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A STUDY OF WAVE SYNTHESIS BY MECHANICAL MEANS—IV

PART II.—SOME USES OF THE SYNTHESIS MODEL, IN PARTICULAR THOSE RELATING TO WIRELESS PRACTICE

This article was commenced in the June number of THE MARCONI REVIEW. *In the following Section the phenomenon of Beats is discussed, and the methods of using the synthesis model to investigate this and allied phenomena are given. The article concludes with a brief discussion of "Push-Pull" circuits and the Synthesis of Alternate Current waveforms.*

Section 3—Mechanical Investigation of the Phenomenon of Beats particularly as it concerns envelope shape.

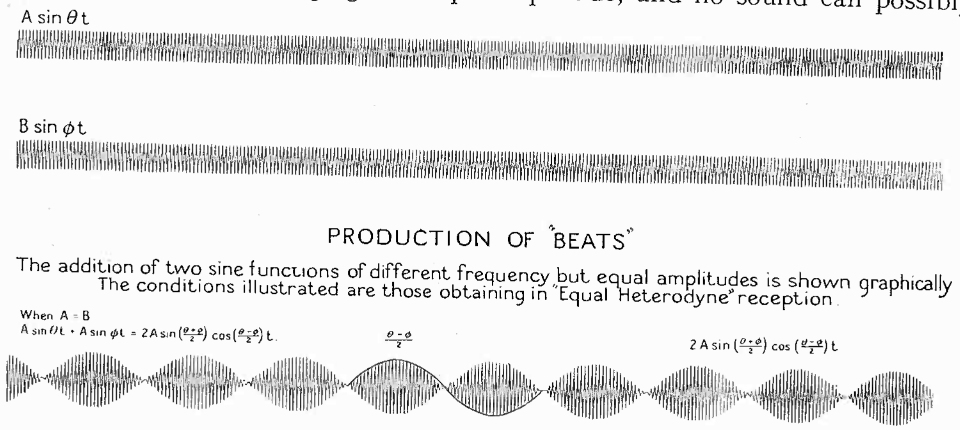
WHEN a transmitting station signals a continuous wave chopped up by morse signals, the receiving station would, if it received these signals as sent, get only a succession of clicks and although the intelligence is being conveyed, this type of signal would be very unsatisfactory for aural reception. The receiving station can, however, impress its own note modulation by adding a local continuous oscillator, so adjusted as to beat with the incoming signal and produce an audio frequency envelop, which, when rectified will give a convenient aural signal to the receiver; or beats at a supersonic frequency can be obtained if it is desired to create a change of high frequency for the purpose of gaining greater selectivity or amplification. The phenomenon of beats has, of course, been known for a very long time, and considerably investigated by students of sound, and it is suggested that certain erroneous ideas may have resulted from studying this phenomenon with the aid of musical notes, if one can judge by popular statements as to their composition.

The following quotation regarding this phenomenon represents an often accepted idea of the meaning of musical beats :—

> "When two notes differing slightly in frequency are produced at the same time, a throbbing sound or 'beat' is heard at regular intervals depending upon the difference in frequency of the two sources. Thus, if

two tuning forks with periods of 1,000 and 1,002 per second are made to vibrate, beats will be heard at the rate of two per second. If the detuning is still greater the beats become so rapid that they produce a musical note or combination tone; for instance, two notes with frequencies of 1,000 and 1,200 would give rise to a note with a frequency of 200."

Such a statement gives the erroneous idea that the beat, when it lies within the aural frequency band can be heard, but this is not a fact, for the beat is merely a throbbing due to a changing envelope amplitude, and no sound can possibly be



PRODUCTION OF "BEATS"

The addition of two sine functions of different frequency but equal amplitudes is shown graphically. The conditions illustrated are those obtaining in "Equal Heterodyne" reception.

detected unless a rectifier is included in circuit. This may be seen by studying the records of Figs. 21 and 22, regarding which the following comments are made.

