SHORT WAVE SUPER-HETERODYNE RECEIVER

On the shorter waves there is much less atmospheric interference than obtained on the longer wavelengths. This desirable condition enables the use of a short wave receiver having a very high degree of sensitivity. In actual

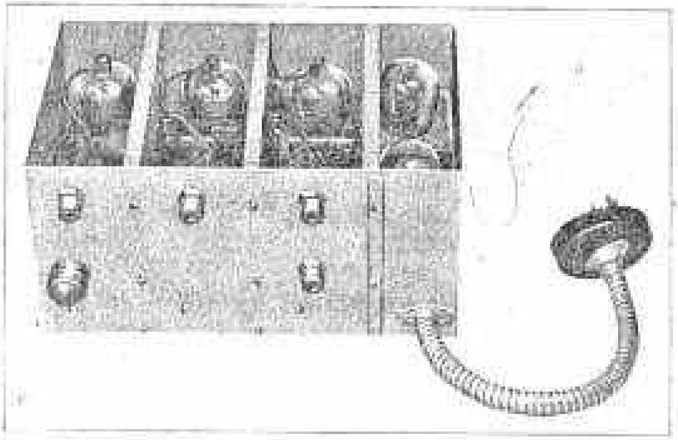


Fig. 155(b)

Delco Automobile Radio, note provision for cable connections and remote control

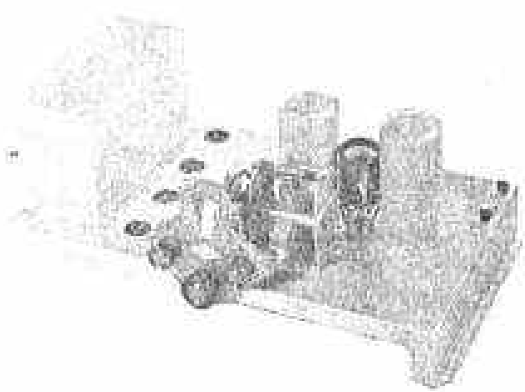


Fig. 156 (a)

Short-Wave Regenerative Receiver, A. C. Type.

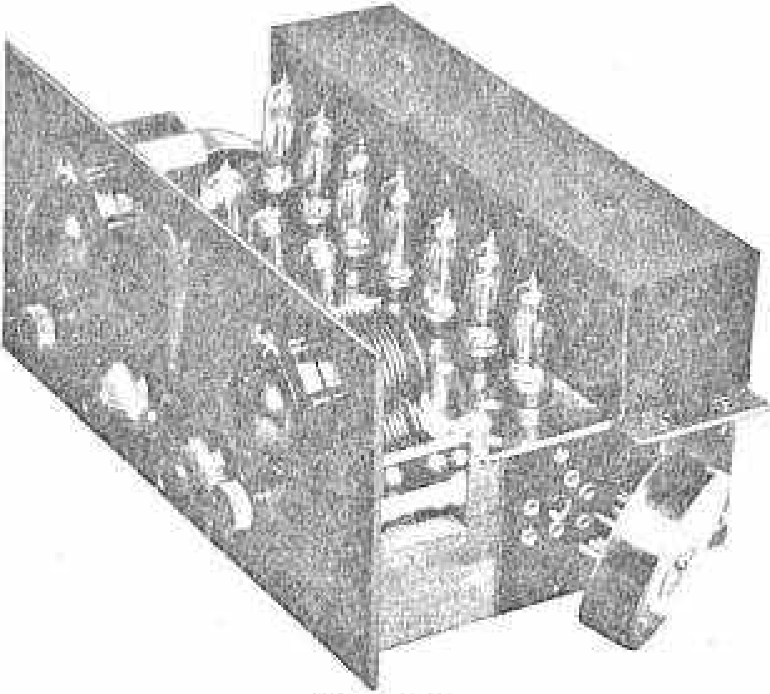


Fig. 156 (b)

Short-Wave Super-Heterodyne for Battery Operation, Using Peanut Tubes, Tube Arrangement; Detector—Oscillator—The Intermediate Stages—Detector—Two Audio Stages.

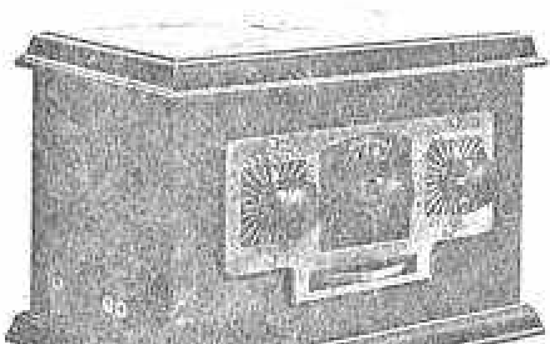


Fig. 156 (c)

German Telefunken Short-Wave Receiver

practice with a receiver of this type very strong signals can be obtained from short-wave transmitters and in many cases regardless of the distances involved.

In the case of a simple short-wave receiver having only a regenerative detector and audio amplifier, it is apparent that the overall amplification will be very small. Likewise even with such a receiver having in addition a stage of radio freguency amplification, the sensitivity will still be of relatively small proportions.

In making plans to secure more amplification additional stages of tuned radio frequency amplification can be added. In the case of a receiver where the wavelength range is confined to narrow limits, this would not be a difficult problem. On the other hand, assuming that it is desired to cover all the short wave bands, a tuned radio frequency receiver having several stages, while satisfactory in operation, would be complicated to operate due to the number of variable controls involved.

The commercial companies in their experiments to obtain strong short-wave signals even from long distances have decided upon the Super-Heterodyne method of reception. In this system there is the advantage of simplicity in operation, relatively high overall amplification and stability. In such a receiver the radio frequency amplifier and the overall gain obtained at that point is really the only limitation of the receiving range with ideal radio conditions. In simple forms the Super-Heterodyne is not exceedingly selective but meets the requirements of amateur experimenters. For additional selectivity it is necessary to add preliminary band-pass filters and it is difficult to construct these to cover wide wavelength ranges.

A short wave Super-Heterodyne receiver having a degree of amplification far superior to any of the other short-wave receivers now available has been developed and will be described herein. Fig. 156(d) shows a front view and Fig. 156(e) a plan view of the complete receiver which, however, does not include the power pack. This is due to the fact that the power pack may be of several different styles depending upon the tubes used in the receiver arrangement. The design as outlined specifies the best tubes which will give the greatest overall amplification. Smaller tubes or tubes for battery operation can be used with a proportional decrease in total sensitivity. The receiver is really divided into three major sections of which (A) is the first detector with its associated oscillator and power pack; (B) is the intermediate frequency amplifier with a second detector; and (C) is the audio amplifier together with power audio amplifier and the associated power pack.

In this method of reception the radio frequency amplification is carried on at the intermediate frequency of 250 kilocycles through the intermediate frequency amplifier. Regardless of what wavelength is received, the tuning of this intermediate radio frequency amplifier remains constant. To change from one received wavelength to another, it is only necessary to change the

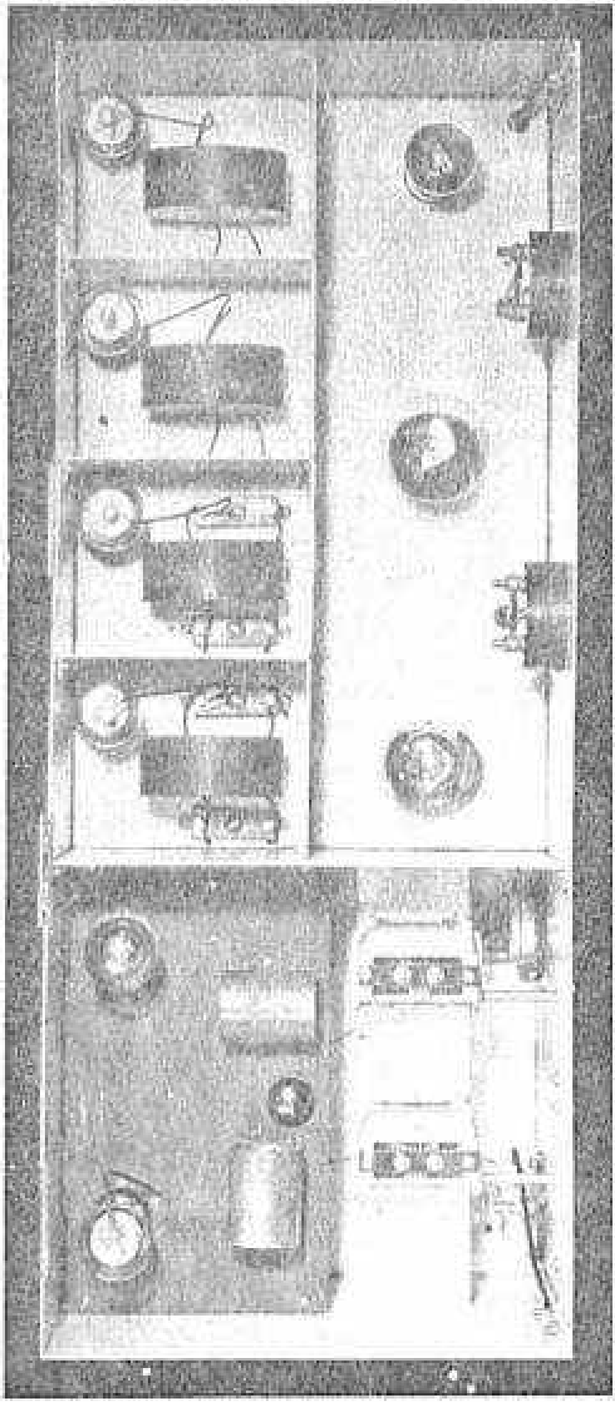


Fig. 156 (d)

Plan View Special Super-Heterodyne Short-Wave Receiver, Showing Sub-Panels and Tube Locations.

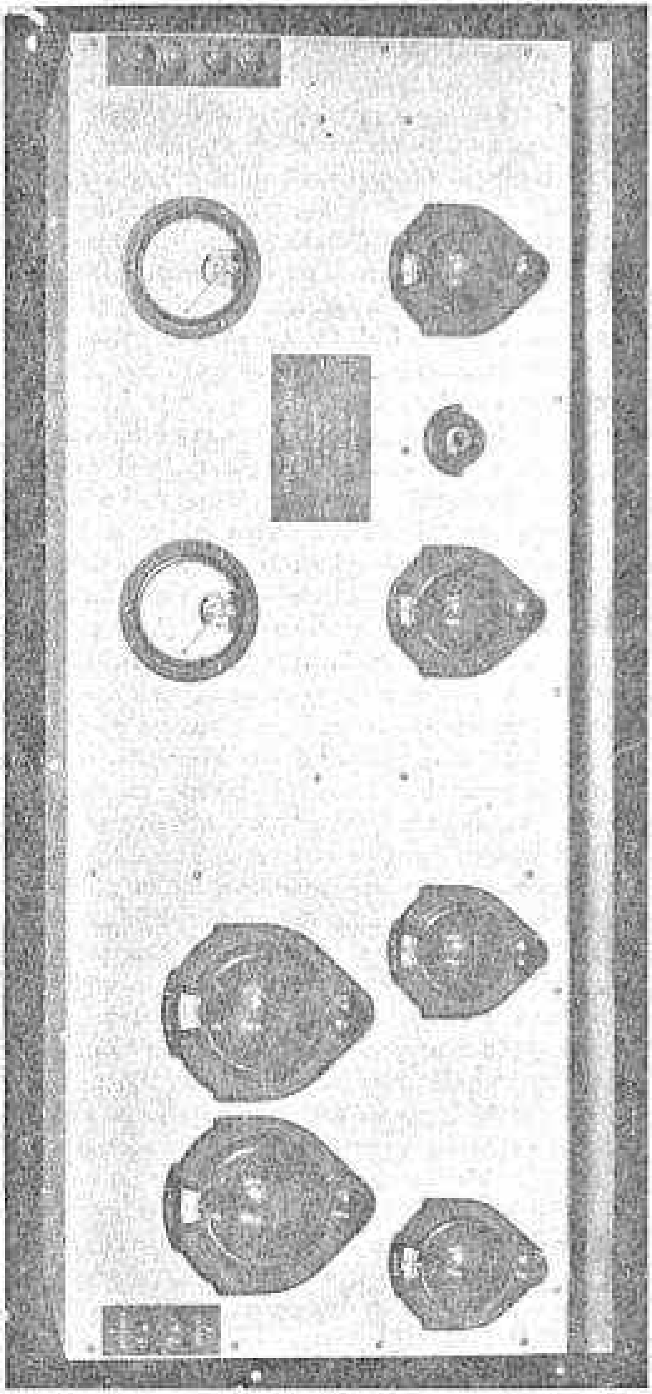


Fig. 156 (e)
Front View Special Super-Heterodyne Short-Wave Receiver, Showing External Appearance.

tuning of the antenna circuit and the associated super-hetrodyne oscillator, reducing the tuning operation to two controls. These are shown in the front view as Selector 1 and Selector 2. The other variable adjustments shown are incidental to obtaining the desired degree of sensitivity or signal strength.

In commercial designs where each tube is worked to its maximum advantage, the mechanical placements and electrical shielding are carried to the highest possible degree of efficiency. This is accomplished by having a separate shielded compartment for each individual tube. Furthermore, each of these tubes is provided with all the necessary chokes and by-pass condensers. For the matter of convenience this design has been simplified and while the results obtained will not compare with the commercial product, the performance will be entirely satisfactory for all average purposes and far superior to any experimental design so far offered.

As the intermediate frequency amplifier is one of the most important considerations, the details of this circuit will be considered first. There are four intermediate frequency tuned transformers associated with three screen grid radio frequency amplifier tubes and a screen grid second detector tube. These are shown in the upper right-hand section of the top view photograph. It will be noticed from the schematic wiring diagram that both the primary and secondary of these transformers are tuned by variable condensers each having a maximum capacity of .001 m. f. This system is followed to produce a radio frequency amplifier having a sharp resonant peak as the overall degree of selectivity depends on this factor. As a matter of fact these condensers can be so adjusted that the overall degree of selectivity can be varied as desired. It must be remembered that for perfect reproduction of the speech frequencies, this amplifier must not be too selective or else distortion will appear; the band width should be at least 5000 cycles. Articles have appeared from time to time describing band-pass filters which add to the degree of selectivity obtainable in a radio frequency amplifier. An advanced experimenter could add such a band-pass filter to this intermediate frequency amplifier if an exceptionally high degree of selectivity was required.

Each intermediate radio frequency amplifier transformer consists of two windings, a primary and secondary, both identical in specifications. Each of these windings has a total of 68 turns No. 28 B & S, D.C.C. magnet wire in a form 2⅛ inches inside diameter and 3/32 inch wide, random wound. These pies are wound on a form, covered with hot carnarba wax and are then ready for assembly. The inside diameter of these pies is 2⅛ inches. For matter of convenience in assembly the two pies comprising a transformer can be mounted within a container preferably of a non-metallic material. Referring to the wiring diagram again, it will be noted that the variable condenser in parallel to either the primary or secondary winding has a maximum capacity of .001 m.f. At about three-quarters of their maximum capacity, the resultant frequency with the above described inductances is 250 kc. The

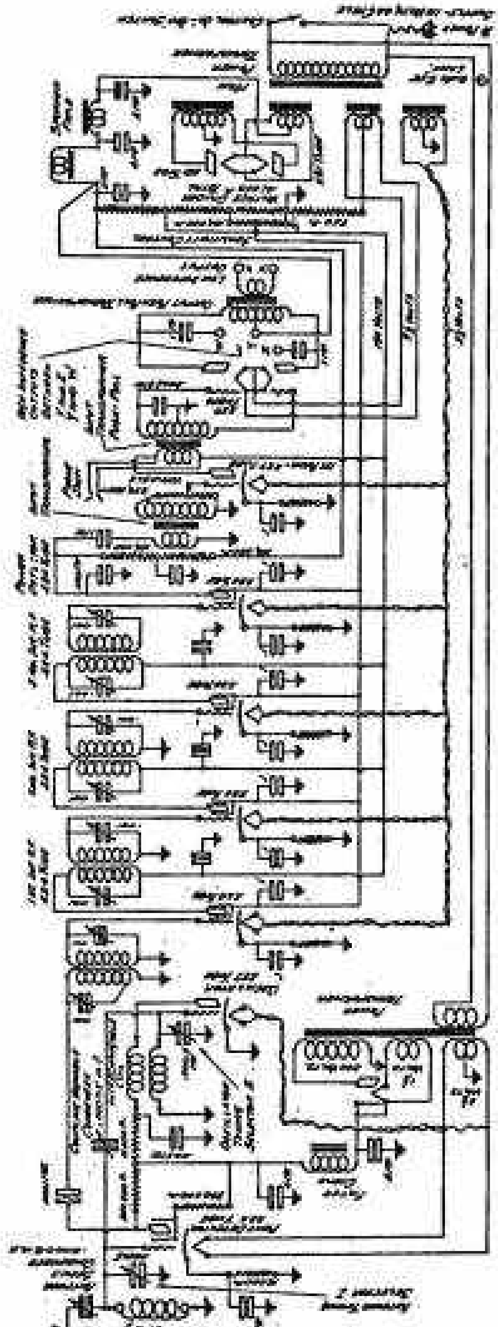


Fig. 156 (f)
Complete Schematic Wiring Diagram, Special Short Wave Super-Heterodyne Receiver.

condensers can then be regulated so that the primaries and secondaries are in exact resonance according to the degree of coupling employed. In giving the specifications of the primary and secondary windings above, the mechanical distance between these pies was not mentioned. When the pies are concentric and close together, the amplification is at a maximum but the degree of selectivity is at a minimum. Increasing the distance between the pies increases the degree of selectivity and with a small reduction of amplification. It must be remembered that experimenting with an amplifier of this type, when any change is made in the distance between the primary and secondary winding, the associated variable tuning condensers must be re-adjusted for resonance.

The radio frequency amplifier tubes are properly biased by having a resistance of 450 ohms in each of the cathode circuits. These resistors in turn are by-passed by a 0.1 m.f. fixed condenser. The screen grid bias, on the other hand, is arranged so that the voltage that may be applied to that point is variable from 0 to 90 volts positive. This variation in voltage controls the sensitivity of the intermediate frequency amplifier.

It will be noted that the second detector screen grid voltage is varied simultaneously to the same value as the intermediate frequency tubes. For all ordinary purposes this is sufficiently accurate.

The intermediate frequency circuits are further by-passed by condensers from each screen grid lead to ground and from each plate return lead to ground.

Referring to the schematic wiring diagram Fig. 156(f) of the detector circuit, it will be noted that the —24 tube is used as a power detector with plate rectification. As the first audio transformer primary impedance is not suitable for the detector to plate circuit, this transformer is indirectly coupled. This is accomplished by providing the detector plate with a resistance coupled output circuit which in turn is capacity coupled to the first audio transformer. On the secondary of this audio frequency transformer is connected a 250,000 ohm variable gain control regulating the input to the grid of the first audio amplifier which is a type —27 tube. This tube in turn is properly biased with a 900 ohm resistor in the cathode circuit and the associated by-pass condenser. An important part of the detector circuit is the .003 m.f. condenser from the detector plate to ground which prevents radio frequency currents from entering the audio amplifier. If desired, this condenser can be replaced by a more elaborate filter circuit consisting of radio frequency chokes and associated condensers. For all ordinary purposes the method shown is the most satisfactory.

From the first audio frequency amplifier the audio currents are fed into the input transformer of the push-pull power amplifier which consists of two —50 tubes. Across the secondary of this transformer, on one side only, is connected a .00025 fixed condenser to prevent unbalancing. In the plate circuit of the two —50 tubes is an output transformer, the secondary of which has a low impedance winding suitable to match the average dynamic speaker moving coil. For an output involving high impedances the loud speakers may be connected between points Z and Y or W and Z. Reception with head telephones may be obtained from jack connected in the plate circuit of the first audio stage.

As mentioned previously, the tube arrangement shown in this design is one which is ideal for maximum results. In view of this, the power pack shown has specifications to match the receiver. It is, of course, understood that if the tube specifications in the receiver are altered, the power pack will be changed to match. For the tubes specified the power pack requires two —81 rectifier tubes each of the half-wave type and so connected to form a full-wave rectifier. The main power transformer, in addition to supplying 650 volts AC for each of the two —81 tubes which is subsequently rectified for the plate circuits, also has supplementary windings, one of 2½ volts for the radio frequency detector and oscillator tubes, one of 7½ volts for the two power tubes and one of 7½ volts for the two rectifier tubes, these last three mentioned voltages being for the filament circuits. Ordinarily, the transformer would be supplied for 110-volt 60-cycle operation. For operation on voltages and frequencies of different values the transformer would have to be of special design, but these are available.

The rectified alternating current is filtered and smoothed out by two chokes and a series of reservoir condensers. One of these chokes consists of the field winding of the dynamic speaker which should have a resistance of 1,000 ohms. This is shown clearly in the schematic diagram. The other choke should have a capacity of approximately 100 m.h. and capable of handling 150 milliamps. The reservoir condenser shown has three separate sections, one of 4 m.f. and two of 2 m.f. In the case where head phone operation is used to great extent and there should be an absolute freedom from any A/C interference, an additional reservoir condenser having a capacity of 8 m.f. can be connected between the top of the voltage dividing resistance and ground.

A voltage dividing resistance having a total of 41,000 ohms is connected between the high voltage point and ground. This resistor should have a series of taps so that proportionally smaller values of voltage can be tapped off as desired. The schematic diagram indicates that value of 180 volts is required for the plates of the radio frequency amplifier and for the plate of the first audio amplifier.

The adjustable voltage regulator for the radio frequency screen grid bias is connected between the minus points of the voltage divider and approximately 100 volts positive. Therefore, with the adjustable control the screen grid bias can be regulated any point between 0 and 100 volts positive.

In the schematic wiring diagram given there is a separate power pack shown for the first detector and oscillator. It is recommended that this procedure be followed if maximum results are desired. By using this system the various radio frequency currents are kept isolated in a more effective manner. This extra power pack is of relatively small capacity and uses a type —26 tube as a rectifier which gives sufficient output for the —24 screen grid detector and —27 super-heterodyne oscillator. This small power pack has a filtering circuit consisting of a choke coil and two 4 m.f. reservoir condensers.

Here we have the situation where the primary of the first radio frequency transformer does not have an impedance suitable for the plate circuit of the first detector tube. Accordingly, the plate circuit is supplied with a suitable resistance output coupling and the output in turn capacity coupled to the primary of the first tuned radio frequency transformer. With a —24 screen grid tube and with a voltage of approximately 180, this coupling resistance should be approximately 300,000 ohms. The screen grid detector has a cathode bias of approximately 10,000 ohms and is by-passed. The screen grid voltage of this detector tube is given a fixed value of approximately 67½ volts which is obtained by a drop resistor of 300,000 ohms value. In a more elaborate set this scren grid voltage could be variable which would give an effective control on the signal input. The cathode resistor at this point is variable.

In the antenna circuit the antenna is coupled directly to the grid of the detector tube through a series antenna variable condenser. The adjustment of this condenser is controlled externally and for all ordinary purposes can be regulated to a value which is suitable over a wide wavelength range for any given aerial. Readjustment for extremely short waves is essential. In the arrangement shown, the coupling is only suitable for an average size single-wire antenna. A more elaborate short-wave aerial could be used in which case it would be coupled inductively to the first antenna tuning inductance. Ideas of this sort will be obtained from other parts of this book.

As far as the antenna tuning circuit is concerned, maximum signal strength and efficiency will be obtained using the largest possible inductance and the smallest value tuning condenser for any given wavelength. For the matter of economy, four interchangeable inductances will cover a wavelength range of approximately 19 meters to 200 meters. It is apparent, however, that by having a larger number of interchangeable coils, improved results will be obtained on certain bands. By obtaining the necessary interchangeable coil forms, the experimenter can wind coils of different specifications to secure the results desired. This situation is also true in the interchangeable inductances in the oscillator circuit and in designing coils to use at this point, it must be remembered to provide sufficient coupling between the coils to produce oscillation over the entire wavelength range.