General Study of Beat Phenomenon.

The phenomenon is studied by adding two frequencies differing by a very small percentage, and although of course, the frequencies used with the model are low frequencies, it will be seen that since the beat envelope obtained is dependent upon difference of frequency, we can make this beat envelope of as low a value as we desire, whether low or high frequencies are being considered.

BEATS. (1) *The sum of two different frequencies,* very closely approximating.

(A) *Of Equal Amplitude.*

$$Ft = A \sin \phi t + A \sin \theta t$$

$$= 2 A \sin \frac{(\phi + \theta)}{2} t . \operatorname{Cos} \frac{(\phi - \theta)}{2} t$$

The wave resulting from the addition of two such frequencies is seen from Fig. 21 to be a wave of one definite frequency varying in amplitude.

The resultant wave is of definite frequency $\frac{\phi + \theta}{2}$ rising and falling in amplitude, and it is to be noted that the rise and fall, *i.e.*, the beat, occurs once for every *Half Cycle* of the second product term. The second product term shown dotted is symmetrical about the zero line, its sinusoidal variation being at a frequency of $\frac{\phi - \theta}{2}$. The beat frequency, however, is the frequency of the rectified envelope and as the change occurs at every *Half Cycle* of the product term, its frequency will be $\phi - \theta$, and not $\frac{\phi - \theta}{2}$.

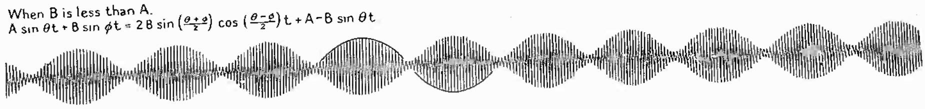
B sin ϕt

A sin θt

PRODUCTION OF "BEATS"

Addition of two sine functions differing in frequency and amplitude.
When the amplitudes are very unequal the envelope approximates to a sine wave-form.
Note also that the product term is a broken function.

When B is less than A.
$A \sin \theta t + B \sin \phi t = 2B \sin\left(\frac{\theta+\phi}{2}\right) \cos\left(\frac{\theta-\phi}{2}\right) t + A - B \sin \theta t$



In order to be able to take out such a beat, no matter whether the frequencies are audio or high frequency, it is essential to rectify, as otherwise the mean value is still zero. It is observed that the envelope is not a sine wave in character, and although the form of equation for the rectified envelope can be obtained mathematically it does not appear to be a simple function.

Notice that the amplitude of the beat wave varies between 2 A (*i.e.*, the sum of the amplitude of the two waves) and zero, and this variation represents the strength of the received aural signal if rectification is carried out, and if the beat frequency lies within the aural band.

(B) *Of Unequal Amplitude.*

$A \sin \phi t + B \sin \theta t$ — Where A and B are unequal and B say, is greater than A. Frequency values as before.

$$= 2 A \sin \frac{(\phi + \theta)}{2} t . \ \mathrm{Cos} \frac{(\phi - \theta)}{2} t + (B - A) \sin \theta t$$

In this case the resulting frequency and the beat frequency remain unaltered as they are determined by the relative frequencies beating together and, therefore,