The necessary coupling between the detector grid and oscillator grid is obtained by means of a variable coupling condenser. This condenser is also

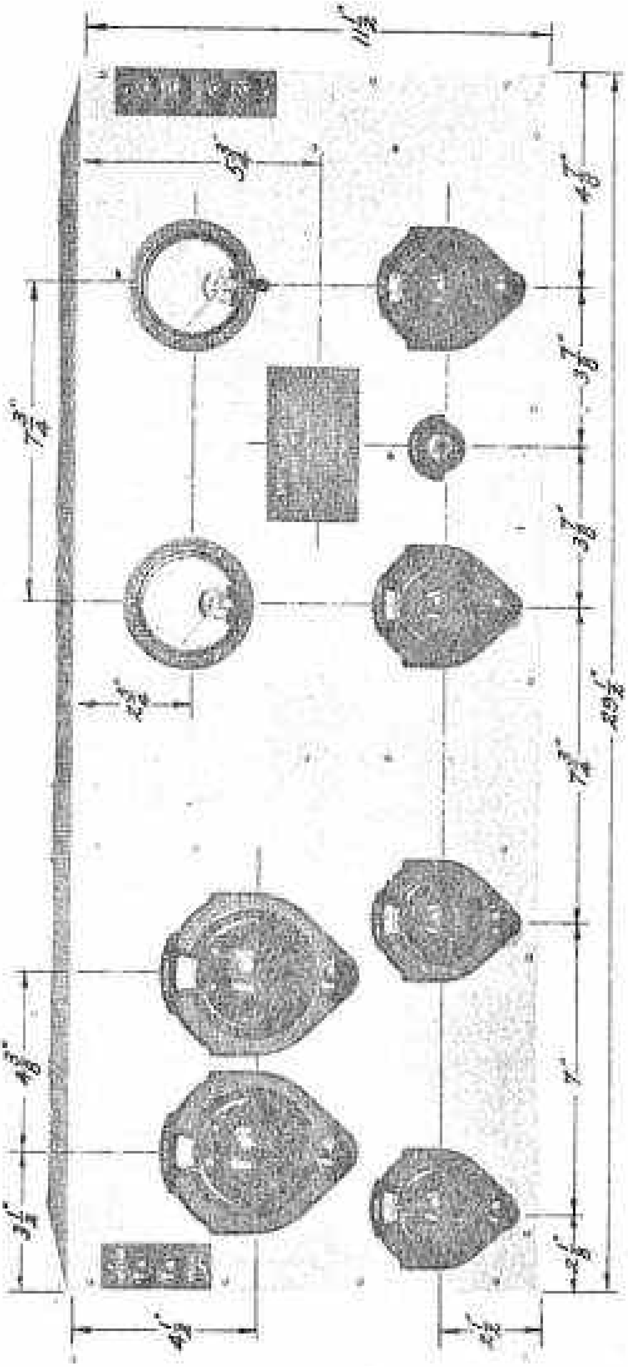


Fig. 156 (g)

Front View, Special Super-Heterodyne Receiver, Showing Essential Dimensions.

adjustable internally and once properly regulated need not be disturbed for all average purposes. It will be found in operation that if the value of this condenser is too small, the signal strength will be impaired and on the other hand, if the value of the condenser is too large, there will be excessive coupling between these two circuits which, under certain circumstances, may prevent the oscillating circuit from functioning. Before reaching this last mentioned extreme a condition will be noted where there will be a decided "click" in tuning when the oscillator and detector circuits are so tuned to approach resonance.

Assuming the intermediate frequency amplifier is tuned to a wavelength of 1,200 meters and remembering that the receiver may be used in different locations throughout the world, it is possible that there will be a local transmitting station which transmits on a wavelength of 1,200 meters or approximately that value. In this case there would be considerable interference from the local transmitting station as the simple form of preliminary detector circuit used could not discriminate against such a strong local signal. Under such circumstances it is necessary to change the intermediate frequency wavelength to a value which will be free of such local interference. This can be accomplished by regulating the individual variable condenser connected in parallel to the primary and secondary winding to a value either lower or higher than 1,200 meters as the situation may warrant.

The essential dimensions of the mechanical arrangement are given in Fig. 156(g) and 156(h). It will be noted that the front panel is 29½ inches long, 11½ inches high and that the containing cabinet has a depth of 12 inches. Referring to the plan view, the detector and oscillator circuit are concentrated at the left-hand end towards the rear on a sub-panel 6½ inches deep, 11 inches wide, this panel being 5½ inches high from the bottom. There is a sub-panel holding the two variable tuning condensers which is 11 inches long, 5½ inches wide and a distance of 4¾ inches from the bottom. In the remaining portion of the rear sub-panel there is a series of compartments for the radio frequency and second detector stages. Each of these compartments are 6 inches wide and 4⅝ inches long. Immediately in front of this compartment is another sub-panel 6 inches wide and 18½ inches long which provides space for the first audio amplifier and the two power audio amplifier tubes. The case is made of 1/16" sheet aluminum, half hard temper.

Referring to the front view again, we find the two main station-selector dials are to the extreme left, the first taking care of the antenna tuning and the second regulating the heterodyne oscillator. Immediately below and to the left is the antenna series variable condenser and to the right of that is a variable adjustment to regulate the screen grid bias on the first RF tubes. Continuing to the right the next variable adjustment controls the screen grid bias on the balance of the radio frequency tubes. The remaining variable adjustment is the gain control for the input of the first audio amplifier tube.

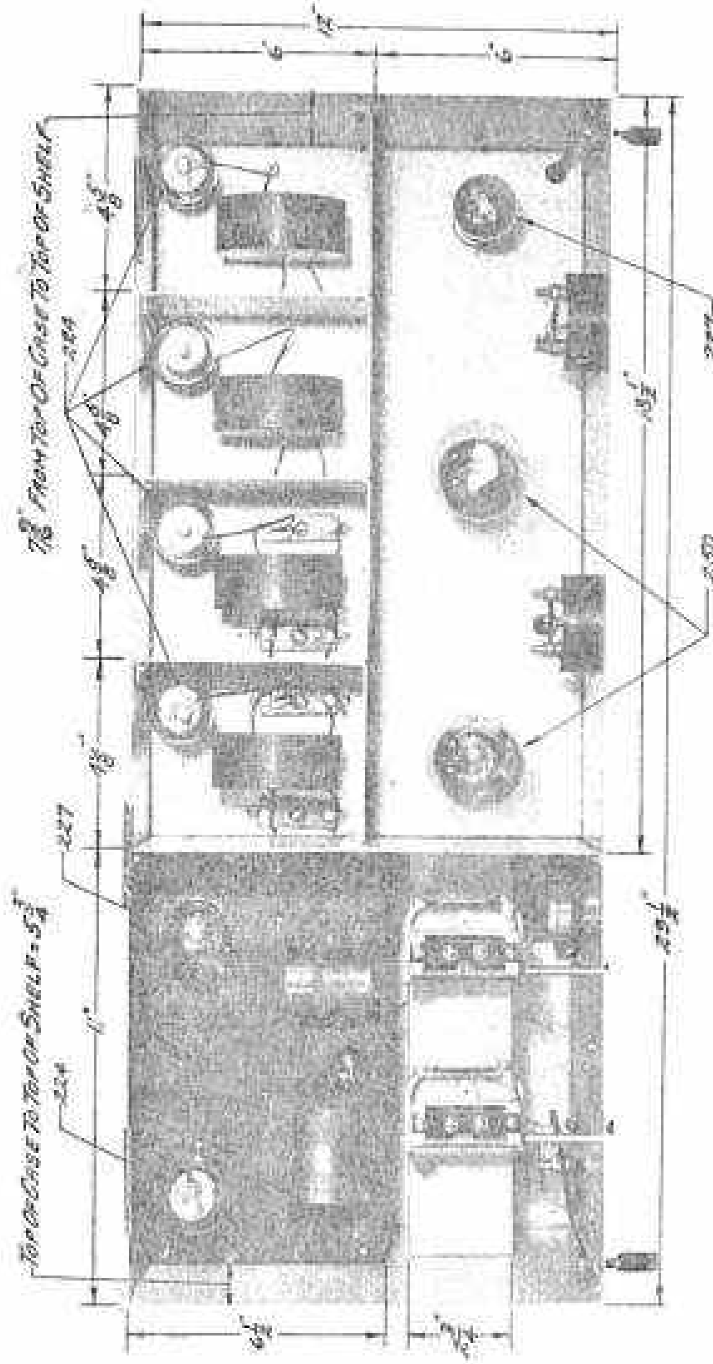


Fig. 156 (b)

Plan View, Special Super-Heterodyne Receiver, Showing Essential Dimensions.

A jack is provided to enable head phone reception and at the same time the volume control is available to regulate the signal strength for this service. The two indicating meters are provided, one measuring the total current consumption of the two power tubes and the other measuring the current consumption of the remaining two. Instead of having two milliammeters it would also be possible to have one milliammeter read the total consumption of the entire receiver and in the other aperture insert a multiple-range high-resistance voltmeter. It would not be advisable to make elaborate connections between this voltmeter and the various circuits on account of the excessive length of leads. It would be better to provide the voltmeter with flexible leads and pick points so that the voltages could be measured at any points required.

The antenna and ground binding posts are brought out at the front of the receiver and likewise binding posts for the dynamic speaker. In the latter case provision is made for both low and high impedance outputs. In the first mentioned case the output is obtained from the secondary winding of the output transformer and in the second case the output is obtained across the primary winding of the output transformer with a protective condenser in series to isolate the high voltages involved.

The interchangeable inductances and transformers for the antenna tuning and oscillator circuit are all wound on forms having a diameter as indicated. The coil data is as follows: (the antenna inductance).

Coil No.	Size Wire	Wave Length Range	No. of Turns	Turns per Inch	Diameter
1	28	200-119	24	22	3"
2	20	120- 71	21	22	1¾"
3	20	74- 45	12	18	1¾"
4	20	50- 31	7	18	1¾"
5	20	34- 22	4	18	1¾"
6	20	23- 18	4	18	⅞"

The coil data for the oscillator inductance is as follows: (Form diameters same.)

Coil No.	Wave Length Range	Grid Turns	Turns per Inch	Plate Turns	Turns per Inch
1	200-119	24	22	20	close wound
2	120- 71	21	22	18	"
3	74- 45	12	18	14	"
4	50- 31	7	18	10	"
5	34- 22	4	18	8	"
6	23- 18	4	18	4	"

It should be remembered that the direction of these coils and the distance between the two windings should be in exact accordance with the data;

otherwise; the oscillator will not function properly, if at all. The tuning of the antenna inductance will approximate the wavelength range given and will deviate from these values depending upon the size of the antenna used and the adjustment of the antenna series variable condenser. On the other hand, the wavelength range of the oscillator coil will vary according to the intermediate frequency wavelength selected and the amount of coupling between the oscillator and the detector. However, with the six coils provided there should be sufficient overlap to provide for all ordinary variations.

There will be cases where the experimenter will probably have a desire to cover the regular broadcast band in addition to the short waves. It should be remembered that while this is possible by using larger inductances, there will not be any preliminary band pass tuning and the system will not be selective if there is predominating amount of local interference. For the wavelength range of 200 to 600 meters three additional coils for both the antenna inductance and oscillator would ordinarily be required. This could be simplified by having each of the two variable condensers in the form of a double condenser of two sections. In this case there would be one section of .00015 for short-wave work and an additional section of .0005 which would be thrown in and connected parallel for the upper wavelength work. With such an arrangement one set of inductances would give two different wavelength ranges. There would also be additional advantages in as much as the large inductances ordinarily used for the broadcast band with the large condensers could also be used in short-wave work with the small condenser and at the same time give an advantageous high L/C ratio. There would, therefore, be a number of different wavelength bands covered by the different combinations and an efficient arrangement could be selected. Figs. 156(g) and 156(h) give the essential dimensions of the front and plan view of the completed receiver. Referring to the front view it will be noted that the two tuning condensers are located on the center line 7 inches from the bottom of the receiver. The first condenser is on the center line 3½ inches from the left side and the other condenser is located 4⅜ inches from the first. A sub-panel of aluminum to support these two variable condensers is located 4¾ inches from the base. Immediately in back of the two variable condensers is a bakelite sub-panel 6¼ inches deep, 11 inches long and located 5¼ inches above the base. This sub-panel has a UX type socket for the antenna inductance to the left, UY type base for the oscillator inductance to the right, the grid-to-grid coupling condensers located immediately between; to the rear and left is located the socket for the first detector of the type —24 and to the right is located the socket for the —27 oscillator tube.

The smaller variable controls are located on the center line 2½ inches above the base and reading left to right consist of the antenna series variable condenser, first detector RF bias control, second RF bias control (on the intermediate radio frequency RF tubes) and finally the audio volume control.

The telephone jack for head phones is located between the last two mentioned dials. Of the two indicating meters one indicates the total B current consumption of the entire receiver and should be located in series with a negative lead between the voltage dividing resistor and ground. This meter should be shunted by a 1 m.f. condenser. The other meter should be in series with the 180 volt tap before it reaches the voltage dividing resistor and should also be shunted by a 1 m.f. condenser. These meters are not shown in the wiring diagram as they may be located to suit the individual requirements. Instead of having two milliammeters some experimenters might desire to have one voltmeter. In this case it is not recommended that the wiring between the voltmeter and certain points in the receiver be made permanent. It would be better to have a two-scale voltmeter reading 0 to 8 and 0 to 200 volts provided with flexible leads and pick points so that readings could be taken at any points on the circuit desired. These readings will only be of comparative value unless the voltmeter is of the high resistance type.

The intermediate radio-frequency amplifier is located to the rear and to the right as shown in the plan view consisting of four compartments, first, second and third intermediate radio frequency amplifier and the second detector. These four intermediate radio frequency transformers are identical in construction. In this particular sample illustrated the transformer-tuning condensers for the first two stages are located above the sub-panel and in the case of the last two transformers are located below the sub-panel. All these eight condensers may be located either above or below the sub-panel as may be required. The total sub-panel of the intermediate-frequency amplifier is 18½ inches long, 6 inches wide and located 3 15/16 inches above the base. This sub-panel is divided into four compartments each of which is 4⅝ inches long.

The audio sub-panel is located at the same height and is also 18½ inches long and 6 inches wide. A —27 tube used as a first audio amplifier is located to the right followed by the two 250 tubes which are used in a push-pull system power audio amplifier. The component parts not shown in the photograph are, of course, located below the sub-panel.

In the schematic wiring diagram there is shown an ideal arrangement where a separate small power pack together with a type —26 tube as a rectifier is used to feed the first detector and oscillator. In this case the —26 type tube should be located in the first compartment. If this feature is not desired it is possible to obtain the necessary voltages for the first detector and oscillator from the main power pack.

The power pack is not illustrated due to the fact that it can be constructed in a large number of different forms. It is recommended that the various component parts be located in a steel case which would include the main power transformer, the 281 rectifier tubes, reservoir condensers, voltage dividing resistor, and filter choke. The control switch is associated with a red bull's eye and indicating lamp which would show when the unit is in operation. Ordinarily the power pack would be supplied for operation on 110 volts 60 cycles AC and in cases where a special voltage and frequency is involved the specification would be altered accordingly. The main secondary winding should give 650 volts each side of the center tap which when rectified and filtered would allow applying 450 volts in place of the 250-power tubes in addition to the other loads involved. In addition, there would of course be required 7½ volts, 2½ amperes for the rectifier tubes and a similar winding for the power transformers. In addition there should be a 2½ volt winding with center tap to feed the 2½ volt AC tubes. It will be noted that in addition to the filter choke in the power pack having a capacity of 100 millihenries at 100 milliamps the field of the dynamic speaker is used as an additional filter choke. This dynamic speaker field should have a resistance of 1,000 volts and capable of handling a continuous load of 100 to 150 milliamperes.

The voltage dividing resistor has a total resistance of 41,000 ohms which includes a section of 750 ohms which gives the correct bias to the two 250 tubes. This voltage dividing resistor should have as many taps as possible so that the proper voltages can be selected for the various other tubes of the receiver particularly if it is desired to operate the first detector and oscillator from the same power pack. In the schematic wiring diagram the first detector cathode bias resistor is shown as having a fixed value of 20,000 ohms. A better method than the one used in this actual design is that of having a 100,000-ohm resistor connected across the voltage dividing resistor as shown so that the voltage applied to the cathode can be varied over a wide range. This controls the sensitivity of the receiver at the first detector.

Considering the plate circuit of the first detector, if the plate were connected direct to the primary of the intermediate transformer the impedance load at that point would not be high enough to secure full output from the tube. As an alternative the plate circuit is coupled to a resistor of 300,000 ohms and the output thereafter capacity coupled through the primary of the first intermediate transformer. This arrangement allows a higher operating efficiency for the first detector.

The cathode for each of the intermediate radio frequency stages is 450 ohms. The cathode for the second detector should be approximately 10,000 ohms. Under certain circumstances a value of 25,000 ohms may be desirable. The by-pass condensers on the cathode should be one-quarter m.f. and the other by-pass condensers in the plate return leads should have a value of .4 m.f. and capable of standing continuous operation at 200 volts. The gain control in the audio amplifier is regulated by a 250,000 ohm variable resistor shunted across the secondary of the first audio transformer as indicated in the diagram. A jack is connected across the primary of the input transformer for head phone reception (push-pull input transformer). In the output circuit of the two 250-power tubes an output transformer is connected the secondary of which has a low impedance winding suitable for connection between the moving coil of an average dynamic speaker. In cases where a high impedance output is involved such as a high impedance dynamic speaker or a high impedance magnetic speaker these may be connected between points of W and Y or Z and Y.

The aluminum used to make the case should be scratch-brushed before bending, washed and lacquered. This will give a permanent satin finish.

The necessary connections between the receiver and power pack are in the form of a cable, a special multiple plug being used at the power pack end. Binding posts could be used if desired.

The filament leads (2½ Volt) carry heavy current and must be of large diameter. Brush cable ⅛" diam. is suitable. All the balance of the wiring is made with flexible wire, heavily insulated. The soldering must be made using a non-corrosive flux such as alcohol and rosin.

In operating the receiver, assuming all "B" and "C" voltages have been adjusted to the correct value, it is only necessary to tune the two Station Selector Dials. In inserting the interchangable coils, two of the same size are of course used at the same time, and then the tuning on both the main dials will follow each other quite closely as far as calibrations are concerned. In the event the oscillator dial does not give any action, it indicates that the oscillator plate inductance winding is in the wrong direction and the two leads to this coil should be reversed.

Tuning up and down the scale, resonance will be indicated by received static, the intensity of which will depend upon the sensitivity adjustment of the receiver and the length of aerial used. Broadcast short-wave stations and radio-telegraph stations using damped wave signals will be heard without the intermediate amplifier oscillating. In order to receive pure continuous wave-telegraph signals it is necessary to have the intermediate amplifier oscillating and this is possible by adjusting the screen grid bias control to secure this condition. Maximum broadcast signal strength is obtained with the intermediate amplifier adjusted just below the oscillating condition.

The selection of an antenna depends upon each individual location. The information given in this book on short-wave antennas should be of considerable assistance in making a decision. Where space is available, a single wire antenna pointing in the direction it is desired to receive and having a length which is a multiple of the wavelength most desired will give the best results. For example in the eastern states an experimenter desiring to concentrate on 5SW (approx. 25 m) would point the single wire aerial on the great circle bearing to London and have the aerial anywhere from 100 to 1,000 feet long. Such an aerial would also have directional effects on other wavelengths which were multiplies of the 25-meter wave, i.e., 100 m, 50 m, 12½ m, and would give proportionally good results on the wavelengths intermediate to these.

Experimenters planning to build this receiver are warned that good re-

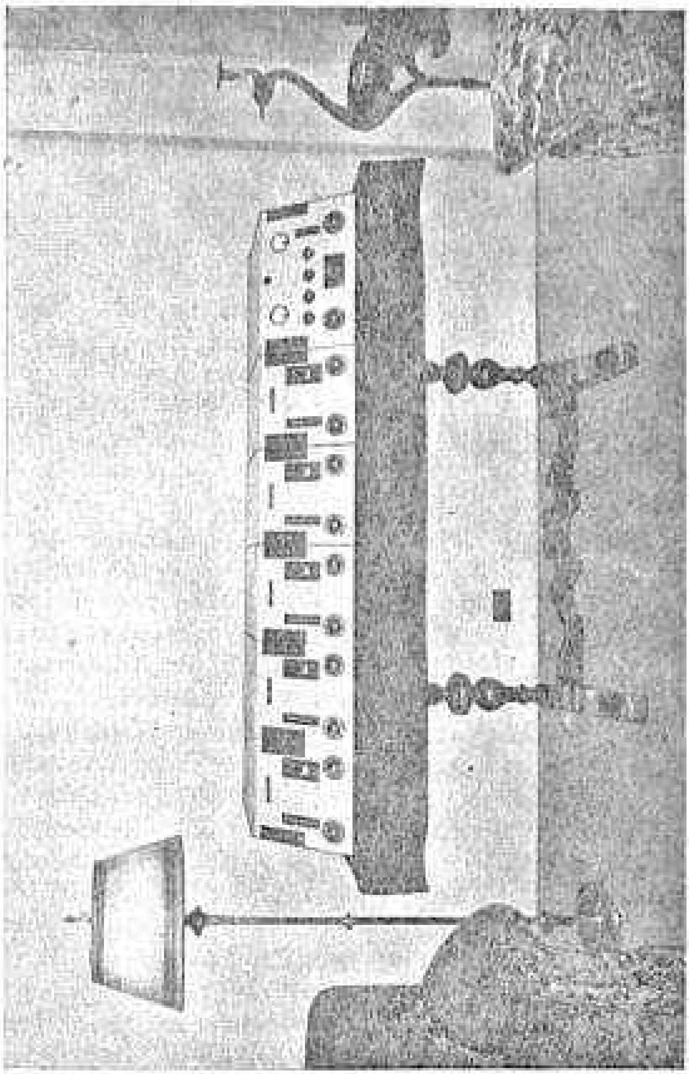


Fig. 156(i)

Universal Transoceanic "Silver Ghost" Broadcast Receiver, wavelength range 200-500 meters; with seventh unit range extends down to 15 meters sults cannot be possibly obtained unless the highest grade component parts are used throughout, otherwise certain parts will break down in service or only be partially effective and the design will be blamed. This receiver and power pack as illustrated and described has been used in actual practice for a number of months and gave actual results by far superior to any short-wave receiver with which it was compared. The results were only exceeded by using a Super-Heterodyne Short-Wave combination consisting of an adapter with a Silver Ghost broadcast receiver, the interchangeable transformers of which were changed to 1,200 meters. It should be explained that this Silver

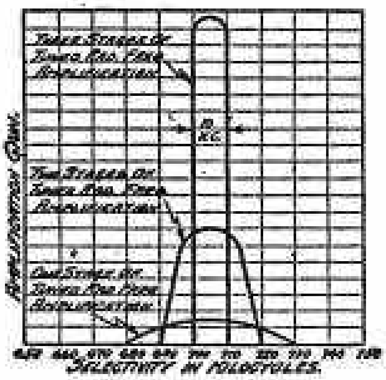


Fig. 156(J)

Graph showing increase in selectivity in a radio frequency amplifier, by adding tuned stages

Ghost broadcast receiver is a scientific instrument over six feet long and too expensive to be popular, but it is capable of results not obtainable with any other broadcast receiver available on the market today. This is not stated as a claim but based on the results as reported by the owners.

The fact that the special short-wave receiver approached the Silver Ghost short-wave combination in performance is a very significant fact.

The Silver Ghost is shown in Figure 156(i) illustrating the six unit table model consisting of one antenna stage (first radio frequency stage), second, third, and fourth radio frequency stages, detector stage, and the audio unit. The audio unit has an initial stage using a —27 tube, two 227's used in an interstage push pull system and two 250's in the power output stage also push pull. In the simple form of Silver Ghost only the grid circuits of the radio frequency tubes are tuned the plate winding being aperiodic. In the advanced Silver Ghost the radio frequency transformers are tuned both on the plate and grid windings giving a still higher degree of selectivity. It should be remembered, however, that if the degree of selectivity is carried to an extreme, the quality of reproduction will be impaired. The graph in figure 156(j) shows the effect of adding the additional stages of tuned radio frequency amplification whether this is straight radio frequency amplification or as used in the intermediate frequency amplifier. It will be noted in the graph that this selectivity increases rapidly with each stage of radio frequency amplification that is added. Obviously this can be carried to an extreme and the cut-off of frequency will be so abrupt as to cause distortion. Accordingly, in the design of a high-grade radio receiver there must be a happy medium between the degree of selectivity obtainable and the quality of reproduction desired.

It is obvious that the Silver Ghost just described would make an ideal intermediate frequency amplifier to use in connection with a Super-Heterodyne short wave adapter as described in figures 153 and 154.

In this receiver design each radio frequency stage is thoroughly shielded from the adjacent stage allowing each radio frequency tube to be operated at its maximum value of amplification. As a matter of fact if desired interstage coupling can be eliminated totally by providing each of the radio frequency stages with a built-in power pack to supply each individual tube. The radio frequency transformers in the Silver Ghost are arranged on interchangeable bases so that they are readily removable. The size A transformers cover 200 to 560 meters and this is a fairly suitable wavelength when used as an intermediate frequency amplifier with the short-wave adapter. To secure a still higher degree of efficiency these size A transformers can be removed and special transformers inserted which cover a wavelength range of 1000 to 2000 meters approximately. These transformers arranged and tuned at a frequency approximating 1200 meters would present an ideal point to carry on the intermediate frequency amplification.

In receiver design it should be appreciated that radio frequency transformers have a wavelength at which there is a peaked efficiency. In the case of the broadcast band, while good results are received on all wavelengths from 200 to 560 meters, there is one point where maximum results are obtained. Accordingly, in selecting an intermediate frequency highly suitable for Super-Heterodyne work the transformers which tune from 1000 to 2000 meters can be operated at their peaked efficient point of approximately 1200 meters. Under these conditions it will be noted that the ratio of L to C is high.

In ordinary tuned radio frequency amplifier usually only the grid circuit is tuned with a shunt variable condenser. When the circuit is altered so that both the plate and grid circuits are tuned, the degree of sensitivity is increased and at the same time with increased selectivity.

In the antenna unit of the Silver Ghost there is an elaborate arrangement which gives the highest possible degree of selectivity without sacrificing any degree of sensitivity. There is a double tuned circuit between the antenna and the grid of the first radio frequency tube and the coupling between these circuits is variable so that the optimum coupling point for any particular wavelength can be selected. With this preliminary tuning circuit it is possible to differentiate between powerful signals even though they are only separated by 10 kilocycles.

It should be remembered that in a coupling device of this sort the maximum signal transfer is not obtained with maximum or 100% coupling. As the coupling is decreased the high frequency resistance of both the tuned circuits is decreased and accordingly, the voltage is increased in each circuit. There is a point reached, however, where the decrease in high frequency resistance is followed by a decrease in transfer energy more than the initial object desired. Therefore, when we reach a point where the energy transfer is less than the added advantage gained by the decrease in radio frequency resistance the optimum coupling point is obtained.

CHAPTER IX

Ultra Short Waves

Producing Artificial Fever

Dr. Whitney and Messrs. Carpenter and Page of the General Electric Company have been studying the action of very short-wave radio fields under a number of varying conditions. Most of these experiments are based on the fact that the various objects placed in this high frequency generate heat. Furthermore, the heat can be generated in the object without consideration to the surrounding material provided it is of a certain substance. For medical service the value of heat as a means of combating and curing disease has been used practically since the beginning of medicine history. The significance of fever and its relation to the course of an infectious disease or to the healing of trauma has been the subject of considerable debate. Ordinarily, a rise in body temperature was considered only as a sign of disease as in pain and to establish relief means were taken to dissipate this abnormal heat. New experiments made during the past few years contradict this old belief and in

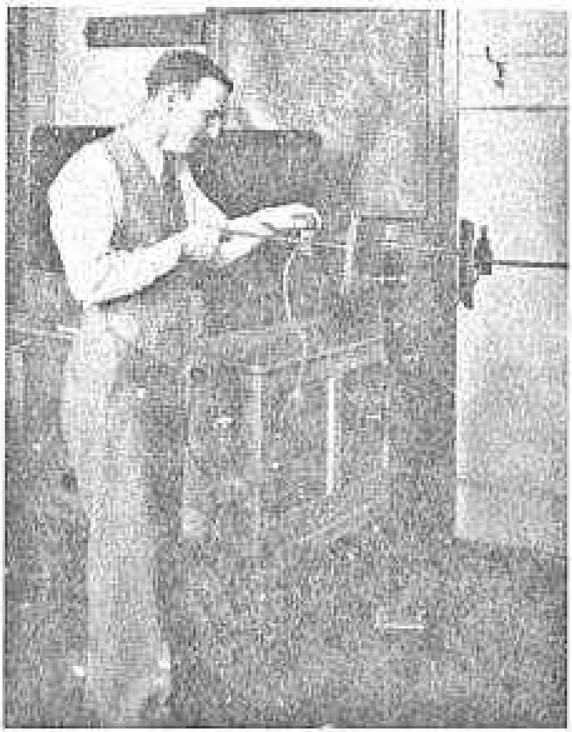


Fig. 157

High Frequency Oscillator Developed by G. E. Co.

contrast show that a fever, disregarding hyperpyrexia of central origin, may be a phenomenon valuable to the diseased animal body as a defensive mechanism for the body. Under certain circumstances a combination of certain diseases occurring in the same individual sometimes results in one curing the other. An example of this is an acute febrile disease with a chronic afebrile malady, in some cases the former making a decided improvement or cure of the latter. Wagner von Jauregg in his development of the malaria treatment for paresis made many observations along this line. His success in this direction has led to the study of the value of fever in an infectious disease syndrome by a large number of other investigators. It is believed that heat associated with the febrile phenomenon, due to the injection of a protein, is the responsible factor for the beneficial results and this is suggested by the favorable results obtained in the treatment of neurosyphilis by heat alone. The present methods used to establish an artificial fever in a body are more or less unsatisfactory and this is particularly true inasmuch as the degree of heat cannot be controlled or kept constant satisfactorily. The injection of foreign protein is hazardous. The use of plasmodium malariae or spirochaetes for the treatment of general paresis often fails because of the danger connected with the administration of a living virus and because of the failure to infect certain individuals who are immune. The start of these investigations was probably due to Dr. Whitney's investigation that the men and operators working in the vicinity of short-wave transmitters were subject to an artificial fever. Since that time much additional research work has been conducted. Hosmer has made investigations of these heating effects on salt solutions of various concentrations and on small laboratory animals. Further investigations showed that this was a definite means of producing artificial fevers at will into animal bodies without the introduction of foreign substances. Contrary to the present methods of applying heat externally the heat is produced direct in the animal body the same as it would occur in the course of an infectious disease fever. There is a further advantage in as much as the internal tissues are heated directly more rapidly, that is, this constitutes a method of internal heating in which heat is generated in the organs of the body as rapidly as in the body walls but because of the greater heat loss at the surface the temperature of the internal tissues rises more rapidly Research laboratories of the General Electric Company have been experimenting continuously during the past two years to develop a short-wave generator which would enable creating a fever in a man rapidly without great discomfort to the patient and at the same time to a degree high enough to be valuable. The final apparatus (Fig. 157) devised is very similar to the transmitters for short-wave radio propagation. However, in the case of radio transmission the short waves are directed or distributed over considerable area while in this case they are concentrated between two plates in the form of a condenser. The short-wave oscillations are obtained from a vacuum tube oscillator, the necessary high voltages being obtained from a full-wave rectifier. Two tubes of 500 watt rating (Fig. 160) are used in the high frequency oscillator which in turn operates at a frequency of 10,000 to 14,000 kilocycles, the output, as mentioned before, being concentrated between two plates. The rectifier circuit (see Fig. 159) consists of a 7,000-volt oil-immersed transformer connected to two half-wave, hot-cathode, mercury-vapor tubes. The resulting voltage from the rectifier and applied to the oscillator is 3,000 volts direct current, (see Fig. 158). Regulation of the high voltage

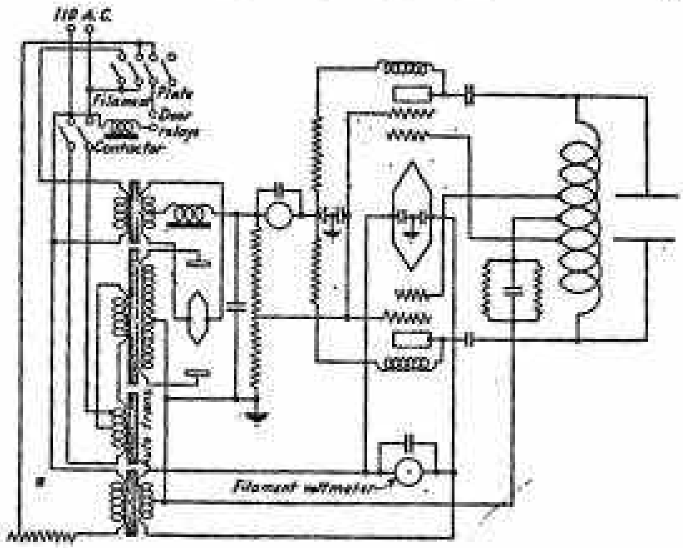


Fig. 158
Schematic Wiring Diagram, G. E. Short-Wave Oscillator, Including High Voltage Rectifier Circuit.

transformers is accomplished at the primary end using an auto-transformer. The condenser plates are made of aluminum 20 inches long, 18 inches high and ⅛-inch thick and in turn are covered with hard rubber plates 20 inches long, 18 inches high and ¼-inch thick. The purpose of these insulated plates is to prevent arcing in case the patient or attendant should accidentally come in contact with the plates. The high frequency alternating current made up of undamped waves between these plates has a drop of 3,000 volts in potential at these two points. To date the greatest heating effect has been obtained with a 30-meter wave which oscillated 10,000,000 times per second between the plates. Other wavelengths tried included 6, 15 and 18 meters but did not produce the artificial fever as effectively as the oscillator just described. The complete oscillator and associated equipment is shown in the accompanying photographs. To support the patient there is provided a frame approximately

6 by 2 feet made of timbers with interlaced cotton tape. Directly underneath and about 6 inches below the frame is covered with celotex ½ inch thick, this forming an air chamber beneath the body. A similar celotex cover 8 inches high and about 5 feet long is fitted over the frame so that the head of the patient projects at one end. This arrangement presents a fairly air-tight chamber around the body as it lies on the tapes. With the patient resting on his back the plates are placed at each side of the celotex box so that the waves oscillate through the body from one side to the other. The distance between the plates can be varied but so far has been kept approximately at 30 inches. Two small centrifugal blowers are placed, one below and one above, to circulate hot air around the body. This decreases the heat loss and equalizes the humidity throughout the enclosure. This arrangement of plates and the fact that the body is enclosed enables rapid heating without causing great discomfort to the patient. In actual experiments the normal temperature of 98.6 degrees F. has been raised to 104 degrees F. and to 105 degrees F. in from

Fig. 159

Short-Wave Oscillator. Electrodes Shown at Top. Rectifier Compartment Open to Show Rectifier Tubes.

60 to 80 minutes. In one instance a temperature of 106.5 degrees F. was recorded. This is not by any means the limit, higher temperature may easily be obtained with the same apparatus but because of limited experience and knowledge the experimenters have proceeded cautiously. After the desired temperature is obtained it can be maintained either by decreasing the voltage, increasing the plate distance, or by hot air blowers. There is no question but that the present apparatus used is a mere start and that it will be greatly improved in the near future. Various theories have ben presented explaining this rise in temperature when exposed to short radio waves. Carpenter and Page believe that this development of heat is due to the resistance of the body to the conduction of current between surfaces adjacent to the opposed plates. The corresponding polarities are induced upon the adjacent boundaries of the interposed body and current is conducted through the material for a brief interval. The heating of solutions similar to blood serum is dependent directly upon their electrical resistance. This is proved by the fact that solutions of different salts when of the same electrical resistance show practically the same identical heating effects. The use of therapeutic fevers is, of course, in the experimental stage but is believed that they have great possibilities especially if the present theories of a febrile action is correct. The effects of these artificial fevers produced on short radio waves has been noted on various laboratory animals and on a good number of patients and to date no observations have been made of any objectionable effect unless extremely high temperatures are maintained for a long period. While noting the increase in body temperature similar observations have been made of blood pressure, the pulse and respiration. Naturally due to the lack of complete information on the subject and the meager data that has been accumulated so far, the progress of these experiments has been retarded by a conservative policy. It is believed, however, that because of the practicability of this method of heating, they will not only be of value to the clinician but also to the physiologist, the biochemist and the bacteriologist. The study of infectious diseases in laboratory animals leads the experimenters to believe that two advantageous effects are obtained by raising the body temperature. There are: first, the increased heat in the body makes a less favorable environment for the multiplication of virus; secondly, the heat increases the rate of those chemical processes concerned with the development of immunity and with the general defense mechanism of the body against infectious agents.

Very Short Waves

Dr. Whitney, continuing his experiments with the very short waves, undertook the investigation to determine how a gall fly makes a gall. This gall-fly investigation led to the development of a new type heater employing a new type of vacuum tubes. It should be pointed out that the matter of insects is one of Dr. Whitney's hobbies. On his farm, abundant with golden rod there were large numbers of small flies, the grub of which causes a large, round swelling or gall in the stock of the plant. This gall is a swelling or excrescence of the tissues of plants resulting from the attacks of certain parasites which cause an abnormal and at other times very extraordinary proliferation of the cells of the host plant. The insect punctures the bark and after laying an egg in this insert, the larva lives in and feeds on the gall. The question to be determined was the cause of the swelling. One suggestion was that when the egg is laid the insect at the same time injects some acid such as the formic acid of ants which causes the plants to swell so noticeably at that point. Another suggestion was that certain bacteria or moulds are injected into the plant when the egg is laid. Dr. Whitney reasoned that possibly the swelling resulted from the local heating of the plant at that point by the growing grub within it, this theory probably being suggested by the fact that it is well known that the growth of plants is accelerated by heat. With this in mind, experiments were started to try to grow artificial galls on plant stems by means of localized heating. The first experiments were conducted with an induction furnace which was an electric heater using alternating current of from 300,000 to 500,000 cycles per second. A furnace of this type which in reality consists of a few turns of a lower voltage side of a trans-

Fig. 160

Front View Short-Wave Oscillator, Oscillator Compartment Open Showing Vacuum Tubes and Main Inductance.

former will quickly heat and melt metals placed within the coil but has no effect on electrical non-conductors.

The first experiment was to see if galls could be grown by means of artificial grubs of steel heated by induction; small pieces of needle points were inserted in the stocks of the healthy golden rod plants which had been parted and taken into the laboratory. The stocks were placed within the small induction furnace coils at a point where the needle points had been inserted. Of course, the small particles of steel were heated by the induction furnace but only in one case did a gall develop and in that one case it was not the usual large and circular type but long, thin and irregular—but at any rate it was a gall. While it seemed that success was being obtained it was also discovered that a new kind of grub was found in the gall. Incidentally, the coil had been placed right over the spot where a different kind of gall fly had laid an egg. Producing galls with steel grubs was not successful but interest in the possibilities of the high frequencies had been raised. After the publicity relating to the gall-fly experiments had been released, the government inquired of Dr. Whitney if radio waves could be used for fighting the boll weevil. Weevils, of course, were not available in Schenectady, but Drosophila (the fruit-fly) was available and made the subject of investigations. The induction furnace which has a maximum frequency of 500,000 cycles was discarded and in its place an induction coil through which very high frequencies (10,000,000 to 30,000,000) could be passed was used. The result was that these insects could be heated readily but when subject to short waves it was found that they could be killed instantly in intense fields. The experiments were facilitated by keeping the insects in glass tubes and out of contact with the condenser plates, this providing more uniform fields and more easily controlled temperature. Fruit-flies kept in glass tubes under a short-wave field were made to hibernate by passing cold air over them. While there is no question about the ability to kill flies with short waves, it did not appear as a practical method of combating the boll weevil.

The next experiments were conducted with the white rat. It was provided with a long glass tube, cotton waste on one end, so that it could select a resting place either on the open end or back within the heating coil. The field intensity was regulated at just enough to elevate the rat's body temperature slightly and the animal selected the heated area as its home. Other observations were being made, radio engineers operating the regular radio transmitting sets. It was found that the men working around the six to eight kilowatt high frequency generators at wave lengths of 20 to 30 meters, their blood temperature was raised slowly when they were close to the equipment. This data coincided with the experiments which had been previously conducted with the induction coil so one of the new tubes was used in further experiments with rats. Placing a mouse between the condenser plates connected with the new short-wave generator tube and subjecting it to increasing field intensities, a steady increase in body temperature was noted. No discomfiture seemed to have been experienced by the rodent until the field intensity was on a very high order. The mouse then lost its tail but with no apparent discomfort. This narrows down to a case of dehydration—the short-wave field having driven out all the moisture from the mouse's tail and in turn the tail shriveled and dropped away. This experiment of dehydrating the mouse's tail led to investigations in the curing of raw porcelain. It is well known that before moulded porcelain can be fired and baked it is necessary to dry it thoroughly. This requires considerable time especially in the case of pieces having considerable thickness. Drying the exterior surface is

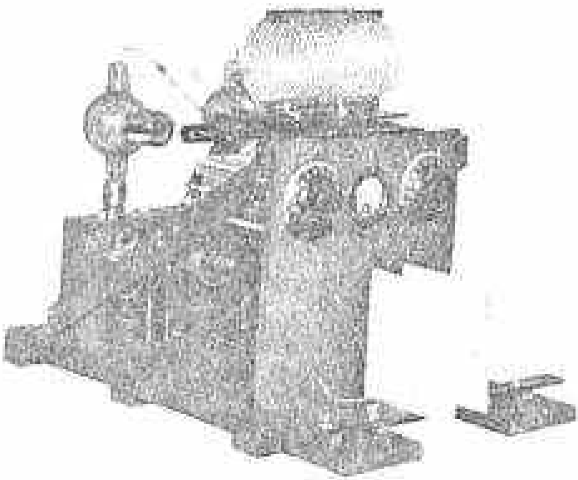


Fig. 161

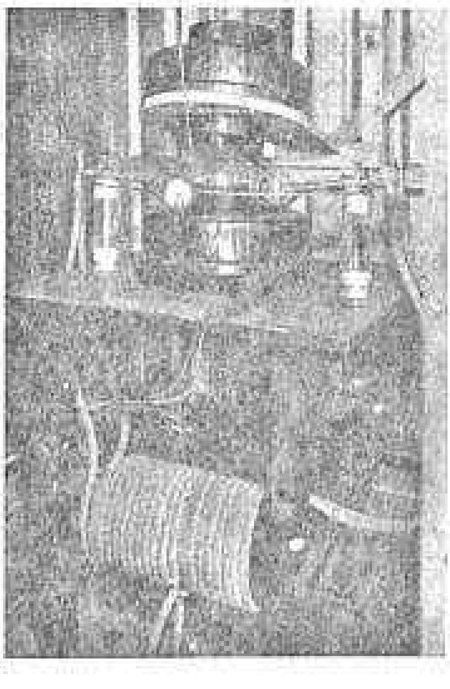
Experimental High Frequency Oscillator to Enable Studying Effects of Short Waves on Different Objects.

easy enough but the moisture within the mass always offers difficulties. It has been noted that the short wave equipment has the peculiar property of heating objects from the inside and working out which is ideal for this work inasmuch as it is possible to dry porcelain thoroughly within a few minutes. The experiments along this line have been purely technical and have not reached a point where they can be used for commercial application.

The oscillating tube used in this investigation is the G. E. Pliotron PR-861, a screen grid, four-electrode tube. The output rating is 500 watts, this construction making it possible is especially adapted for production of high frequencies. The connection of the internal elements, filament, grid and plate are supported on separate stems and the leads brought out at individual seals insuring high insulation and low electrostatic capacity between electrodes. The filament is thoriated tungsten in the form of a double helix supported from a center rod and not requiring any tension springs. Both the grid and plate are cylindrical and the plate has six additional flanges for the dissipation of heat. The screen grid electrode consists of a close mesh placed between the control grid and plate and extends the full height of the tube. This is supported between the filament and control grid stems. This second grid provides the electrostatic shield between the plate and control grid. The screen grid potential is held constant and variation in potential of the plate has practically no effect on the control grid potential. In view of the above there is no feed-back to the tube from the plate circuit. This reduces the necessity of any neutralizing to prevent any feed-back in any radio frequency circuits. This high frequency heater provides a means of heating materials in a high frequency (10,000 kilocycles) electrostatic field with a maximum output of the oscillating tubes of approximately one kilowatt. All the other equipment is housed within a case three feet high, three feet wide and six feet long and arranged on wheels to be portable. It is exactly the same as a short wave radio transmitter except, as mentioned before, the radio frequency energy is concentrated between two condenser plates instead of being directed to an antenna. In one type these condenser plates are mounted on top this case and in another model the plates are on a separate adjustable stand. The variable controls and indicating meters are on the front panel of the case. The set is arranged to operate on any voltage of 105 to 125, 60 or 25 cycles, alternating current, at normal operating conditions draws approximately 30 amperes which would total 3 kilowatts. The screen grid voltage is not critical the value being about 500 volts and obtained from a voltage divider

Fig. 162

Magnetron, Showing Arrangement of the Tube and Electro-Magnetic Coil.



across the main 3,000 volt main current supply. The oscillating circuit is a shunt-feed Mesny push-pull circuit operating from transformers of 3,000 to 9,000 kilocycles. The most impressive and efficient operation is at about 10,000 kilocycles. The heater plates in this circuit are in parallel with the oscillator tank coil. Blocking condensers having a working voltage of 6,000

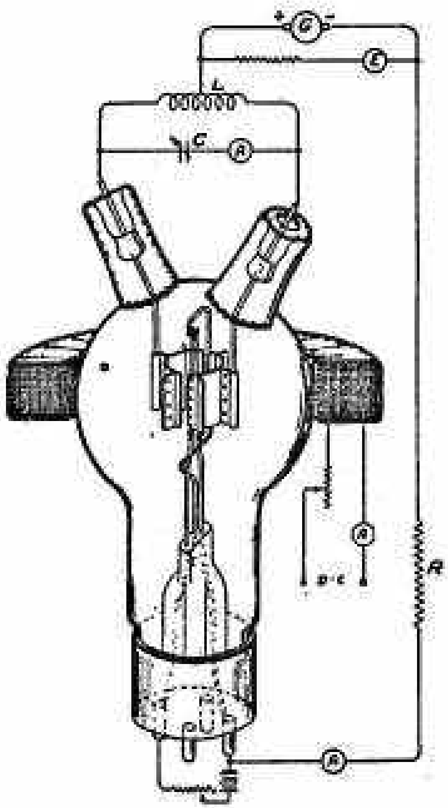


Fig. 163
Magnetron Oscillator Circuit, The Concentrated High Frequency Field is Obtained at Point C, Which May be the Capacity of the Electrodes Alone.

volts keep the high voltage direct current from the heater plates. The operator is protected from the apparatus inasmuch as all equipment is enclosed in a hardwood framework. In the event the doors are opened during operation, relays automatically shut down the set and disconnect all the current.

Generation of Very High Frequencies by Means of the Magnetron

In the past, methods proposed for obtaining very high frequencies on the order of 100,000 kilocycles (100,000,000 cycles) per second and higher have been proposed through the use of vacuum tubes but in each case, only small amounts of power have been obtained at these frequencies. The following system described outlines a method allowing the production of relatively high amounts of power at very high frequencies. Through this method, electromagnetic and electrostatic fields of unusually high intensity for these very high frequencies can be produced. This system is of particular interest in connection with the present interesting experiments in therapeutics, bacteriology, chemical reactions and the properties of insulating materials, etc.

Magnetrons for the production of high frequencies have been previously described. This term "magnetron" is the G.E. trade name for magnetically-controlled high-vacuum tubes. To date, the entire possibilities of these tubes and their design together with the many practical applications have not been fully realized. In simple form, this type of magnetron tube consists of a cylinder which is split so as to form two equal semi-cylindrical anodes using a filament as a hot cathode at the axis of the cylinder.

In the low power tubes, the two similar anodes are made similar to the ordinary power tubes and are constructed of nickel, molybdenum or other suitable metals having a high melting point. The anodes are so shaped to be cooled by radiation. In high power magnetrons, the anodes are water cooled. The filament or other form of cathode is usually tungsten, thoriated tungsten or coated depending upon the rating of the tube and the anode voltage and current. In this form of magnetron oscillator, the frequency obtained is not a function of the time of passage of the electrons from the cathode to the anode except to a minor consideration. The anode diameter, therefore, is not a direct factor in the design of a tube for a desired frequency. Furthermore, it follows that the oscillations from this form of magnetron oscillator are not of the so-called Barkhausen type. (The Barkhausen oscillations are of a different sort than those generated by the magnetron. They are generated in a three-electrode tube by making the grid positive and the plate negative. The electrons coming through the grid are repelled by the plate and again return into the field of the grid; then repeating the cycles. The time for one cycle is controlled by the geometry of the tube. These very high frequency oscillations offer extremely interesting possibilities in communication, therapeutics and similar researches).

The anode potential being of a high order—several thousand volts—the technique of design and manufacture of the tube closely follows the three-electrode type transmitting tubes. Dr. A. W. Hull has previously described the action and path of travel of electrons under a combined electromagnetic and electrostatic field. A typical arrangement of tube and electromagnetic coil is shown in Fig. 162. The magnetic lines of force are arranged to be parallel to the axis of the split cylindrical anode. At the non-shielding condition, the field strength must be sufficient to cut the anode current to 0 at the plate voltage used. For example—operating a small tube with 1500 volts DC to the anode, a magnetic field strength of 750 gausses is required. The optimum magnetic field varies with the DC voltage to the anode and accordingly, it is desirable to have a variable control of the direct current to the

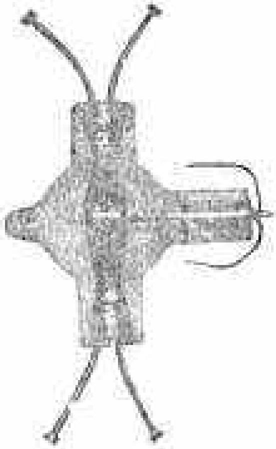


Fig. 164
Large Size
Magnetron Tube.

electromagnetic coils. In view of the fact that the oscillation frequency is not a function of the time of travel to the anodes, a frequency does not depend upon the strength of the magnetic field and the latter need not be constant. The circuit arrangement is shown in Fig. 163 and it is apparent that the oscillating circuit includes the two anodes. The inductance and capacity components in the external oscillating circuit have the primary determination of the frequency obtained. On the other hand, the inductance of the leads between the external coil and the anode between the two is a factor as well as the capacity between the leads and anodes, this being particula.ly true in the case of very high frequencies. For example—high frequencies in external concentrated capacity are used and the external inductance is simply

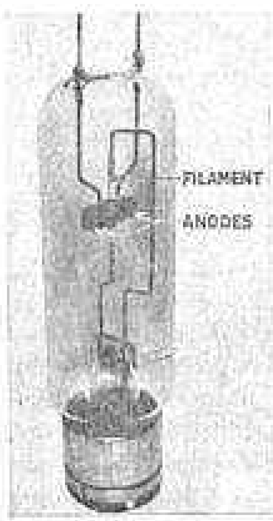


Fig. 165
Small
Magnetron
Tube.

a lead long enough to connect the two anodes together. Therefore, in the design of the circuit used in these tubes and the capacity between leads to the two anodes must be kept at a minimum. With a medium size water-cooled tube, an output of 2.5 kilowatts is obtained at 75,000 cycles. An interesting consideration is the reason why high outputs at these very high frequencies can be obtained from this form of magnetron and its circuit than from the special conventional design of the three-electrode tube. Two principal reasons are given: first, the effective capacity between the two anodes of the magnetron can be reduced to a much smaller value than the grid-to-plate capacity of the regular three-electrode tube. Furthermore, in the regular three-electrode tube, under high frequency conditions it is difficult to maintain a 180 degree phase relationship between the grid and plate voltages. The combined magnetron tube and circuit described has been shown to be particularly suitable for production of high frequency power in a range between 40,000 and 400,000 kilocycles. For lower frequencies, special three-electrode tubes and circuits are available and for still higher frequencies, the magnetron of this type required further special design and while the high frequencies are obtained, there is a considerable reduction in power output. At the same time, it should not be overlooked that the magnetron is suitable to produce low frequencies even down as low as 60 cycles when using very large inductances and condensers. Not including power consumed by the external electromagnet, the efficiency of the electromagnetic arrangement compares favorably with the regular three-electrode tube.

In very high frequency circuits, it is very difficult to measure the output and in the case of these experiments, it is considered to be the direct current input of the circuit of the anodes less the loss in the two anodes. In a small magnetron (Fig. 165) operating on a voltage of 1500, an output of approximately 10 watts can be obtained at 400,000 kilocycles. With the same tube, an output of 40 watts can be obtained at 100,000 kilocycles or less. With a medium size water-cooled tube, an output of 1 kilowatt can be obtained at 84,000 kilocycles. The output can be increased to 5 kilowatts by reducing the frequency to 20,000 kilocycles. With these outputs, the anode supplies 10,000 volts direct current. In the case of the small magnetrons, on account of the filament power of about 25 watts and the power loss in the electromagnets of about 125 watts, the over-all efficiency is low. In tubes of larger design and water-cooled, the power consumption by the electromagnet is small in proportion to the output. This particular type of tube and circuit is invariably an oscillator and not an amplifier. In using this device to experiment with high frequency electrostatic fields, it is usually desired to concentrate the field between two points. This can be accomplished by connecting the two plates or electrons between which the field is desired to the two anode terminals of the magnetron. In other words, these electrons are the plates of the external condenser. The size of electrons and the distance that they can be separated is governed, of course, by the amount of additional capacity that can be added to the circuit without causing undesired changes in these characteristics. In a case of an intense and highly localized field within the minimum wavelength of the tube, this is accomplished by the addition of an open resonator to the circuit, as shown in the accompanying Fig. 165 and consists of two leads in a straight line and the length of each one must be adjusted so that together they should be about one-half wavelength long. The desired intense electrostatic field if found at the outer end of each rod after they have been adjusted to resonance.

High Frequency Currents in Surgery

The first introduction of high-frequency currents in therapeutics in the United States was that of Nikola Tesla in 1890. These experiments ran parallel to D'Arsonval's. Previous to that, heat has been used in surgery for many years, for example: electric cautery which destroys pathological tissues but piles up a mass of carbonized debris around it. As early as 1907, Doyen, lecturing before the French Surgical Congress, stated that among the various means available for the destruction of pathological tissues the only certain method was that of applying heat.

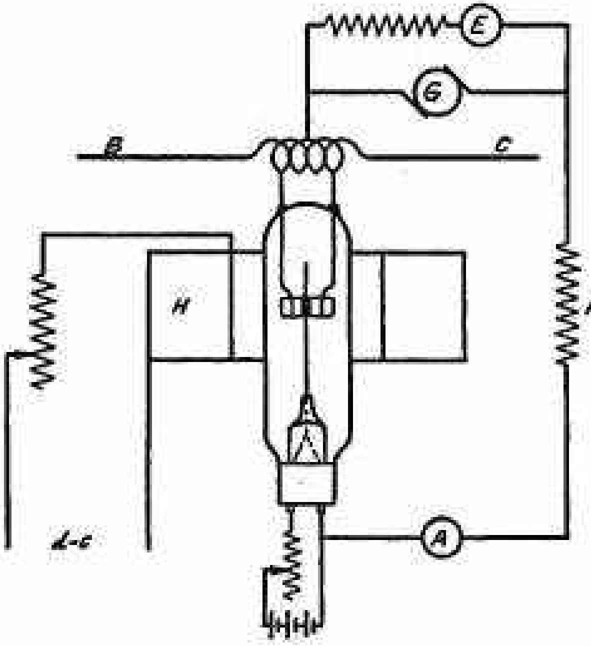


Fig. 165 (a)

Magnetron Oscillator, Arrangement to Obtain Concentrated Fields, Which Are Obtained at Points B and C.

Heat is produced in the tissues by high-frequency and other electric currents. This is similar to the heat dissipated by an electrically operated device. In medical diathermy, large areas or sections are quite often heated but it is important that destructive temperatures be avoided. For example: one ampere of high-frequency current flowing through an average size wrist very quickly becomes unbearable. In actual practice, the application electrodes are made of relatively large areas which will keep the current density low in cases where intense concentrated and localized heat is not desired. On the other hand, in surgical endothermy (heat from within), the application is just the opposite, the current density being made purposely great by the use of relatively small electrodes at the point of application so that boiling or cooking will result quickly. The greatest current density is obtained at needle points.

The radio knife consists of a cambric needle applied to the living tissue and under proper conditions, this produces instantaneous boiling when applied to the living tissues, see Fig. 167. This is due to the high current density and the small spark present. At the point of contact there are minute steam explosions which separate the molecules of the tissue producing a clean cut similar to that obtained with a knife but with the added advantage that lymphatics and capillaries are sealed closed so there is no bleeding except, of course, where arteries and veins are not encountered. The mechanical implantation of harmful cells therein cannot occur. In other words this radio knife sterilizes as it cuts and also heats the separated nerve ends to such an extent that post operative or surgical shock is greatly reduced and furthermore, the healing is accelerated. Of course, skill is required with the application of the electric knife and with the proper technique the tissue is not burned excessively nor heated any more than necessary.

Electrical surgery has proved valuable in the treatment of cancer simply as an aid and not as a cure. In the removal of superficial and semi-superficial lesions, electrical surgery is of prime importance. In the early methods of knife surgery the operator first cuts and removes the living lesion, the malignant, of course, associating with the blood stream and in turn carried elsewhere through the body and afterwards destroys it which is just the opposite of the procedure followed by the electrical method which first destroys the lesion and then removes it as a harmless mass.

This destruction is accomplished through electrocoagulation and dessication (meaning dehydration or drying). Needle electrodes varying in size up to an inch or more in diameter and available in different shapes are used in the process of electrocoagulation which is extremely valuable in the destruction of malignant tissue as well as to prevent and stop bleeding. In practice it is found that much stronger currents and greater time intervals are required in electrocoagulation and in cutting. Under certain conditions the cutting current may be more or less coagulating as well. In either procedure, two electrodes are connected to the patient, the "common" electrode being attached to some extremity over a relatively large area to reduce the heat at that point and the "active" electrode is the one applied to the point where the useful heat is to be developed. In the case of treating an accessible tumor by electrocoagulation, similar electrodes are placed on each side of the tumor in which case they are both effective and give the best results. The dessication process may be employed to stop bleeding in which case the needle is held within the tissue to be destroyed, the controlling spark passing between the needle and the tissue. Some operators practice the removal of moles, warts, etc. by dessication. The required current is available from a Tesla coil or an Oudin resonator. The contact with the patient is "monopolar" as the capacity between the patient and ground is sufficient as a return circuit. In electrotherapeutistic practice there are a large number of methods of applying electrical currents both direct and alternating to treat various disorders. The forms of direct and alternating current, the latter for special wave forms, etc., are relatively weak. These currents, if as strong as the high-frequency types used, would become feeble. The body cells are electrolytic in character and neuro-muscular contraction develops partially when the ions are displaced in the cells. With increased current frequency there is a reduction in the displacement of ions and that reduces contraction. In general, it is desirable that high-frequency physical and surgical diothermy machines be free from any cause of neuromuscular contraction. The seriousness of this is realized when it is considered that the application of the radio knife because of twitching muscles may throw the knife against the large blood vessels or organs which if damaged by cutting may cause serious consequences. In other words, the cutting must be under absolute control of the surgeon and contraction must be avoided to prevent accidents. Underhill has outlined the results of some interesting experiences in actual practice for example: in high breast amputations, operations started with electric knives had to be concluded with the scalpel because of contraction of the pectoral muscle which tended to force the radio knife against the axillary vessels at which point contact could not be made without disastrous results. Other surgeons have used electrical insulating materials placing them adjacent to large blood vessels thereby preventing their being accidentally cut on account of neuro-muscular contraction. In experimenting with contraction, Underhill placed raw meat in his mouth and then performed simple simulative operations on the meat using a mirror. In these experiments, there was no evidence of any contraction or faradic sensation. Continuing and using the same machine in opening various abdomens, no objectional contraction would result in some instances but in others the contraction would be excessive causing the tissue to thrust up towards the needle thus endangering the organs beneath. It is generally thought that all the electric surgical machines of this type are more or less subject to some difficulty due to contraction of the spark gaps used for the production of high-frequency currents for cutting, electrocoagulation and dessication but the production of high-frequency currents through the use of electronic tubes is preferable for cutting and certain electrocoagulation. The latter and dessication can be accomplished by spark-gap high-frequency currents from the same machine containing the electronic-tube cutting apparatus either by a switching arrangement or through the use of separate terminals. With this arrangement the same transformer feeds the electrocoagulation and dessication currents while a second transformer feeds the cutting current. The principal advantage of the electronic-tube generator of high-frequency currents over the spark gap method for cutting apparatus is the smoothness of the electrical current output and the consequent lack of faradic sensation or contraction. The spark gap machine produces damped high-frequency currents compared with the continuous wave type of the electronic tube. Other conditions equal, the separation of the spark gap electrodes requires a high voltage for spark production. This causes a reduction in the frequency of the sparks. The number of sparks per second is independent of the frequencies of the supply and output currents provided there is no ionization between the gap electrodes. The maximum number of sparks per second is obtained with the gap electrodes close together and having the capacity of the oscillating circuit condenser small. Lowering the power input will decrease the number of sparks per second but stronger output currents are obtained when the spark gap electrodes are separated farther apart. In the event the output currents are too strong, this will increase the neuromuscular contraction and will also cause the tissues to be overheated and scorched. Cutting under this condition is more difficult. Spark gap machines have the advantage of being quite compact and less expensive than the electronic tube type. They are also free from damage in handling due to being of more rigid construction. In both type machines, the patient is protected through insulated inductive couplings or by inserting condensers in the patient's circuit. This in turn reduces effective contraction. The accompanying schematic diagram illustrates the simple electronic tube cutting and coagulating machine. The second diagram shows the rectifier circuit used to energize this oscillator in place of the battery or motor generator. It will be noticed from these circuits that the radio designs have been followed. The input currents can be regulated by switches or variable reactors. The output connections are obtained through a coupling circuit and suitable condensers. Naturally, many surgeons prefer the scalpel for operating but the decided advantages of electrocoagulation in connection with electrically performed operations are realized especially as bleeding can be prevented or immediately stopped in many cases without the use of ligatures.

A typical example is the case of operating on the abdomen. The first incision is made with a needle cutting two blood vessels which requires the application of four clamps. Additional clamps are required in the operations on the organs but these two blood vessels will serve as an example. When these clamps are to be removed, the surgeon can apply coagulating current and quickly touches each clamp with the needle successively and this causes the ends of the blood vessels to be completely cooked and the clamps can then be removed. When the scalpel alone is used, four clamps must be applied. Eventually, the operation will be performed more rapidly by the surgeon holding the blood vessels with tweezers and touch them with the needle, thus avoiding the use of clamps.

The needle cuts without pressure and ordinarily no trace of sparking is apparent but it must be remembered that some kind of sparking is necessary for cutting since the sparks produce the heat that causes the incision in the tissue. Electrical surgery has been successful in the resection of the prostate gland and it is claimed that in this particular case it has reduced mortality from 50% to 5%. In this electrical operation, an irrigation catheter if ingenious construction is used, including a telescope, lamp and a cutting loop which in necessity cuts under water. Of course, special electrodes and operating technique are required. The actual cutting is confined to the prostate gland itself. The patient is hardly inconvenienced, as only a local anesthetic is required. The removal of tonsils and hemorrhoids is facilitated through the use of electrical surgery partly through electrocoagulation and partly through electrical cutting. Two of the standard electrical generating machines of this type are illustrated. The upper portion contains the electronic-tube cutting apparatus which may also be used for some forms of electrocoagulation. A volt meter is provided to indicate the filament voltage and a neon lamp indicates when the resonance has been obtained. The lower half retains the spark-gap operating apparatus for electrocoagulation and dessication. Meters are provided to indicate the current strength of the patient through controls provided to regulate the strength. Electrical machines and apparatus of this nature is in constant use and it is expected that in the near future still more important improvements will be made and while contraction is not important in some operations, the elimination of this undesirable feature will be quite welcome. It is quite apparent that the great possibilities along this line of research have not been scratched and that new and important contributions to the art will be introduced continually.

Experiments With Radio Waves of 3 Meters

The follow reports on ultra-short-wave experiments are based on experiments conducted by Abraham Esau and Walter M. Hannemann of the German firm of C. Lorenz.

Experiments on Wave Propagation

On the basis of the experiments of the Technical Physical Institute in Jena, it had become possible, at the end of 1925, to generate waves with a length of about 3 m, with a capacity of about 100 watts. The next problem

_' 'n up was the investigation of the behavior of these waves during their propagation. In the absence of a suitable tube receiver, a simple dipole was first used as a receiver which was tuned to the transmission wave and containing in its center, a normal crystal detector. It was found at once, that as compared with longer waves, only a very few crystal combinations were suitable in this range of extremely short lengths. The most sensitive detector was one consisting of silicon and a metal whisker. This detector arrangement retains its sensitivity even for wavelengths as short as 30 cm, and in all prob'bility, it will still work for considerably shorter wavelengths.

The ranges covered with this device were still very short, however, and could not be increased to any appreciable degree by the application of low-frequency amplifiers. Upon increasing the distance from the transmitter, the limit of sensitivity of the detector was very soon reached.

With a view to longer ranges, the problem therefore consisted in greatly incr... the sensitivity of the receiver. This was done by replacing the

Fig. 166
A Portable High Frequency Surgical Outfit.

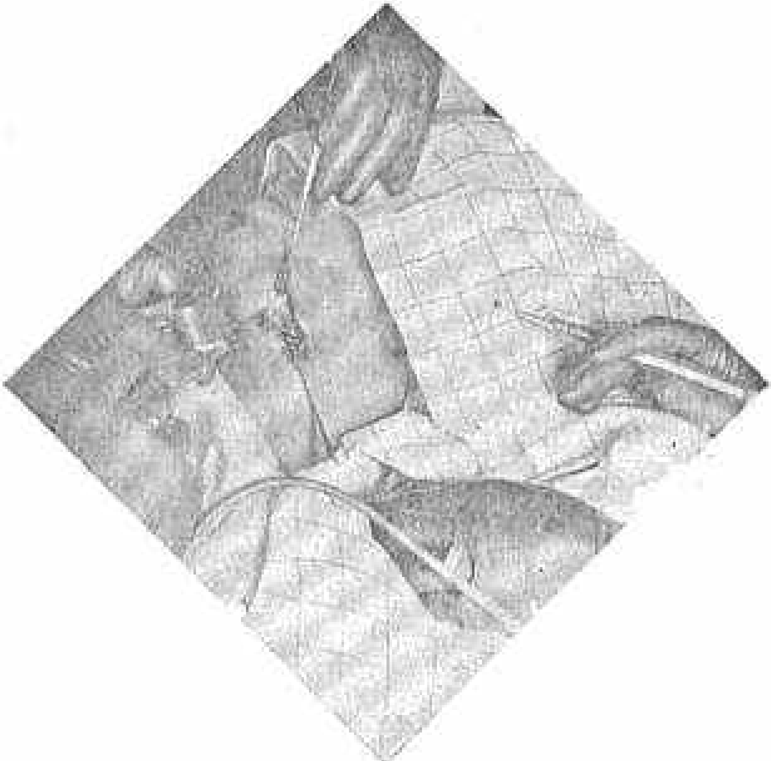


Fig. 167
Actual Operation, Using Electric Knife.

detector by a tube, as first developed by O. Cords and consisted of a simple wire loop and a rotary condenser for tuning. The return coupling was made by a three-point connection. In addition to this, a three-stage low-frequency amplifier was provided. The receiver worked, it is true, with any kind of receiving tube commonly used, but it appeared that tubes containing some gas produced greater amplification than those with a higher vacuum.

With this receiver and a 70-watt transmitter more extensive long-range experiments were carried out during the winter of 1925-1926. Distances from 4 to about 40 km were bridged with success. The latter range was, however, the maximum limit and could be attained only if the capacity of the transmitter was raised to about 200 watts.

These experiments were still very difficult to carry out as the adjustment of the receiver required a good deal of effort due to the difficulty of the sudden starting oscillations, since it was possible only in a few cases to render the receiver really sensitive. It was shown by these experiments that the atmosphere did not influence the propagation of the waves, the intensity of the eption always being the same in all kinds of weather and also during daylight and dark. It was found to be very advantageous to place the transmitter, if possible, in an open, instead of in an enclosed space, in order not to impair its radiation. The maximum intensity of reception was attained when an isolated spot, situated at a high level, was selected as the location for the transmitter. Similar results were also obtained when the transmitter was placed at the seacoast, the receiver being located aboard a ship at sea.

After a number of improvements had been made to the above receiver, an effort was then made during the rest of the year 1926 to adapt the transmitter and the receiver for the purpose of telephony. After many receiver design difficulties had been overcome, it became possible to telephone a distance of 20 km. There still occurred, however, much distortion which was not due to the transmitter (as was easily proved), but to the nature of the reception. The basic cause was that (as already mentioned above) the point where oscillations started could not be regulated to a satisfactory degree, so that either a non-distorted, low volume of tone, or else a much stronger tone more or less distorted was obtained.

During the year 1927, the improvement of the receiving equipment was continued, and after a large number of failures, success was finally reached in getting satisfactory sensitivity and at the same time easy adjustment of the receiver, first, by making the feedback coupling in a different manner (inductive) and secondly, by introducing the principle of super-regeneration (oscillating return coupling). These two factors were responsible for the improvement of the receiver and to them is due the elimination of all the difficulties which had been previously encountered in receiving.

During the second half of 1927, it was easily possible to bridge a distance of 20 km and more by telephone, while the transmitter capacity required (which in the first experiments covering the same range had amounted to more than 100 watts), could be reduced to below 1 watt, without the clarity of reception being impaired in the least.

The experiments on the maximum ranges were then taken up again, and in the beginning of 1928 it was possible to hold a duplex telephone conversation over a distance of 20 km with technical perfection, the sender having a capacity of about 0.5 watt, and the difference in wavelength being only 2 cm (active wave 3 m). Transmitter and receiver were placed close together, in these experiments.

At the end of February, 1928, the same duplex conversation was held over a distance of 85 km. In these experiments, the transmitter was located on the Inselberg (Thuringer Wald, 916 m above sea level), while the receiver was located on the "Fuchsturn" (an isolated mountain in the vicinity of Jena). In this case, also, it was shown that the tone volume at the receiving end was not influenced by the condition of the atmosphere, and moreover that atmospheric disturbances did not occur, not even—as had already been found during the experiments made in the spring—when lightning str· in the immediate vicinity of the receiving station.

Together with these experiments, another was carried out for the purpose of concentrating the transmitter energy in a single direction by means of reflectors. Detailed reports on these experiments have been made by Gresky. The results of his investigations may be summarized to the effect that by means of a parabolic reflector, consisting of wires and adapted to the wavelength, a concentration of energy of 1 to 12 may be attained. If the dimensions of the reflector are correctly chosen, the radiation characteristic (that is, the sector in which the radiation occurs) becomes very acute, while moreover the back radiation (that is, the amount of energy penetrating backward through the reflector) becomes very small. The opening of the reflector must be made practically about one and a half times the wavelength and it appeared to be essential that the ratio between wavelength and the distance of the sender from the mirror (vertex of the parabola) should not equal 0.25, as was heretofore generally done, but to a somewhat higher value,

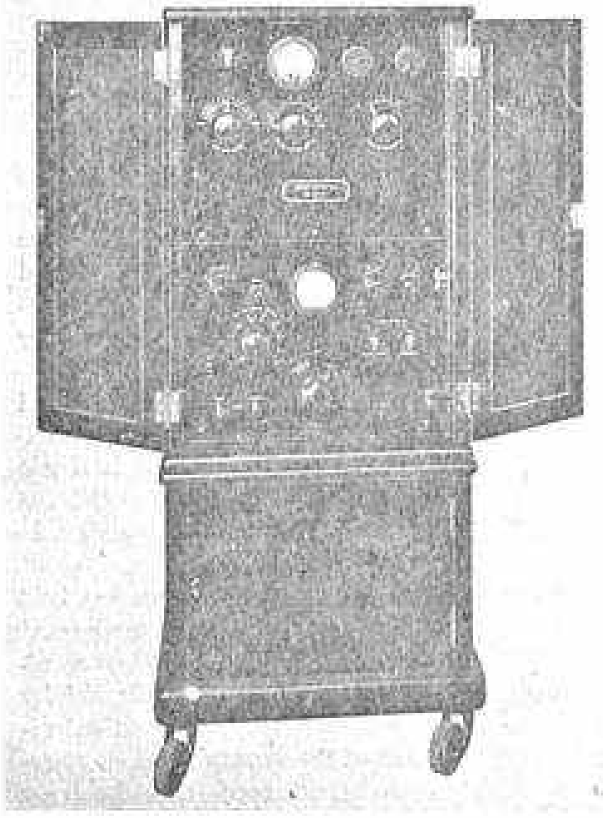
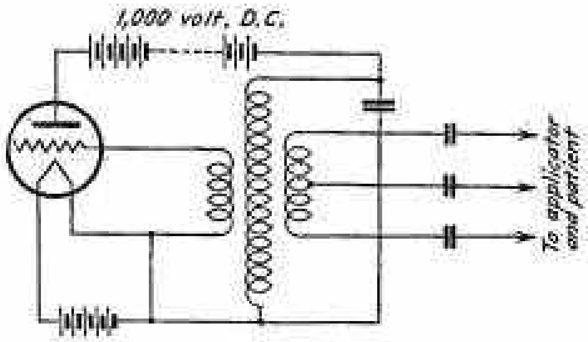


Fig. 168

Westinghouse High Frequency Oscillator for Electric Surgery.



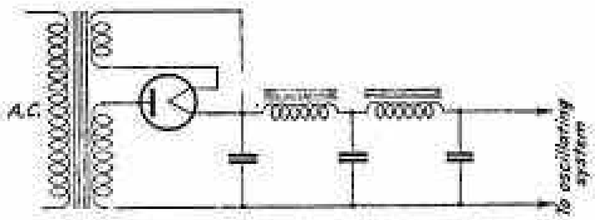


Fig. 169

Above—Circuit of simple electronic-tube device for surgical cutting and coagulating.

Fig. 170

Below—Source of Direct-Current Supply for Portable Apparatus.

in the present case 0.28. A further increase in the opening of the reflector c.p. does not result in any appreciable increase in concentration and acuteness of the radiation characteristic. If the parabolic arrangement is replaced by a plane (all reflectors arranged in a straight line), the results obtained are less favorable. The concentration, as well as the directive action and the back radiation, is impaired, the former, for example, being reduced to half its original value.

The question of the transmitting antenna also influences the maximum range. For short ranges, the radiation from the closed oscillation circuit between the anode and the grid is sufficient, and the addition of a dipole coupled to this circuit causes no appreciable increase in volume at the reception end. The influence of this antenna does make itself felt at longer ranges, however, so that in order to cover longer ranges, it is necessary to use dipole antennas, both at the transmitter and the receiver end. It is immaterial in this case, whether the coupling with the generator circuit is inductive or conductive or whether the dipole is horizontal or vertical.

In the above experiments, obstructions between transmitter and rece' that would affect the propagation of the waves had been avoided as much as possible by suitable selection of the locations for transmitter and receiver. There now followed a number of experiments in which the transmitter could freely radiate into space at a high level above the ground, while the receiver was moved around in an automobile in order to determine what influence would be exerted by obstructions such as hills, houses, etc., located between transmitter and receiver. It was found, contrary to expectation, that a screening effect caused by groups of buildings and conductors could not be observed, or only to a very slight degree. During a test ride, made first through the streets of the city of Jena, and then through a valley to a point at a distance of about 20 km there occurred a considerable decrease in intensity of reception in only two cases, while at all other points the signals were received without difficulty.

In the meantime it had become possible to build transmitters with capacities above 1 kw. Experiments were made with these transmitters in July, 1928, in Upper Bavaria. The transmitter was located on the Herzogstand, at a level of about 1700 m (between Kochel and Walchensee), while the receiver could change its location at will. It then appeared, among other things, that in one particular case, signals in the loudspeaker were still extremely strong at a distance of 180 km, while nothing could be heard even with considerable amplifications, at a distance of about 50 km. The cause of this sudden drop was assumed to lie in the fact that the optical range has a controlling influence on the reception, as has also been shown by the experiments

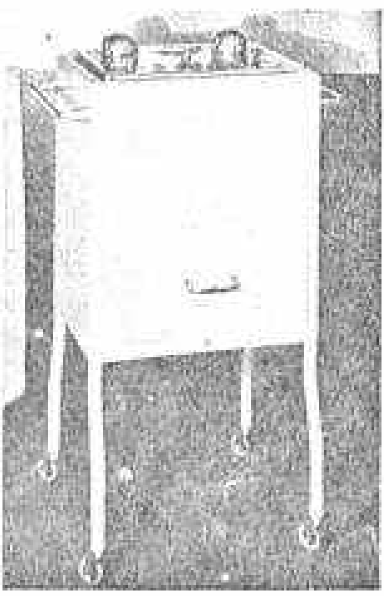


Fig. 171
The Oscillator for Supplying High-Frequency Power to Radio Knife.

... described later on. At one of the nearer reception points, where unexpectedly no reception was possible, it was found that there was a mountain range between transmitter and receiver, which had screened off the waves.

In cases where the receiver was located in one of the valleys adjoining the Herzogstand, reception was obtained, it is true, even when, strictly speaking, optical sight was not possible between transmitting and reception points, but the signal intensity vanished in those cases where high mountains were located between transmitter and receiver.

Continuation of the Range Experiments by the Firm C. Lorenz

As a continuation of the experiments described above, made by the Jena Institute, the laboratory of the C. Lorenz Aktiengesellschaft, Berlin-Tempelhof, carried out a number of tentative range experiments early in 1928, using small portable apparatus for a wavelength of 3 m, which experiments showed great irregularities in wave propagation. Even for very short ranges of about 1 to 2 km, great differences in tone volume were found, depending on whether the receiver was located close to the ground, or at a certain level above the ground. For example, within an experimental range of 2 km, no reception could be obtained, if transmitter and receiver were both located close to the ground. If the receiver was located, for example, at a height of about 10 to 15 m above the ground, the transmitter could be heard with satisfactory tone volume in every case. In this case also, there was found to be particularly great uniformity in the intensity of reception.

These results also pointed to the fact that a connection between transmitter and receiver is always guaranteed, if direct sight exists between the two. In order to obtain further confirmation of this assumption, the practical importance of which will be emphasized at the end of this paper, the series of experiments described in the following pages were carried out in which the transmitter or receiver, or both, were located in airplanes.

Airplane Experiments

In these experiments apparatus was used whereby the high-frequency parts of sender and receiver were separated from other portions of the apparatus. Both portions were connected with each other by an armored cable.

The high-frequency parts of each and the connecting cable leading to the rest of the apparatus are distinctly visible. The transmitter (at left) was adapted to telephony and audible telegraphy. The receiver was built on the principle of super-regeneration.

In the high-frequency part of the transmitter, the tubes with the oscillation circuit are arranged between the anode and the grid, consisting of a small rotary condenser and a self inductance bent into the shape of a *U*. No antenna was used in addition to this small transmitting frame, in these sets. The capacity of the transmitter was about 1 to 2 watts.

In the high-frequency part of the receiver, the tuning and return coup' condenser, and the self inductance are made as a yoke bent into the shape of a *U* which functioned at the same time as the loop antenna for reception.

The next series of experiments was carried out during the period from September 3 to 22, 1928, with the assistance of a Junkers cabin airplane, type F13, courteously put at the disposal of the experimenters through the aid of Dr. Herath of the Federal Department of Transportation. The high-frequency part of the transmitter was placed under the cabin outside the plane, by means of a spring suspension. The receiver with its high-frequency part was inside the cabin, this part being located close to a window, by means of a spring connection. In these experiments, no antenna was used either for receiving or sending. The first experiment consisted in sending from the airplane and receiving on the ground. First, the maximum range was determined while the airplane was flying at an altitude of 1000 m. The tone volume was R 8 to 9 in this case up to a distance of about 30 km, and then decreased gradually until at a distance of 50 km, reception ceased completely. For distances up to about 10 km, the intensity of the tone received was uniform when the airplane was flying at an altitude of from 100 to 1200 meters, but below an altitude of 100 m the volume decreased, and at an altitude of 30 m reception failed completely at a distance as short as about 5 km.

As a result of the great uniformity of the tone volume in the reception observed for the ultra-short waves within the maximum ranges so far established as contrasted with the effect of regular short waves the next obvious step was to try out another means of communication; namely, the transmission of pictures by telegraphy. For this purpose a picture transmitting set functioning on the principle of the telautograph was built into the airplane and connected to the 2-watt short-wave transmitter by the grid-control method. The ground station was provided with the receiver used in the experiment described above, the picture receiver being connected through rectifiers and relays. Transmission was carried out at an altitude of about 1000 m, the airplane being a few kilometers from the ground station. The experiment showed that the low transmitter capacities used permit the transmission of pictures from the airplane without any difficulty over the ranges that could be reached.

The only telautographic apparatus available for this experiment was a very primitive one and only very simple pictures could be transmitted.

Subsequent to the transmitting experiments from the airplane to the ground, reception of ground messages in the airplane was carried out, this being a far more difficult problem since it was not possible to place the receiver outside the airplane, as was done with the transmitter since it was necessary to vary tuning and the return coupling. Moreover, the noise of the motor ignition was disturbing, this noise being a rattling when the motor was getting up to speed, so that reception seemed to be entirely out of the question. At speed of the motor, however, there was a very considerable decrease in disturbance caused by the noise of the ignition, and the latter was no longer of importance. At an altitude of 100 m, the first telegraphic signals were received with a volume of about R 4 to 6. It could be heard up to a distance of about 10 km. This result also checks with the experiments in which the high-frequency part of the transmitter was located inside the cabin. Reception often failed even within the ranges mentioned. Evidently, the airplane in some position then screened the receiver against the sender. When the airplane was landing, the signals could be heard until the altitude was about 30 m, the volume decreasing gradually, beginning at 100 m. In all of the experiments so far described, telegraphy and telephony were received with equally good results within the maximum ranges, the capacity of the sender in all cases being 1 to 2 watts.

The maximum ranges found in the reception tests with the airplane being relatively short, the transmitting power of the ground transmitter was considerably increased, and the transmitter was arranged as high above the ground as possible. Further test flights were then made during which a 70-watt transmitter acting on a tuned dipole was located at a high point, namely on Fuchsturn near Jena. Reception took place in the airplane during a flight from Berlin to Nurnberg, and in the opposite direction from Nurnberg to Berlin.

On the outward flight the sender was heard first at a distance of 44 km, at an altitude of 600 m, with a tone volume of R 4 to 5, which soon increased to R 9 to 10, the airplane rising in the meantime to an altitude of about 1000 m. During the further part of the flight, the signal intensity remained nearly constant for a distance of from 52 to 80 km; and then decreased rapidly, until reception disappeared completely at a distance of about 100 km. During the return flight, the transmitter was heard first at a distance of 38 km, at an altitude of 500 m. In the beginning, the volume increased strongly again, until after continued flight reception became no longer possible at a distance of about 90 km. It is true that the altitude in this case was only 300 to 350 m. This very probably explains the decrease in maximum range during the return flight. It should also be noted that the reception in the airplane never started before the plane had reached a lateral position in relation to the sending station, and became most favorable when the plane was flying away from the latter. Probably this phenomenon is due to a screening action exerted by the wings of the airplane which are located underneath and in front of the cabin in which the receiver was placed, so that the wings were located between the transmitting and the receiving stations, when the plane was flying toward the transmitting station.

Theory of the Optical Range

The above experiments confirmed with relative certainty the assumption that the transmission of waves with a length of about 3 m requires direct sight. The experiments also showed that ground-wave extension can hardly play a part here and there is no reflection by layers in the higher portion of the atmosphere, and therefore no fading. We have consequently to deal with a normal optical propagation of the waves.

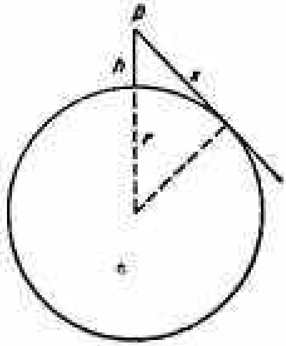


Fig. 171 (a)
Theory of Maximum Optical Range.

On the basis of this assumption, which now had become very probable, we find for the maximum range without flexion into the shadow of the earth, the following:

If in Fig. 171 (a), the circle represents the earth, supposed to be a sphere with a radius r, and h be the height of the transmitter above the surface of the earth, then the describing lines of the tangential cone of the sphere which has P for its apex, forms the extreme limit of direct radiation from the point P. The length of these tangents is $x = \sqrt{2rh + h^2}$, or, as h^2 is negligible with regard to $2\,rh$, $x = \sqrt{2\,rh}$. The maximum range is therefore proportional to the square root of the height, and as $r \cong 6.4 \times 10^6$ m, we find: $x = 3{,}550\,\text{m.}\sqrt{h_m} = 3.55\,\text{km}\,x\sqrt{h_m}$.

Fig. 171(b) shows the maximum ranges for direct radiation, as a function of the height of the transmitter above the surface of the earth. If the receiver is also located at a high point (Fig. 171 (c)), and if the height of the transmitter above the surface of the earth be h_1 and that of the receiver h_2, then we find as the longest range attainable with direct radiation; $x = \sqrt{2rx}$

$$(\sqrt{h_1}\sqrt{h_2}) \text{ or: } (1)\ x = 3.55\,\text{km}\,x\,(\sqrt{h_{1m}} + \sqrt{h_{2m}})$$

The maximum range may therefore be read from Fig. 171(b), by adding the maximum ranges for the two heights. Placing both the transmitter and the receiver at a certain height above the ground, consequently means a corresponding increase in maximum range. Within the range of direct vision between transmitter and receiver, the radiating energy decreases according to a quadratic law, that is, rather slowly. From the limit of the maximum range attainable for direct sight, the reception tone volume must decrease very rapidly, because there is flexion. Furthermore, it must be assumed that energy in the shade of an obstruction located between transmitter and receiver, which has a large size in relation to the wavelength, must amount to only a fraction of the energy of the direct radiation, as it can get into this shadow by flexion only.

If the results of the experiments described above, particularly also those of the experiments with the airplane, are compared, it will be found that in general they are in accordance with the theory. Its probability is based especially on the rapid decrease of the tone volume from a minimum altitude of

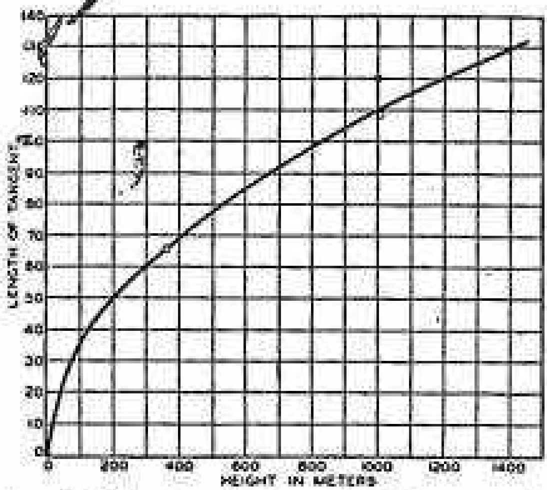


Fig. 171 (b)
Curve of Maximum Optical Range.

the airplane, toward the earth. However, the variations in screening effect caused by the different positions of the transmitter or the receiver with regard to the airplane, could not be explained in a satisfactory manner by the above theory of the maximum ranges to be expected, so that further experiments had still to be undertaken.

In the meantime, H. Fassbender and G. Kurlbaum published experiments made from an airplane with a wavelength of about 3 m, which also confirm the above theory.

The Experiments on the Brocken

In October, 1928, experiments were carried out jointly by the laboratory of the C. Lorenz Aktiengesellschaft, Berlin-Tempelhof, and the Technical Institute, Jena, from the Brocken (highest peak of the Harz mountains, 1,142 m above sea level) by means of which the above theory was to be checked; for this purpose, the transmitting equipment was located partly on the top of the Brocken, and partly half way up the mountain. The receiving set was in an automobile, in order to determine easily the maximum range in different directions from the foot of the Brocken. For the reception, the field of the northeast of the Brocken (about 150 m above sea level) was chosen as it is rather flat and permits direct sight to the Brocken. In addition to pla- the transmission set at different heights, the energy radiated was also varied in order to find the law of the wave propagation which would predict, for direct optical sight, the independence of the reception from the transmission energy, up to a certain minimum limit.

The transmitter was provided with a Telefunken tube, type R S 229 g, operated by a 500-cycle anode voltage of about 2000 volts. The capacity of the transmitter was about 200 watts and the wavelength of the transmitter

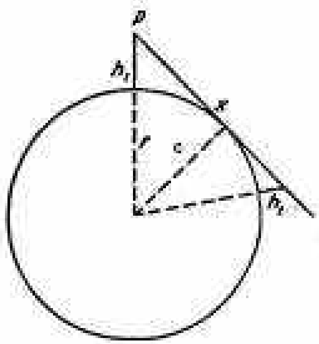


Fig. 171 (c)
Theory of Maximum Optics Range.

was adjusted to 3.2 m. The transmitter acted through a tuned vertical dipole with a length of 1.6 m. The receiving set was the same as that used in the airplane experiments. Reception took place either without an antenna, or with horizontal antenna with a length of about 2.5 m, or again with a vertical antenna with a length of about 8 m. The transmitter was first placed on the top of the Brocken, quite close to the ground. It was then found that the maximum range in the different directions varied between 75 and 100 km. In all experiments, the tone volume at the reception end varied but little, up to a certain range, while beyond this range it decreased rapidly to zero. The width of this zone of rapid decrease of the tone volume varied between 5 and 15 km. Within this zone, the effect was therefore due exclusively to the deflected radiation and no longer to the direct radiation. The cause of the variation of the maximum ranges in the different directions may lie in the different elevation of the receiving stations, and in the wavy character of the terrain between transmitter and receiver. In order to make a further check on the theory, the capacity of the transmitter was varied in steps, in one experiment, in the ratio 80:1. It was found that up to the limit of 80 km, each transmitter power gave successful reception, although with different tone volume. For ranges longer than 80 km, the tone volume decreased rapidly, and at a distance of 85 km reception was possible with full capacity of the transmitter only. This extremely instructive experiment, in which the attainable range of the transmitter varies but very little, in spite of a change in power of 1:80, shows very distinctly that the maximum range is mainly dependent on the range of direct sight, while the differences in attainable ranges caused by variations in transmitter capacity, are simply due to the fact that in the zone of deflected radiation, a lower capacity becomes insufficient, with increasing range, because of the limit of sensitivity of the receiver, at a somewhat shorter distance than the higher capacity. The next experiments were made by placing the transmitter on the panorama tower with a height of 20 m, on top of the Brocken (consequently about 1160 m above sea level). The maximum range was increased, in a direction where it was 95 km during the previous experiments, by about 20 km, to 115 km: if receiving antennas were used, no difference in tone volume of any importance could be observed, in the zone of direct radiation, as compared with reception without an antenna. In the zone of flexion, however, the maximum range could be increased by a number of kilometers by the use of a receiving antenna; thus, for example, the limit of the direct radiation zone in the experiments mentioned last was about 107 km. The limit of reception was in the zone of the flexion 115 km, without an antenna; and 120 km, with a vertical antenna of 8 m. If the results thus found are compared with the above theory, complete agreement will be found. From Fig. 171(b) it follows, that for the relative height of the Brocken above the surrounding country of about 1000 m, the limit of the zone of direct radiation is $x = 110$ km. It will therefore be seen that the maximum ranges for direct radiation, found through the experiments mentioned last in which the transmitter is located at a height of several wave-lengths above the immediate surroundings, thus evidently radiating freely into space, are in relatively good agreement with the theory. When the transmitter was located close to the ground, the maximum range was shorter than might be expected on the basis of the theory. This difference may perhaps be explained by the assumption that, as a consequence of the large mass of ground in close proximity, an influence is exerted on the radiation which has the same effect as if the radiating point were shifted a certain distance downward.

In order further to check the theory, a second series of experiments were carried out in which the transmitter was placed at about half the height of the Brocken, that is, about 500 m above sea level, and therefore about 350 m above the surroundings. The transmitter was arranged on a tower with a height of 16 m in order to avoid in advance any disturbing influence exerted by the ground. The reception tests were carried out in a direction from the Brocken in which there was direct sight, from the location of the transmitter, for all of the ranges under consideration. Up to the range of 66 km, no essential decrease in tone volume could be observed. From there on, the tone volume dropped off rapidly, until reception ceased entirely at a distance of about 77 km. The reception with and without receiving antenna was practically the same; whereas for a distance as great as 76 km, a tone volume of $R = 1$ could be still heard when the transmitter antenna was omitted and with reduced capacity; the transmitter could no longer be heard at a distance of 77 km, even when the transmitter antenna was used and with the maximum transmitter capacity. If the maximum range, as found, is compared with maximum range which should result from theory, we find, for an average height of the transmitter 350 m above the experimental grounds, an attainable range of 67 km, read off in Fig. 171(b). According to the measurements, the zone of direct radiation is 66 km wide, and the zone of deflected radiation 11 km.

The agreement with theory therefore appeared to be very good even for these experiments carried out at half the height of the mountain, and the theory is consequently further confirmed by the latter.

The Possibility of Applying the 3-Meter Waves

In Fig. 171(b) the values resulting from the experiments on the Brocken have been plotted as small circles and dots; the values of the distances (small circles) for which the reception showed a sudden drop (limit of sight) agree very well with the theoretical curve. The surplus in attainable range above the limit of sight, resulting from flexion, is about the same in both cases (small dots). Therefore experimental data obtained confirm the law established above.

The following characteristics of the maximum ranges for ultra-short waves (3 m) may be considered as having been confirmed by experiment:

The maximum range of these waves depends on the height of the transmitter and the receiver above the surroundings, as expressed by equation (1) established above. The effect of the energy of the transmitter and the sensitivity of the receiver on the maximum range is, above the certain limit, of no importance as compared with the influence of the height of the transmitter and the receiver. The increase in attainable range caused by flexion of the waves over the distance of direct sight as determined by the height referred to above cannot exceed a definite, relatively small amount (5 to 20 km). Inside this maximum range the reception is satisfactory and uniform, without fading or atmospheric disturbances.

As these waves also make it possible to use reflectors of not too large a size which may be mounted rigidly or pivotably, the several points of view relating to the application of these waves are as follows:

The ultra-short waves (3 m) are the most appropriate signaling means for short-distance communication. As far as can be seen at present, they do not have undesirable ranges; within the attainable short ranges, they guarantee good reception, without the possibility of disturbances inherent to the long and short waves used up to now. Their transmitters and receivers may be provided with reflectors in order to function as directed sets, the dimensions of which are small enough for practical use.

CHAPTER X

Amateur Short-Wave Equipment

Many owners of broadcast receivers have at times considered the possibility of building a low-powered short-wave radio-telegraph or radio-telephone transmitter. Equipment of this type can be constructed for a reasonable cost and even with low power international communication is possible in an experimental manner. Most of the apparatus used for this purpose is individually designed and constructed by the different experimenters. In order to give the novice a good idea of the apparatus used and procedure followed, a manufactured set is described for the purpose of simplicity.

Multi-Stage Short-Wave Transmitter Kit

The modern radio amateur, whether he be an oldtimer or a beginner, realizes that an efficient, up-to-date transmitter must be of the oscillator amplifier or multi-stage type and not of the self-excited single-tube type. The narrowed amateur wave channels which are now congested with more transmitters than ever before require the use of absolute frequency precision and frequency stability. The multi-stage transmitter, which may be either of the master oscillator or Piezo crystal excited type, fulfills the requirements for modern times.

Radio Engineering Laboratories have developed a low-power basic unit known as their No. 215. The tubes employed and the power supply required are practically the same as that used in modern broadcast receivers, thereby thus meaning that the cost for accessories is reduced to a minimum. This is a very essential thought because in most cases the actual transmitter is cheap when compared with the cost of the tubes and power supply required. The amateur who has been used to a one-tube set need not despair of tuning a three-tube multi-stage transmitter. The procedure is definite and positive. No unnecessary experimentation is required when the inductances, condensers and the choke coils have the correct values. The tuning and placing of the transmitter in operation is actually simpler than tuning some of the modern custom-built broadcast receivers.

This apparatus can be employed as a basic telegraph transmitter the output of which can be fed directly into any standard type of antenna system. The standard No. 215 unit is equipped and designed to employ a master oscillator type of frequency control stage. This allows for quick shifting of frequency in any of the regular assigned amateur channels. A Piezo crystal control oscillator stage can be added if desired. However, this will limit the transmitter to one definite frequency and will not allow shifting in the band.

The oscillator stage employs a UY-227 or equal. The filament power may be derived either from AC or DC. 2½ volts at 1.75 amperes are necessary. The 180 volt plate supply may be obtained from a rectifier unit, a "B" eliminator, or, best of all, from four medium size or heavy duty 45 volt B batteries connected in series to give a total of 180 volts. When using a pure DC plate supply such as is obtained from batteries, the tone will in all respects resemble a crystal controlled transmitter.

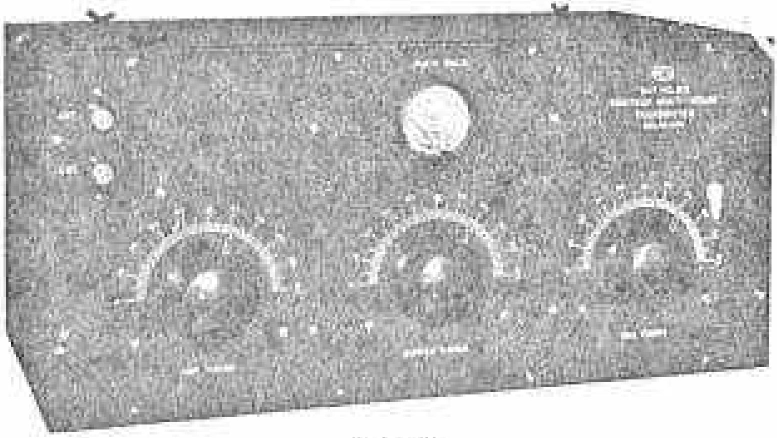


Fig. 172

The illustration shows the front assembly view of the No. 215 unit. A neat metal case provides an enclosure for the apparatus. The overall dimensions are 19 in. x 9 in. front x 10 in. deep. The approximate weight is 18 pounds.

The next stage is the buffer "Class B" type amplifier which employs a UY-224 or equal tube. The filament has the same specifications as that for the tube employed in the oscillator stage. Plate supply likewise is 180 volts and may be obtained from the same source as that which furnishes the oscillator tube. The 75 volts necessary for the screen grid may be tapped off from the B supply. The C battery bias may be secured from small size B batteries. One large C battery bank is sufficient to operate all three tubes in the No. 215 unit. The various required C voltages can be tapped off from this bank.

The power amplifier stages employ a UY-245 or equal. The filament supply necessary is 2½ volts at 1.5 amperes. As the filament in this tube is not of the separately heated type such as employed in the other two tubes, it will be necessary to employ a filament heating transformer which has an accurate center tap. The same filament transformer may also be used to heat the filaments of the oscillator and buffer tubes. This, therefore, means that the filament heating transformer if alternating current is employed or the battery if direct current is employed must be capable of delivering 2½ volts at 5 amperes. As previously mentioned, if an AC transformer is used it should be center tapped so that the return of the power-amplifier tube will go to this connection. Such a center tap transformer is very advantageous when the No. 215 transmitter is employed for telegraphic purposes. The key may be inserted in this center tap lead. It will then break only the power-amplifier circuit without in any way interrupting either the buffer or oscillator. The plate supply for the power amplifier should be about 250 to 300 volts. This may be obtained from a rectifier, motor generator or B batteries. When this stage is in absolute resonance and properly adjusted it is not necessary to employ the purest type of DC for the plate. Therefore, a half-wave rectifier unit will be found sufficient. The main requisite is that the tone emitted from the oscillator be pure and the adjustment stable. If this is correctly accomplished and the succeeding stages are tuned to resonance, the output tone should be exactly the same as that generated in the oscillator stage. Stress is therefore laid on the necessity for stability and clean plate supply for the control circuit.

The output of this transmitter may be fed into any of the present-day types of antenna systems. As will be noted in the wiring diagram, the only antenna circuit apparatus is the antenna coupling coil "L4." Both leads of this are brought out to two posts mounted on the front panel. Another reason for not including further antenna tuning equipment is because some systems employ two condensers and two meters for balancing two wire zepp feed antenna while others require only one meter and one condenser for standard antenna and counterpoise tuning. The omitting of this equipment will, therefore, be readily appreciated. The amateur can neatly and efficiently mount these parts externally if required. They should be located somewhere between the antenna lead and the connecting posts on the front of the transmitter.

Another reason for omitting additional antenna tuning apparatus is because some amateurs will use this transmitter to feed another amplifier stage of larger power. A connecting diagram showing how this is done is given elsewhere in these specifications.

When the power amplifier stage is tuned to function as a Class B amplifier, that is, operate at the cut-off point, the rated power output of the transmitter when used for CW telegraphing is 10 watts. When the transmitter is used in conjunction with a separate modulator and speech amplifier unit, such as the No. 225, the power amplifier is adjusted to function as a Class C amplifier and as such when modulated by the 100% system will give a peak output of over 20 watts. Incidentally, when adjusted as a Type C amplifier the carrier output is approximately 5 watts. Shifting the amplifier from a Class B to a Class C simply means the increasing of negative biasing voltage.

The standard No. 215 kit is supplied with one set of plug-in inductances. These are designed to operate in the 3,500 to 4,000 KC (80 meter) band.

Additional plug-in coils to operate in any of the other channels can be secured.

Only one milliammeter is supplied. This is provided with a flexible lead and plug so that it may be connected to any of the three jacks which are mounted on the rear terminal strip. Each one of these jacks is wired in the plate lead of that particular tube. Therefore, by using one meter and this plugging arrangement the plate current of any of the tubes may be measured. This is another step towards the reduction of cost of the set.

Assembling the No. 215 Kit

The illustration showing the inside of the No. 215 is exceptionally clear and very definitely shows the correct mounting place for the various parts, Fig. 172. Therefore, a detailed description giving the exact position for mounting will not be given. The builder can follow the photographic scheme. A few words are given regarding the care necessary for the arrangement of some of the parts. The two pieces of sheet aluminum which act as separators for the three compartments are secured to the front panel by means of the ½-inch angle supports. The wooden baseboard is covered with a thin sheet of copper foil. The front panel is fastened to the baseboard by means of 1-inch long round-head wood screws. When fastening this panel to the baseboard be sure to let the panel project about 1-16 inch beyond the baseboard—this is a long the bottom edge. This will then allow the panel to fit flush with the outside metal case when the complete set is assembled. The rear binding post strip is so mounted that when the baseboard assembly is slid into the cabinet it will project through the rectangular opening provided in the rear of the metal case. It is essential to remember that the copper shield on the baseboard is so mounted that the completely covered portion is to the rear.

The plug-in coil bases should be mounted in the positions shown in the photograph—that is, the bayonet slot should be located as shown. This is essential in order that short leads may be obtained from the plug-in coil base. The plug-in coil bases and likewise all of the other parts are securely fastened to the baseboard by means of wood screws. The various fixed-condensers which are mounted on the sides of the aluminum shields are secured with small machine screws. Incidentally, condensers which are thus mounted on the aluminum shields must be provided with the small bakelite mounting strips, thus affording insulation from the shield. To obtain a satisfactory job when finished, the amateur is urged to inspect very thoroughly his mechanical work before proceeding to wire.

For wiring, it is advisable to follow closely the wiring diagram given. Thin busbar is supplied for the connections carrying radio frequency currents. These comprise all grid and plate leads. All R F leads are run direct and clear from other metallic parts. A good grade of rosin core solder should be employed to make the connections. When using rosin core solder on nickel plated parts it is essential first to scrape carefully the nickeling so that the base metal will be reached. Other leads which are not subject to radio frequency currents may be run in the thin flexible red covered wire. They may be grouped together and cabled thus affording a neat appearance.

As the filaments of the three tubes carry approximately five amperes, it is, therefore, essential that a heavy wire be employed to carry this current without any undue heating. The kits are supplied with a heavy red flexible wire for this purpose.

The diagram clearly shows the connection for the stator and rotor plates of all variable condensers. This must be followed out in order to obtain a minimum amount of body capacity effect. The jacks which are connected in the plate circuit of each of the tubes must be wired identically; otherwise, when the milliammeter is plugged into these there will be reverse polarity readings.

After the wiring is completed it is essential to check carefully the continuity of each of the circuits. Also check the soldered joints to make sure that they are tied and that no excess of solder or flux has dropped beyond the lug and may be shorted to the copper base strip.

The selection of the power supply is the next item to discuss. Filament supply may be secured from a filament-heating transformer which, of course, can be used only where alternating current is available. This transformer should have a secondary winding capable of delivering 2½ volts at 5 amperes and accurately center tapped. A transformer such as this would be just sufficient to supply the filaments of the three tubes in the No. 215.

Should the amateur, however, at any time desire to attach a modulator to this unit he would have to secure an additional filament transformer to operate modulator and speech amplifier filaments. Therefore, the ideal combination is a transformer which is large enough to supply both the filaments of the No. 215 transmitter and also the filaments for its accompanying modulator unit. As the standard modulator unit employs one UX-250 tube as modulator and one UY-227 tube as amplifier, the filament transformer would have to have the following specifications: 110 volt primary (variable resistance may be inserted for regulating output voltage); one secondary winding 2½ volts at 7 amperes accurately center tapped; another secondary winding 7½ volts at 1¼ amperes.

If alternating current is not available, the filaments may be heated from a storage battery which is capable of supplying 2½ volts at 5 amperes. This storage battery must be of sufficient size to withstand a continuous 5 ampere drain. It is practically impossible to secure a 2½ volt storage battery. This means that a 4 or a 6 volt battery will have to be employed and with it a suitable resistance must be used so that the voltage will be reduced to 2½ volts.

The B supply may be secured from B batteries or else from rectifier unit

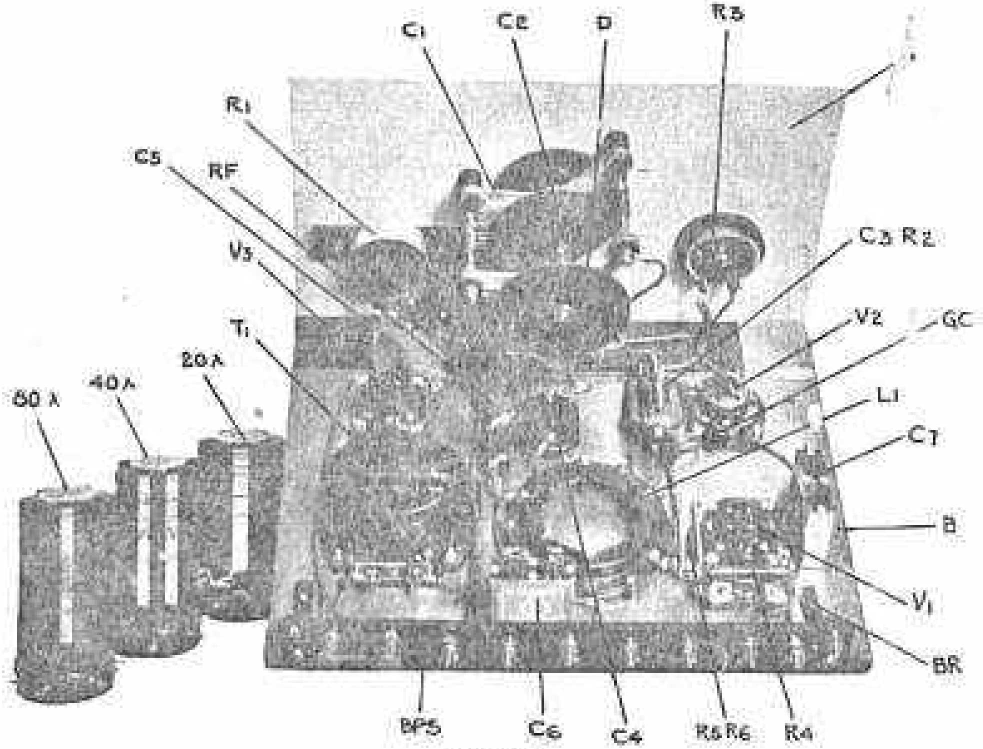


Fig. 172

Internal View of No. 215 Transmitter. This Illustration Gives the Exact Location for Mounting the Various Parts.

or motor generator. The screen grid voltage for the buffer amplifier may be secured by tapping the available B supply. The grid bias for the various stages may be obtained by the use of a small "C" battery bank as previously outlined.

Where direct current is available, the use of a motor generator is necessary providing, of course, that B batteries are not desired. Details on small motor generator units having the same power output ratings as the alternating current power supply will be found elsewhere in these specifications. Let us again stress the desirability of operating the master oscillator from B battery plate supply. If the amateur desires the cleanest possible DC note this is the most positive way of securing it. It may seem rather expensive when considering the cost of our heavy duty B batteries, but in the long run it is not so unreasonable in cost because the batteries stand up over long periods.

Operation and Adjustment

Connect the filament supply to the rear binding post engraved "F," "CT" and "E." If direct current or storage battery is employed for filament heating, connect the plus of the battery to the F post and the minus to the E post. A wire is then shunted from the "CT" post to the "E" post. Irrespective of whether AC or DC is employed, the voltage across the posts "F" and "E" must be 2½. All three tubes are now inserted. The master oscillator tube "V1" is of the UY-227 type. The Buffer Amplifier Tube "V2" is of the UY-224 type. The Power Amplifier Tube "V3" is of the UX-245 type. After all these tubes have been inserted in their respective sockets, the filament supply is turned on. It will take approximately thirty seconds before the filaments arrive at their rated temperature. The filament voltage should be checked with a suitable voltmeter if such an instrument is on hand. If not, adjust the primary of the transformer or the filament rheostat in series with the storage battery until the tubes show a dull red.

The Master Oscillator Inductance "L1" is plugged into its mounting. This inductance is tuned by means of the oscillator tuning variable condenser which is connected in shunt to a large fixed tank condenser thus gaining the benefits of a high C oscillator circuit. Such a high C circuit is designed to insure maximum frequency stability at all times.

The plate supply to the master oscillator is next connected. This is obtained from a 180 volt DC source which should preferably be secured from four 45 volt heavy-duty B batteries connected in series. The milliammeter plug is inserted into jack "J1." In this position it will read the plate current consumed by the master oscillator tube. Should the milliammeter read in the reversed direction, change the wires on the back of the meter.

The next step is to turn on the power and check whether the oscillator is functioning correctly. This is best accomplished by checking whether or not radio frequency is being generated in this circuit. A small size Neon tube is a very useful instrument for checking this. Hold the glass portion of the Neon tube in your hand and touch the oscillator tuning condenser plates. If the circuit is functioning correctly and developing radio frequency the Neon tube should light. Furthermore, it should glow with the same brilliancy irrespective of the position of the oscillator tuning condenser. With this definitely proved it is necessary to set the oscillator on the frequency at which the transmitter is to operate. Several methods for accomplishing this are here quoted.

1—Use an accurately calibrated frequency meter. This is the method which closest approaches precision measurements.

2—Use your present receiver. Your receiver can be used to determine the approximate frequency of your transmitter providing that this receiver has been previously marked so as to note definitely where the upper and lower limits of the band in which you desire to operate are located. Set your receiver at some approximate position in the band then turn on the oscillator of your transmitter and slowly rotate the oscillator tuning condenser until the carrier is picked up in your receiver. This then indicates that your transmitter is operating on a frequency somewhere in the band. The actual frequency cannot be ascertained but you can determine whether you are in the upper part, in the lower part or in the middle.

3—Use a broad range wavemeter for locating approximately the transmitter within the band. A broad range wavemeter may be defined as that type of indicator which covers wavelengths from 15 to 200 meters.

You may next monitor or listen to the note of the oscillator. Use your present receiver or if a small monitor is on hand use this. The note heard will be exactly the same as that which eventually travels out over your antenna system to other receivers. The stability of the signal may be checked by letting the oscillator run for a considerable time and listen in continuously on your receiver or monitor. The tone should not vary. Thus, you will have checked both the character of your emitted signal and also the frequency.

If you are desirous of calibrating your transmitter, you may do this by taking several readings at various settings of the oscillator condenser. An accurate frequency meter is practically the only means against which you may obtain precision calibration. It is a novel feature to be able to shift your frequency up or down within a certain band and it is still more novel to be able to tell the other fellow exactly to where you are shifting. This is a feature which will sooner or later be highly appreciated by all amateurs.

As previously mentioned, a Neon glow lamp is an essential item for checking of radio frequency circuits.

With such a Neon tube you may test the effectiveness of the various radio frequency choke coils employed in the transmitter. For instance, the plate choke "RFC-1" should indicate radio frequency at its plate end and at the other end of the choke it should indicate nothing. In like manner, the end of coil "L1" which is connected to the coil base prong "1" should also be alive. The grid end of the inductance "L1" which connects to the base prong "4" must indicate some RF. Of course, the amount of RF indicated at the grid end is slightly less than that at the plate end. Continuing along these lines the radio frequency is traced through the grid coupling condenser "GCI," and further on up to the top grid connection of the UY-224 Buffer Amplifier Tube.

The oscillator circuit has now been checked and tuned to the desired frequency. The next step is to tune the Buffer Amplifier. Connect another wire from the same 180 volt battery supply to the post marked "+180" at the rear of the Buffer Amplifier compartment. Also connect the plus 75 volts to the post marked "+75." This may be obtained by tapping the 180 volt battery. In most cases 75 volts is difficult to obtain because standard 45 volt batteries are usually furnished with a mid tap at 22½ volts. The nearest screen grid voltage thus obtainable, would be either at 67½ or at 90. The 67 volt tap will be found satisfactory for most purposes. Therefore, connect plus 67 volts to the "+75" volt terminal which appears at the rear of the Buffer Amplifier compartment.

The UY-224 Amplifier tube when employed with 180 volts plate and 67 volts screen grid requires approximately 67½ volts negative C biasing battery for correct operation. This 67½ volts may be obtained from the "C" battery bank. This bank may comprise two 45 volt small size batteries connected in series. The amateur need not be alarmed at the cost of these batteries because their life is exceptionally long and they should stand-up for practically a whole year's operation.

The Buffer Amplifier is now ready for operation. Plug in the inductor "L2." Remove the plate milliammeter plug from the oscillator jack "J1" and insert it in the Buffer Amplifier jack "J2." In this position the plate meter will read the amount of current drawn by the UY-224 tube. Turn on the power and then slowly rotate the buffer amplifier tuning condenser "C2." A definite place will be reached where the milliammeter needle shows a sharp dip downward towards the low end of the scale. Set the condenser at that position where the milliammeter needle gives the lowest reading. This indicates that the Buffer Amplifier is in exact resonance with the master oscillator circuit and therefore operating at the same frequency. A test for radio frequency may now be made. Touch the Neon tube to the stator plates of the buffer tuning condenser "C2." It should glow very brightly. In like manner you may check the grid radio frequency choke coil "RFC3" and the plate radio frequency choke coil "RFC2." One end of each of these chokes must be alive and the other end must be dead. That is, of course, meaning radio frequency.

It is now essential to check whether or not the master oscillator circuit is really controlling or driving the UY-224 tube. By inserting a dummy plug or a small piece of wood into the master oscillator plate jack "J1," you will stop this oscillator circuit from functioning. Immediately, when the oscillator plate circuit is open, you will notice that the Buffer plate current as indicated on meter "M" will fall to zero. Furthermore, if you take the Neon tube and touch it to the stator plates of condenser "C2," you will notice that there is no radio frequency flowing. This means that the oscillator is really controlling the Buffer stage. With the oscillator jack "J1" open, the buffer plate current should fall to zero. If it does not you will have to increase the C voltage which is connected to the minus "C1" terminal. There must be sufficient C bias on the buffer tube so that it will cut the plate current to zero when excitation from the oscillator stage is cut off.

The actual correct amount of C voltage required for the Buffer tube is realized when the Buffer plate meter falls to zero. Do not use more C battery than necessary and likewise, do not use too little. Experiments have definitely proven that 67½ volts are correct.

With the Buffer stage correctly tuned, you should again check the tone by listening in on your receiver or monitor. It should be exactly the same as that which you heard when the master oscillator was functioning independently. You should also note a slight increase in the intensity or volume of the signal. If the Buffer is not in absolute resonance with the master oscillator circuit, you will notice a broad tone not sharp and distinct. Should this be the case a very slight adjustment of condenser "C2" will synchronize both circuits.

The final stage is to place in operation the power amplifier or output circuit. This circuit employs a UX-245 tube which requires approximately 250 to 300 volts plate supply. This may be obtained from any source as previously outlined. The negative biasing battery used may be the same as that employed for the buffer tube, except that 90 volts are necessary. The minus 90 volts is connected to the minus "C2" post. The positive connection of the C battery has previously been connected to the "plus C" or ground post.

The milliammeter plug is now taken out of jack "J2" and inserted in the Power Amplifier jack "J3." In this position the plate meter will indicate the amount of current drawn by the UX-245 tube. Incidentally, this plate circuit must be closed. That is, connect the "plus 300" volt power supply. The open jack "J3" naturally was closed when the meter "M" was inserted.

The next and final step is to rotate the amplifier tuning condenser "C3" until the plate meter needle dips to a minimum position. This now indicates that the power amplifier is in resonance with the Buffer amplifier which, of course, in turn is being controlled by the master oscillator circuit. The Neon tube may be used to check the radio frequency. Touch the stator plates of condenser "C3." Be careful when doing this because the amount of radio frequency developed in the power amplifier stage is considerably more than that had in the previous stages. The operator should always be careful to hold the glass portion of the tube and not touch any of the metallic base portion. The Neon tube may also be used to check the radio frequency choke coils "RFC4" and "RFC5." "RFC4" should indicate very brightly at the plate end and nothing at all at the jack end. Likewise "RFC5" should indicate at the grid end and show no indication at the "minus C2" end.

The Power Amplifier Tube UX-245 will require about 90 volts negative C battery when the Cat. No. 215 set is used for telegraph transmission. Ninety (90) volts will be sufficient to operate this tube at the cut off point. This circuit is then functioning as a class "B" amplifier. Incidentally, the Buffer stage is also functioning as this type of amplifier. It is essential that the operator experiment with the negative C voltage so as to make sure that just sufficient is applied to reduce the plate current mils to zero when excitation from a previous stage is cut off. Experiments with various models have proven that with 300 volts plate supply, 90 volts negative C will be sufficient to accomplish this.

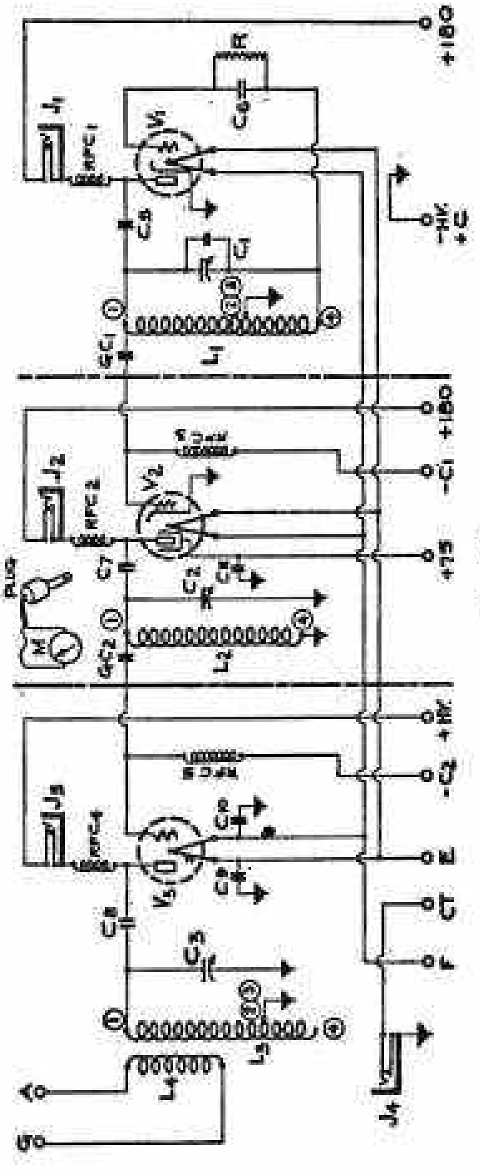


Fig. 173

Schematic Wiring Diagram, No. 215 Multi-Stage Transmitter.*

The transmitter can now be considered completely tuned and ready for feeding the available antenna.

For information regarding various types of antenna refer to the diagrams and tables furnished elsewhere in this chapter.

Outside of the inductor "L4" there is no other additional antenna equipment. As previously stated, this is so that the amateur may connect the set to any type of antenna system or if so desired he may feed the output into another larger amplifier. If the output of the inductor "L4" is to be fed directly into an antenna the operator can very easily assemble the necessary antenna variable condensers and meters. These may be advantageously mounted directly above the transmitter.

The following summary of plate current readings may be more or less closely followed:

Oscillator Plate	...10 milliamperes
Buffer Amp. Plate Current	...12 milliamperes
Power Amplifier Plate Current	...32 milliamperes

The plate current drawn by the power amplifier tube will increase to the above mentioned normal rating when the set has been tuned to resonance with the antenna system or tuned to feed another larger amplifier. When using alternating current to heat the filaments you may insert the key so that it will open and close the center tap connection of the filament transformer. This is accomplished by inserting the key plug into the jack "J4." If direct current is used for heating the filaments the key should be inserted into the amplifier plate jack "J3." Bear in mind that if this last method of keying is employed you will have to take special precaution not to touch any of the metallic portion of the key because this will be carrying 300 volts.

The output characteristic of the transmitter may again be listened to. However, this time you may find that the receiver will not do because of the increased power now available. Under these conditions you will be obliged to use a regular monitor placed at a distance to the transmitter. The character of the note should resemble that which you originally heard while testing the master oscillator circuit. A very good check for frequency stability is to plug the milliammeter into jack "J1" and while keying the set carefully note that this meter needle shows hardly any deflections. This is a positive proof that the master oscillator circuit is driving consistently and is not being subjected to any feed back from the power amplifier circuit. This is also proof that the Buffer stage is functioning correctly and doing what its name implies.

The following parts are required with each No. 215 kit:

L1—3,500 KC band (80 meters) oscillator inductance with internal high C fixed condenser.

L2—3,500 KC band (80 meters) buffer amplifier inductance.

L3, L4—3,500 KC band (80 meters) power amplifier inductance with independent antenna winding.

Three standard plug-in coil bases are required for the above coils.

C1—Oscillator tuning condenser 115 mmfd. capacity.
C2—Buffer amplifier tuning condenser 115 mmfd. capacity
C3—Power amplifier tuning condenser 115 mmfd. capacity.
C5—Oscillator plate blocking condensers, 2,000 mmfds.
C6—Oscillator grid condenser, 2,000 mmfds.
C7—Buffer amplifier plate blocking condenser, 2,000 mmfds.
C8—Power amplifier plate blocking condenser, 2,000 mmfds.
C9, C10—Power amplifier filament bypass condensers, 2,000 mmfds. each.
C11—Buffer amplifier screen grid bypass condenser 1 mmfd. 250 volt type.
GC1—Buffer amplifier grid coupling condenser, 2,000 mmfds.
GC2—Power amplifier grid coupling condenser, 2,000 mmfds.
RFC1—Oscillator plate RF choke coil.
RFC2—Buffer amplifier plate choke coil.
RFC3—Buffer amplifier grid choke coil.
RFC4—Power amplifier plate choke coil.
RFC5—Power amplifier grid choke coil.
J1—Oscillator plate meter jack single circuit closed type.
J2—Buffer amplifier plate meter jack single circuit closed type.
J3—Power amplifier plate meter jack single circuit closed type.
J4—Key jack single circuit closed type.
M—Plate milliammeter, 0-100 mils.
P—Meter plug with 2 foot extension cord.
V1—Oscillator tube socket, UY type.
V2—Power amplifier tube socket, UY type.
V3—Power amplifier tube socket, UX type.
R—Oscillator grid resistance, 5,000 ohms.
F—Drilled and engraved aluminum front panel finished in black crystalline lacquer.
A—Antenna and ground binding post strip.
B—5 ply veneer baseboard finished in black lacquer. Size 18¼" x 9¾" deep x ½" thick.
S—Two aluminum partition shields with necessary ½" angle strips for mounting.
SS—Copper sheet for covering baseboard.
N—Brackets for supporting rear binding post strip.
T—Bakelite rear terminal strip drilled and engraved. This strip is fitted with all necessary terminal screws. The four jacks are to be mounted in this strip.
A neat pressed steel cabinet with a removable top, the finish to match the front panel.

Adding Crystal Control to No. 215 Transmitter

If the amateur so desires, he may use crystal control with the No. 215 unit. The above wiring diagram shows the crystal control oscillator circuit. A direct comparison between this oscillator circuit and the master oscillator circuit in the No. 215 will readily show that only a very small change is necessary.

When considering crystal control the amateur must decide whether he will operate with a 160 meter crystal or with an 80 meter crystal. If a 160 meter crystal is used it will be necessary to double frequency into the buffer stage. If an 80 meter crystal is used the same frequency will be had in all three stages.

The No. 215 unit when crystal controlled can be operated on 40 and 20 meters. It simply becomes necessary to double frequency in succeding stages so as to arrive at the desired output frequency.

The crystal will require C battery. This is connected to the post "—C." The same C battery bank which supplies the buffer and power amplifier may

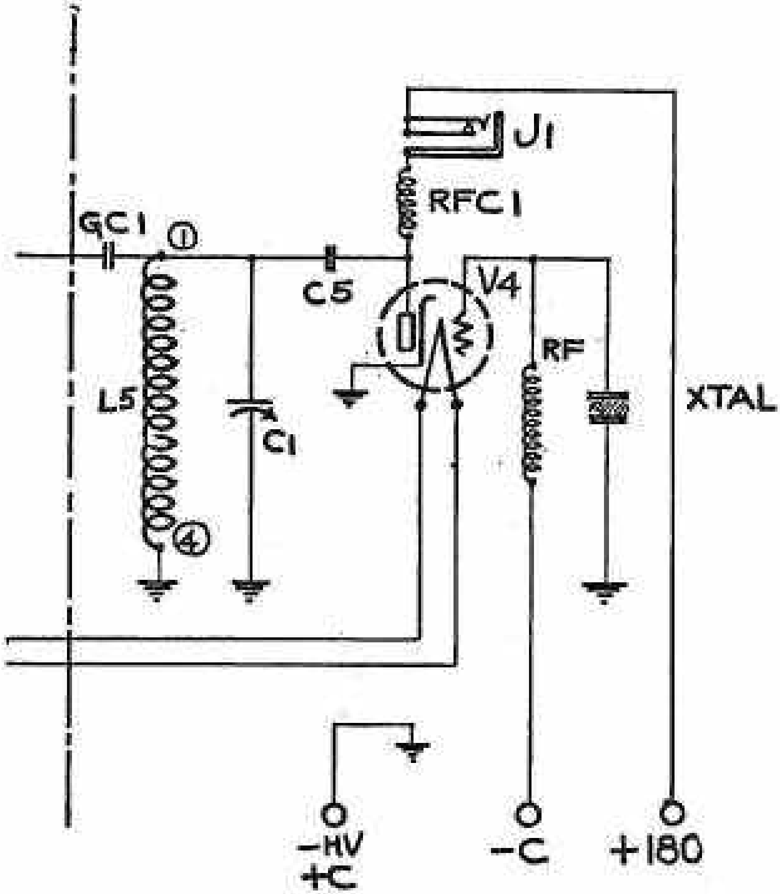


Fig. 174

Schematic Wiring, Cat. 215, Oscillator Stage Fitted for Piezo Crystal Control.

be used for this purpose. Therefore, the connection for the "—C" post should go to —22½ volts on this battery bank.

A few brief hints will be given on how to obtain successful operation with a crystal.

Before inserting the crystal wash it with a carbona solution. Likewise wash the upper and lower crystal holder plates. When the crystal is thus cleaned the surface should not again be touched with the fingers. After it is inserted in the holder and all the necessary power supply connected, rotate the crystal tuning condenser "C1" until a minimum dip is indicated on the plate meter "M." It is, of course, necessary to insert the plate meter plug into jack "J1." The Neon tube may be used as an additional check to see that radio frequency is being generated by the crystal oscillator stage. A good

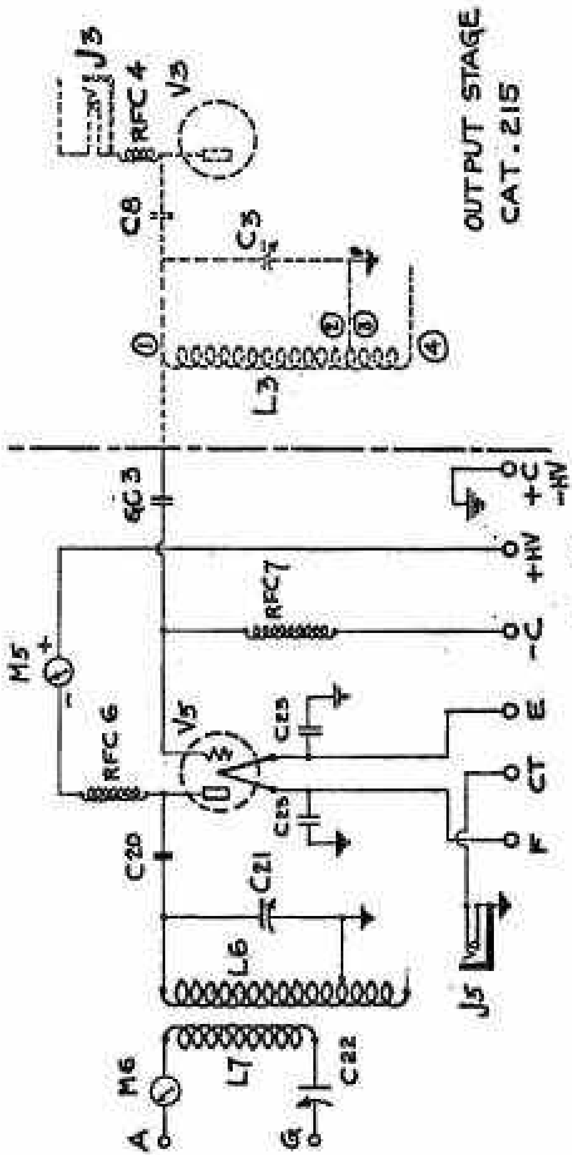


Fig. 175
Wiring Diagram, 50 or 75 Watt Linear Amplifier.

point to determine this is directly at the stator plates of the crystal oscillator tuning condenser "C1."

The tuning of the remaining stages remains the same as previously outlined.

ADDING LINEAR AMPLIFIER TO NO. 215 TRANSMITTER

If the amateur desires higher power than that developed in the power amplifier stage of the No. 215 basic unit he may add a 50 or 75 watt linear amplifier. Any of the following tubes can be used 203A, 211, 852 or 860.

This additional linear amplifier can be tuned to operate either at the same frequency as the power amplifier or at double frequency of this power amplifier.

The following is a parts list of the amplifier:

M5—Plate milliammeter 0-300 mils.
GC3—Linear amplifier grid coupling condenser 2,000 mmfd. 5,000 volt type.
C20—Linear amplifier plate blocking condenser 2,000 mmfd. 5,000 volt type.
C21—Linear amplifier tuning condenser, 200 mmfd. 3,000 volt type.
J5—Key jack, single circuit closed type.
L6—Linear amplifier tank inductance.
L7—Antenna coupling coil.
M6—Antenna meter 0-3 thermo coupled RF.
C22—Antenna series variable condenser, 200 mmfd. 3,000 volt type.
RFC6—Linear amplifier plate choke.
RFC7—Linear amplifier grid choke.
C23—Filament bypass condensers 2,000 mmfd. 1,000 volt type.
V5—Linear amplifier tube socket, either 50 watt or 75 watt type.
1—Metal cabinet, size 9" x 19" x 16" deep.
1—Drilled and engraved panel.
1—Baseboard fit with copper foil.
1—Rear binding post strip.
1—Complete set of hardware.

The power supply necessary for operating the linear amplifier will have to be independent from any of the power supply used for the No. 215 unit or the No. 225 modulator unit. Filaments may be operated either from AC or DC. The supply necessary must furnish 10 volts at 3.25 amperes. If AC is used for filament supply the transformer must be accurately center tapped. The filaments must then be bypassed with two 2,000 mmfd. 1,000 volt type condensers. These bypass condensers should be located directly at the filament tube socket. The plate supply required for the 50 watt tubes is 1,000 volts DC at 150 watts. The plate supply required for the 75 watt tubes is 2,000 volts DC at 150 watts.

The output of the No. 206 linear amplifier is fed to any of the antenna systems illustrated.

100% MODULATOR

The modern amateur radio telephone transmitter is radically different from the sets and systems employed several years ago. Those who desire efficient radio-telephone communication appreciate that as much as possible of the continuous wave carrier should be modulated. This may be more readily explained as follows:

When listening in for a radio-telephone station the amateur has often noticed that the carrier is sufficiently strong but the voice is weak. The sys-

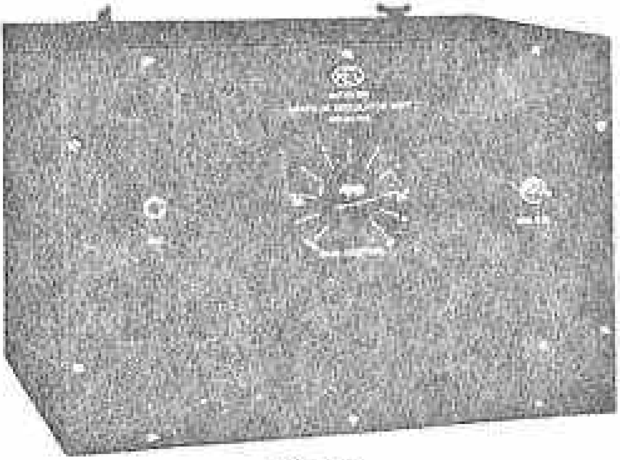


Fig. 176

This illustrates the complete No. 225 Modulator. It has an attractive and businesslike appearance and will enhance any amateur station.

tem employed in the No. 225 amateur modulator units is designed to give practically 100% modulation of the carrier output of the No. 215 basic unit. Therefore, when using the No. 225 unit in conjunction with the No. 215 unit the operator will be able to receive reports which indicate that his modulated voice is just as strong as his CW carrier wave. It has often been reported that low-powered CW telegraph transmitters have covered great distances. It can now well be said that when using the 100% system of modulation these same low-powered telegraph sets can be made into telephone transmitters having the same great DX range.

The No. 225 amateur modulator unit, although expressly designed for use with the No. 215 basic unit, can be made adaptable to any other present oscillator system which employs a power amplifier tube of the UX-245 type or equal. The main requisite is that the tube which is to be modulated must use approximately one-half of the plate voltage that is required for the modulator tube. In the case of the 225 unit a UX-250 type tube is used with 550 to 600 volts plate and in conjunction with this the modulated amplifier tube employs 300 volts plate. Furthermore, the modulator watts output of the 250 tube are sufficient to operate the 245 tube.

The No. 225 unit is designed to use a single-button carbon microphone. This is sufficient to obtain good reproduction over the average voice frequencies employed. If the user so desires, he may very easily employ a two-button carbon microphone.

A complete listing of parts required is given under the schematic wiring diagram.

On the front panel are mounted the microphone jack "J7." The resistor "R2" is mounted on a small strip of bakelite, thus insulating the movable arm from the metal panel. The jack "J7" is mounted directly on the front panel. One arm of this is automatically grounded.

The No. 225 unit is located on the operating table alongside of the No. 215 unit. Connections between the two units are made at the rear.

The complete station is always ready for either telephone or telegraph transmission. The only adjustments necessary is to turn on the microphone switch SW when using telephone, and turn this off when using telegraph. All tubes in the modulator and in the No. 215 unit are always lit. This is a very good feature because it allows instant shifting from telephone to telegraph.

Operating the No. 225 Unit

After the unit has been assembled and all the wiring carefully checked it is ready for operation. The power supply employed can be the same as that used for the No. 215 telegraph set. The filament heating transformer should be of sufficient size to supply the RCA type 250 modulator tube with 7½ volts at 1.25 amperes and also to supply the RCA type 227 Speech Amplifier Tube with 2½ volts at 1.75 amperes. If alternating current is not available the filaments of these tubes may be heated from an 8-volt storage battery. Necessary filament reducing resistor must be employed in the circuit of the 227 speech amplifier tube so that it will only receive 2.5 volts.

The plate supply to the modulator tube must be between 550 and 600 volts DC. This can be secured from a power unit, from a motor generator or from a B battery bank. The plate supply to the speech amplifier tube is secured from B batteries. The same heavy-duty B batteries which are used to supply the oscillator and buffer tubes in the 215 will suffice for this purpose. One hundred and thirty-five volts are necessary. These may be secured by tapping the battery, or in other words using three of the 45-volt batteries. The C battery voltages required for the speech amplifier and modulator tubes may be obtained from the C battery bank which feeds the transmitter unit. The six-volt supply necessary for the microphone may be obtained from any 6-volt battery. The best method is to employ the 6-volt storage battery which is used to heat the filaments in the receiver. The polarity connections are not critical. The wiring diagram for the 225 shows that the positive side is grounded. If the positive side of the receiver battery is also grounded this connection will be satisfactory. If, however, the negative side of the receiver battery is grounded then it will be necessary to reverse the battery connections to the microphone so that the negative side will run to ground. In any case the same side must be grounded as that which is

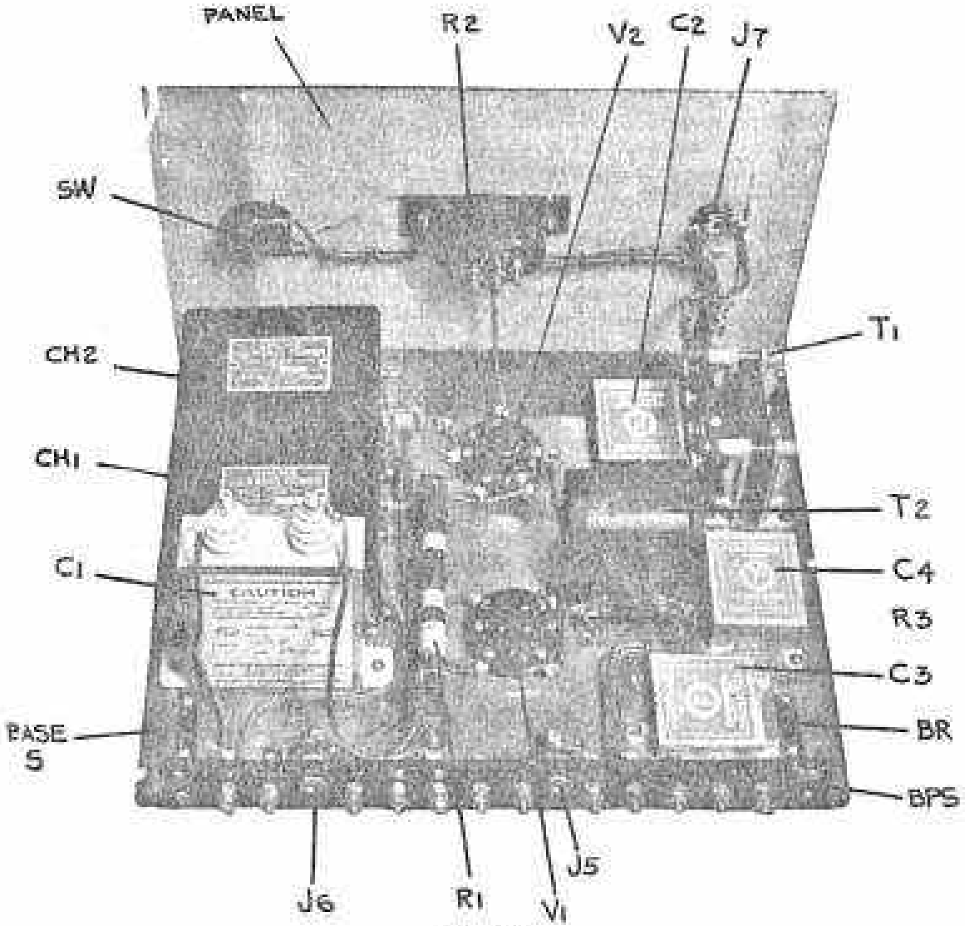


Fig. 177

This is the rear view of the Cat. No. 225 unit. It clearly illustrates the position of the various parts.

grounded in the receiver otherwise the receiver storage battery will be short-circuited.

The following gives correct plate meter readings and "C" battery voltages for the No. 225 unit:

Modulator—Plate Mils 55—C voltage minus 135.

Speech Amplifier—Plate Mils 9—C Voltage minus 9.

When making adjustments it is essential to adhere to the above plate current readings and C battery voltages.

The microphone input is controlled by the resistor "R2." A combination will be found so that the operator will readily know the distance from the microphone mouth-piece to his mouth and the intensity at which the microphone is being actuated. This will vary with various types of microphones employed and also will vary with the voice of the person using the microphone. The correct combination of R2 and voice input to the microphone should be sufficiently strong to show the movement on the plate meter and the speech amplifier tube. If too much gain is used this plate meter needle will fluctuate in synchronism with the input and when thus fluctuating it is a safe indication that distortion is being had.

In like manner, the plate meter when inserted into the modulator tube circuit should remain practically constant and should not fluctuate with the input.

In the instructions given for the No. 215 CW unit no mention was made on the changes necessary to adapt this unit for telephone purposes. Therefore, when using the No. 225 modulator in conjunction with the 215 the following adjustments will have to be made in the 215 power amplifier stage:

The ordinary C voltage employed on the 245 amplifier tube is 90 volts. Therefore, change the C battery from 90 to 157 or 180 volts. By doing this the plate current of the power amplifier tube will be reduced, thus placing the tube in a condition where it will not be overloaded when the highest peaks of modulation are delivered from the modulated tube.

The meter which is used to indicate resonance in the antenna circuit will approximately show 70% of the reading ordinarily had before the C bias was doubled. That is, this reading will be had when the microphone is not spoken into. As the microphone is actuated this antenna meter needle will rise approximately 30% from its low idling position. The best way to test this upward swing is to actuate the microphone with a steady constant tone like that obtained from a buzzer or from the head phones of the receiver when the receiver is in an oscillating condition and howling at an audio frequency. Another simple method is to whistle into the microphone and thereby note the upward swinging of the antenna meter needle. At all times while telephoning it will be noted that the antenna meter will swing upwards in direct proportion with the amount of input to the microphone.

It is of course essential to monitor or check the output when using the telephone transmitter. This may be accomplished by listening in at the receiver when this receiver is in a non-oscillating condition, or better yet, by using the method which employs a crystal detector connected in series with a coil and a pair of phones. This coil can be coupled to the antenna lead going to the transmitter. There is no reason why the amateur should not be able to know exactly what his phone sounds like. It is not necessary to ask for reports on your phone when you can easily and quickly check yourself directly at the station. A good monitor is the best indicator.

Schematic Wiring Diagram Fig. 178 shows exactly how the No. 225 Modulator unit is connected. Follow this out exactly, run all plate and grid

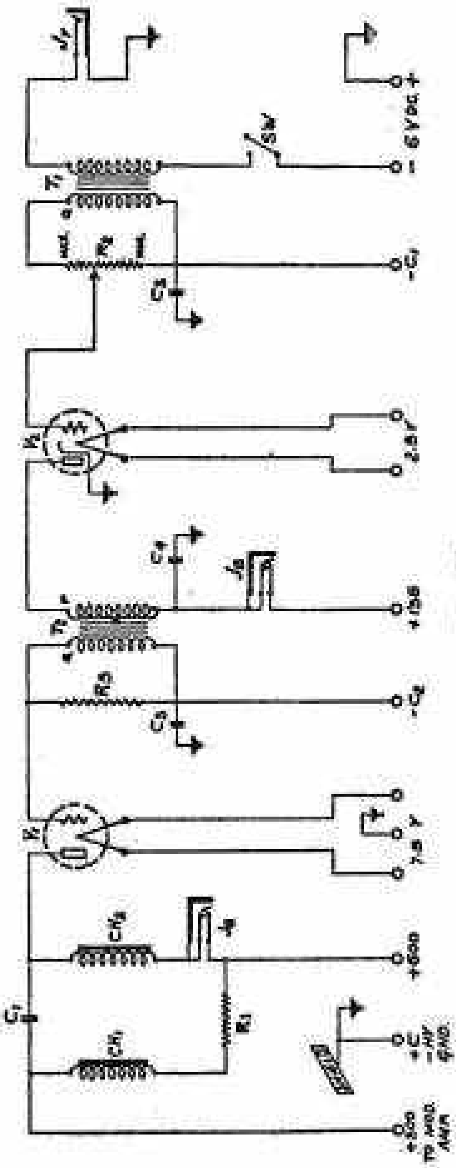


Fig. 178
Schematic Diagram 100% Modulator.

leads short and direct. All other wiring may be cabled as illustrated in the rear view.

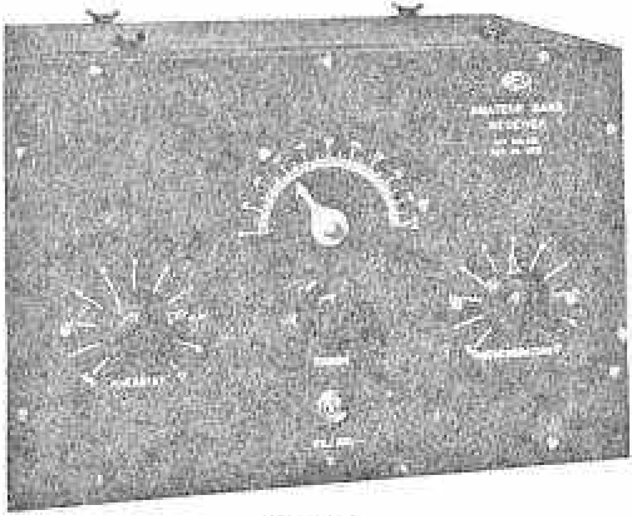


Fig. 179

The following is a description of the parts required with each 225 kit:

C1—Bypass condenser 2 mfd. 1,000 volt type.
C2—Speech amplifier grid bypass condenser .5 mfd. 450 volt type.
C3—Modulator grid bypass condenser .5 mfd. 450 volt type.
C4—Speech amplifier plate bypass condenser .5 mfd. 450 volt type.
CH1—Constant current choke special Dongan type No. 1591, or equivalent.
CH2—Constant current choke special Dongan type No. 1591, or equivalent.
T1—Modulation transformer for use with single button carbon microphones.
T2—Audio frequency transformer, ratio 3 to 1.
R1—Amplifier plate voltage reducing resistor 5,000 ohm 44 watt type.
R2—Gain control variable resistor 500,000 ohm.
R3—Audio transformer shunt resistor 100,000 ohm supplied with 2 grid leak mounting clips.
J5—Speech amplifier meter jack, single circuit closed jack.
J7—Microphone plate, Single circuit open jack.
V1—Modulator tube socket, UX type.
V2—Speech amplifier tube socket, UY type.
SW—Microphone battery switch.
S—Five-ply veneer baseboard finished black lacquer and covered with copper sheet. Baseboard dimensions 13" long, 9¼" deep, ½" thick.
BPS—Rear binding post terminal strip completely fitted with 12 8-32 binding post screws, nuts and washers.
BR—Two angle brackets for supporting rear terminal strip.
P—Front panel aluminum completely drilled and engraved—front side finished black crystalline lacquer. Rear side satin finished aluminum.
C—Pressed steel cabinet—inside finished dull black lacquer—outside finished black crystalline lacquer. Equipped with removable top. Size 13" x 9" front x 10" deep.

Amateur Band Receiver Kit

The average amateur station has employed many different types of receivers during the past several years. This set described will accomplish everything necessary for an amateur station receiver. The various features of the No. 231 receiver will be taken up and discussed individually.

An untuned stage of radio frequency employing a screen grid tube of the UX-222 type was found to be practical and necessary. The untuned stage was selected in preference to a tuned stage because the addition of a tuned stage would have required an extra tuning condenser control. This would mean that the amateur would be obliged to adjust both tuning condensers at the same time. Furthermore, when desiring to cover quickly a certain amateur band, it would be found extremely difficult to keep these two movable controls in exact synchronism. The main advantage of using the untuned stage of screen grid RF ahead of the regenerative detector is that it will act as a blocking tube to oscillation set up in the detector circuit. In other words, it does not allow the oscillating detector circuit signals to be transmitted. The amateur is well aware of the fact that an oscillating receiving tube when connected to an antenna will create considerable disturbance. Another advantage for the radio frequency stage is that it will allow the detector regeneration control to be smooth and not erratic; thus it will block the antenna harmonic effect and provide smooth control of regeneration. The screen grid RF stage will also help to amplify weak signals to some extent, although untuned, screen grid tubes cannot be used to their utmost advantage on short waves—they will furnish some radio frequency gain.

The detector circuit employs a tube of the 201-A type. Regeneration is controlled by means of a variable resistor. This resistor is of the drum type, making perfect noiseless contact at all times. The tickler coil combinations employed are of such ratio that the regeneration control resistor will at all times give absolute positive and smooth control of oscillations.

Three correctly designed plug-in coils are supplied. These are designed to cover with maximum efficiency the 20, 40 and 80 meter amateur bands. By means of the special combined tank and vernier tuning condenser full spread coverage of each amateur band is obtained. A brief description of how this is accomplished follows. The single rotor and the single stator main tuning condenser "C2" is controlled from the front panel. The stator plate is movable; that is, its position to and from the rotor plate may be varied, thus allowing the maximum capacity of this vernier control condenser to be set at any desired capacity. This single stator plate is therefore set at an arbitrary position and the rotor plate is set at minimum capacity or in the "all out" position. This will then indicate as zero on the dial located on the front of the panel. The 80 meter coil is plugged into the coil socket and the large tank condenser "C1" is set to a certain definite position which will tune the lower end of the 80 meter band. This large semi-variable tank capacity condenser is controlled by means of the 3" bakelite disc "D." The ratchet makes friction contact to this bakelite disc. At the exact point where the bottom of the 80 meter band is received scratch a line onto the bakelite disc where the ratchet makes contact. The variable control of the vernier condenser is then set to maximum capacity or in the "all in" position; that is, where the front dial indicates at "100." By moving the single stator plate closer to the single rotor plate of the vernier control a point will be had where the uppermost point of the 80 meter band is received. The user will now note that without any further adjustment of the large tank condenser "C1" it will be possible to cover the complete 80 meter band by simply using a single plate vernier control on the front panel.

The same procedure is followed out with the 40 and the 20 meter coils; that is, leaving the single stator plate in the original position simply adjust the tank condenser by means of disc "D." In each case mark this disc at the position for the 40 and the 20 meter bands. Once this disc has thus been calibrated, notches may be filed so that the ratchet will fit. After this is accomplished the amateur, when shifting from one band to another, is obliged to plug in the correct coil and swing the black bakelite disc to the correct notch; that is, if the 40 meter coil is plugged in, set the tank condenser with its bakelite disc so that the 40 meter notch will coincide with the ratchet. Full spread coverage is then obtained by means of the vernier control on the front panel. This feature for obtaining full spread tuning of each amateur band is simple and positive. The amateur who has had previous experience and knows how bad the congestion and interference is on the various bands should immediately appreciate such widespread tuning.

Without the use of any additional coils the amateur may employ this same receiver for 10 meter reception, only when doing so he will not obtain full widespread coverage. The procedure is to plug in the 20 meter coil and reduce the capacity of the large tank condenser until a position is had where 10 meter signals are heard. The tank condenser may then be left in that position and further tuning in the 10 meter band is accomplished with the vernier control condenser.

The audio-frequency circuit employs a tube of the 12-A type. Only one stage of audio has been incorporated in this receiver because this is sufficient for headphone reception. It has been found through experience that the average amateur uses only headphones and not loud speaker. Should anyone desire to use loud speaker it is a simple matter to add an additional power amplifier to the output of the receiver.

A neatly drilled and engraved aluminum front panel makes the appearance and building of the set a simple matter.

Various parts supplied with the receiver should be mounted in the approximate positions shown in the rear view layout. As this illustration is clear and distinct, it is needless to go into further details regarding the mounting of the equipment. The schematic wiring diagram given should be used when connecting the receiver. All grid and plate leads should be run short and as direct as possible. All other wires may be bunched in cable fashion.

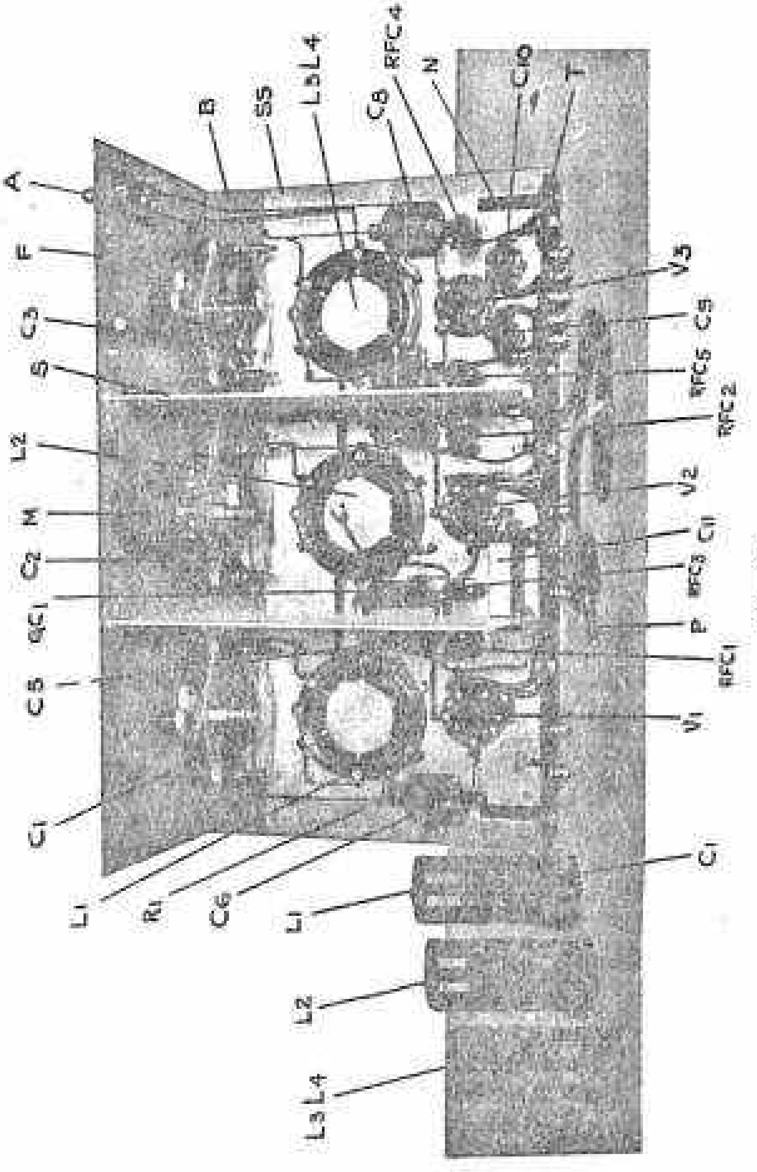


Fig. 180

Rear view of the No. 231. The placement of the various individual parts should be exactly as shown here. Note the well-designed plug-in coils and the specially constructed combined tank and Vernier Tuning Condenser.

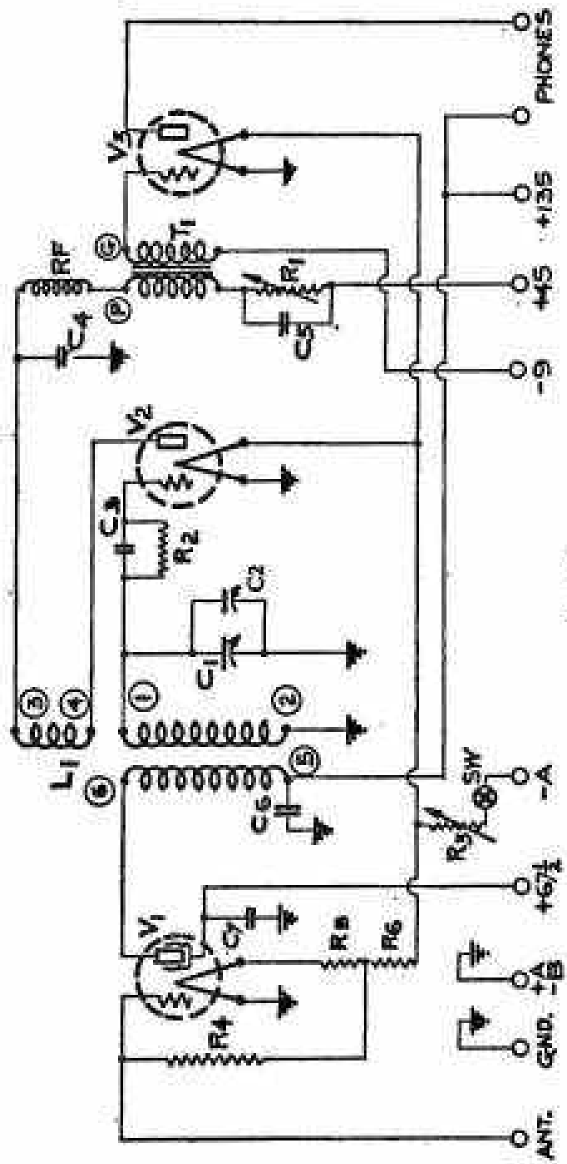

PHONES
+135
+45
-9
-A
SW
R5
+67½
+A
-B
GND.
ANT.
RF
T1
R1
C5
C4
V3
V2
V1
C3
R2
C2
C1
L1
C6
C7
R4
R6

Fig. 181

The following is an explanation of the (Fig. 181) No. 231 schematic wiring diagram and also a complete list of parts which are required:

C1-C2—Tuning condenser supplied with 4" type KK vernier control knob.
C3—.0001 condenser fitted with 1 pair grid leak mountings.
C4—.002 condenser.
C5—1 mfd. 250 volt condenser.
C6, C7—.5 mfd. 250 volt condensers.
L1—One set (3) coils with one coil base.
T1—Audio frequency transformer, 5 to 1 ratio.
R1—Regeneration control resistor, 100,000 ohms, complete.
R2—Grid leak, 10 megohm.
R3—Rheostat 10 ohm.
R4—Antenna resistor, .01 megohm, supplied with small bakelite mounting strip fitted with 1 pair grid leak mountings.
R5-R6—Combined 15 ohm tapped resistor. (Note: The R5 section is 10 ohms and the R6 section is 5 ohms.)
V1—Radio frequency tube socket, UX type.
V2—Detector tube socket, UX type.
V3—Audio frequency amplifier tube socket, UX type.
SW—Filament switch.
RF—Radio frequency choke coil, 5 slot type.
BPS—Rear binding post terminal strip completely fitted with eight 8-32 binding post screws, nuts and washers and also two binding posts for phone connection.
B—5-ply veneer baseboard, finished black lacquer and covered with copper sheet. Baseboard dimensions 13" long, 9¾" deep, ½" thick.
BR—2 angle brackets for supporting rear terminal strip.
P—Front panel aluminum completely drilled and engraved. Front side finished black crystalline lacquer. Rear side satin finish aluminum.
C—Pressed steel cabinet. Inside finished dull black lacquer; outside finished black crystalline lacquer. Equipped with removable top. Size 13" x 9" front x 10" deep.

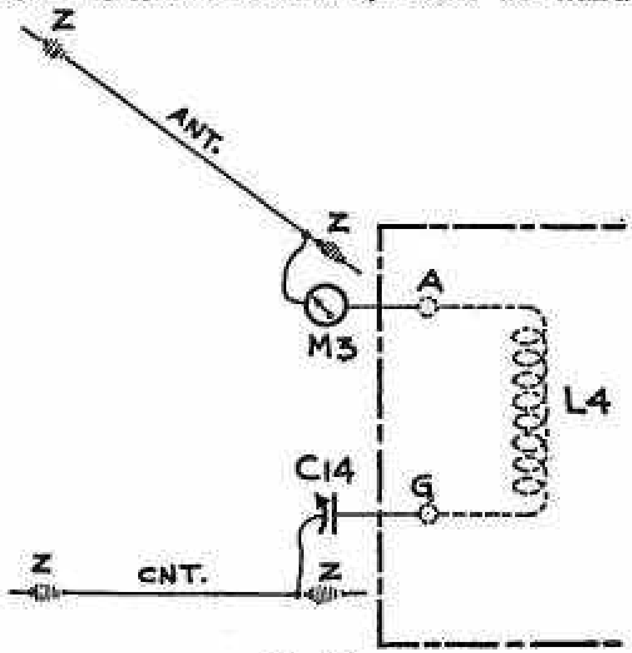


Fig. 182

Antenna Systems for Amateur Wave Bands

General

The antenna or at least the effective radiating portion of an antenna system should be located in an unobstructed area, free from trees, metallic structures or other foreign bodies. In each particular locality certain types of antennas will lend themselves more readily while others will never prove satisfactory. The tuning equipment, such as variable condensers, meters or switches, should be mounted in an appropriate place above the transmitter unit. The antenna leads may be wired from the transmitter posts to these pieces of apparatus and then to the antenna lead out insulators. All points of an antenna system should be equally well insulated by use of pyrex or other suitable material. One poorly insulated portion of an antenna may be the weak link in the whole system.

Antenna Counterpoise System—(Fig. 182)

This type of antenna may be used very well by a beginner. It is simple in adjustment and in most cases is a very good radiator. It may be used wherever one is not compelled to run long leads in order to get to a clear unobstructed area. The antenna and counterpoise should be separated by as great a distance as is possible. The following lengths given will be suitable when the antenna and counterpoise are separated by distance varying between 10 and 50 feet:

20	Meter	Band	17 ft.
40	"	"	32 ft.
80	"	"	64 ft.
160	"	"	130 ft.

When measuring the length of the antenna or counterpoise, include the total length of the wire from its extreme end through the lead-in and antenna tuning apparatus to the antenna post on the transmitter. For example, if an antenna counterpoise system were to be erected for operation in the 80 meter band the antenna wire would be 64 feet long from its extreme insulator "Z" to the antenna binding post on the transmitter "A." Likewise, the counterpoise wire would be 64 feet long from its extreme insulator "Z" to the antenna post on the transmitter "G."

Antenna Ground System—(Fig. 183)

This system will generally adapt itself to the same conditions as the antenna counterpoise system. This is the simplest form of radiator and is recommended for the beginner. It may only be used advantageously where long leads to the antenna are not necessitated. It may be used very well on a small boat or aircraft. With this system the ground must be made positive and good. The length of the antenna wire will be equal to those shown on the table for Fig. 182. The ground being untuned or aperiodic will function with any length of antenna. However, as it is more than likely that several feet of wire will be used in the lead that connects the ground to the transmitter, it may be necessary to vary from the antenna lengths specified slightly. This arrangement should only be used when a good ground is available.

Single Wire Feed Hertz Antenna System—(Fig. 184)

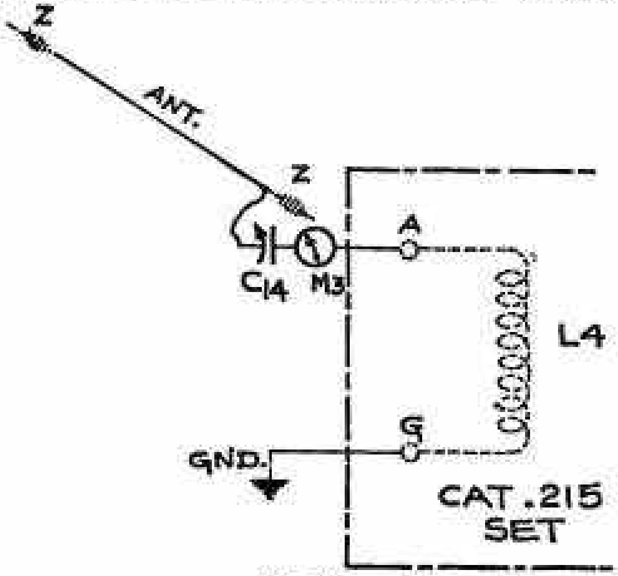


Fig. 183

This type of radiator may be employed where the transmitter is located some distance from a good antenna location. This situation often occurs in an apartment house. With an antenna of this type successful operation may be secured with a feeder lead of over 100 feet in length. In fact, there will be no limit to the length of the feeder within reason. The formula for the correct length of the actual antenna between points "Z" and "Z" is as follows: This dimension is to be calculated in meters. One meter = 39.37 inches.

The wavelength upon which operation is desired equals the length in meters times 2.07.

i. e.— = L x 2.07

The feeder "F1" must now be connected to the proper position on the antenna wire. The following formula shows where "F1" should be connected.

The distance (measured in feet) of the feeder from the center equals the antenna length times 25 and the product divided by 180. That is:

$$\text{Feeder distance from center} = \frac{\text{Length of antenna (ft.)} \times 25}{180}$$

The length of the feeder from "F1" to "R2" may be anything within reason and no specific length is required. The following is a table which will give the exact data for the various amateur bands.

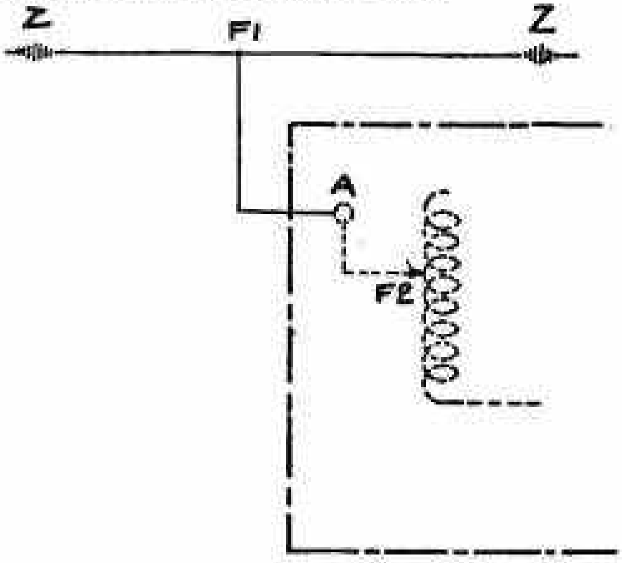


Fig. 184

20 Meter Band.	14,000 Kcs. Antenna length 33 ft. 11 in. Distance from the center for feeder tap 4 ft. 9 in.
40 Meter Band.	7,000 Kcs. Antenna length 67 ft. 10 in. Distance from the center for feeding tap 9 ft. 6 in.
80 Meter Band.	3,500 Kcs. Antenna length 135 ft. 6 in. Distance from the center for feeding tap 18 ft. 11 in.

An antenna of this type may be operated very well at its harmonics. If a 3,500 Kc. antenna were erected, operation on both the 7,000 and 14,000 kilocycle bands will be satisfactory.

Two Wire Feed Hertz Antenna System (Zeppelin)—(Fig. 185)

This type of radiator is probably the most efficient for all amateur purposes. It may be used to extreme advantage where the transmitter is located some distance from the position of a good radiating system. It is possible to slightly wander off the fundamental frequency of a two wire feed system and still secure good efficiency. The following are the requirements in the dimensions of a successful two wire or better known Zeppelin type antenna.

1—The feeder system must be such that each wire is equivalent in length to an odd multiple of one-quarter of the wavelength being used

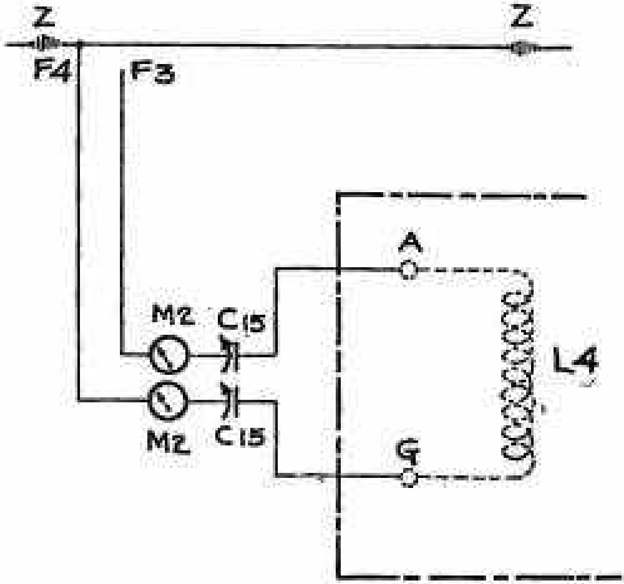


Fig. 185

2—Antenna must have a length equivalent to an even multiple of one-quarter wavelength.

3—The feeder system must be electrically symmetrical.

An antenna that will operate on the four amateur bands 3,500, 7,000, 14,000 and 28,000 Kc. (80, 40, 20 and 10 meters) would be calculated as follows: We would employ a half wave 80 meter system. One meter is 3.28 ft. and the length of a half wave 80 meter antenna is therefore one-half times 3.28 times 80 or 131.2 ft. This would be the length of the radiator suspended in a clear space, as shown in Fig. 185, designated by the wire spread between insulators "Z" and "Z." Feeders may vary in length to suit each particular location. Therefore the wires "F4" and "F3" should be run from one end of the antenna to the transmitting inductances. By use of two condensers "C15" connected in series or by one condenser connected in parallel across inductor "L4" the feeder system may be tuned over a considerable band of frequencies. In this manner "F3" and "F4" may be tuned to the fundamental or an odd multiple of the fundamental of the wavelength being used. The feeder construction must be symmetrical. Each wire must be exactly the same length as the other. This is particularly important when the system is being operated on the higher frequencies. The distance between the wires F3 and F4 may be anywhere from 6 inches to 18 inches.

When adjusting this antenna it must be so tuned that the currents in both the ammeters "M2" are of equal value. When this has been attained the antenna is operating as a real two wire Hertzian voltage feed radiator.

Term	*Abbreviation*
Alternating-current (adjective)	a-c
Alternating-current	spell out
Ampere	a
Antenna	ant.
Audio-frequency (adjective)	a-f
Continuous waves	CW
Cycles per second	~
Decibel	db
Direct-current (adjective)	d-c
Direct current	spell out
Electromotive force	e.m.f.
Frequency	f
Ground	gnd.
Henry	h
Intermediate-frequency (adjective)	i-f
Interrupted continuous waves	ICW
Kilocycle (per second)	kc
Kilowatt	kw
Megohm	MΩ
Microfarad	μf
Microhenry	μh
Micromicrofarad	μμf
Microvolt	μv
Microvolt per meter	μv/m
Millivolt per meter	mv/m
Milliwatt	mw
Ohm	Ω
Power Factor	p.f.
Radio-frequency (adjective)	r-f
Volt	v

Abbrevations for Metric Prefixes

Prefix	*Abbreviation*
centi	c
deci	d
deka	dk
hecto	h
kilo	k
mega	M
micro	μ
milli	m

GENERAL INDEX