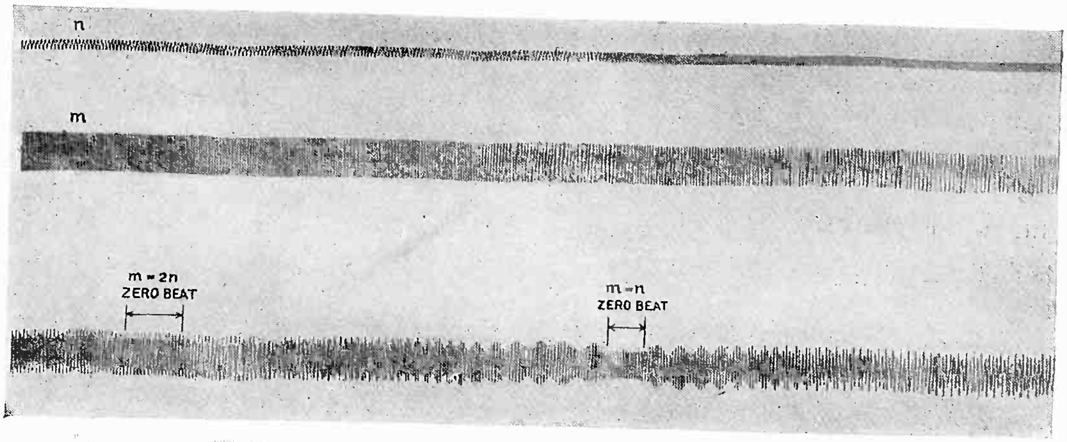


FIG. 23. *Diagram showing the beating of two waves, the frequency of one being kept frequency of the first to one quarter of the frequency of the first. n—smaller*

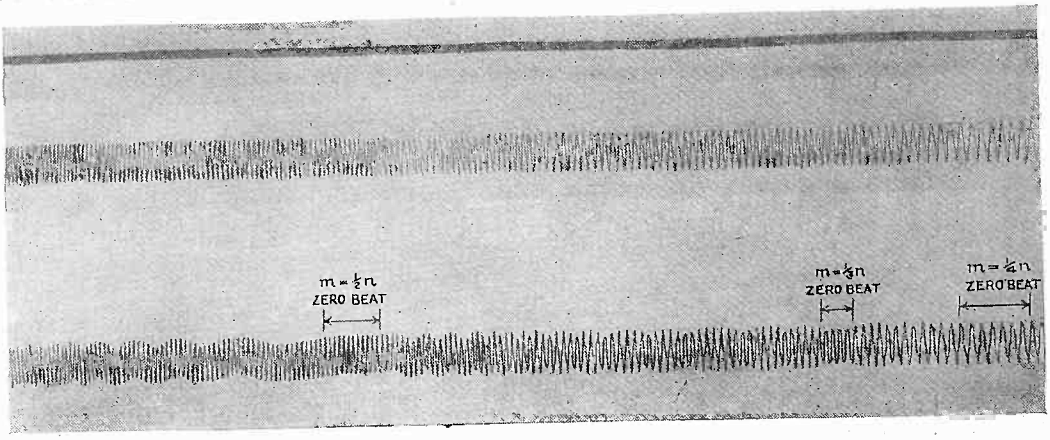
they will be unaffected by the respective amplitudes of the original waves as is seen from Fig. 22.

The second product term can still be traced, now as a broken function, but it should be noted that the change of amplitude will no longer equal the sum of the amplitudes but only twice the amplitude of the smaller beating wave. Thus in this case an equivalent D.C. component has been added of amplitude B — A as shown by the third term above, which would not affect the receiver telephone after rectification.

This means that if a small amplitude continuous wave signal is being received, maximum aural signal will be obtained, theoretically, when the local oscillator is equal in amplitude to the incoming signal, any excess of oscillator amplitude merely contributing to an equivalent D.C. component. Actually in practice rather greater local oscillator amplitude is required as the characteristic of a wireless rectifier is not perfect, but has a law which tends to be more nearly a square law.

Another apparent change is that although the frequency of the beat remains the same whatever the amplitudes of the frequencies, the rectified envelope may be considerably altered in character. For as the difference between the amplitudes increases, the rectified waveform appears to approach more nearly to the sinusoidal, and considering the extreme case, that is when the amplitude of one wave is infinitely great compared to the other the resulting beat becomes a pure sine wave of zero amplitude. This means in the case of W/T reception by beat that the character of the received signal changes as the strength of the local oscillator is altered.

As the local oscillator amplitude is increased, the signal wave shape approaches the sinusoidal, but should the two waves be of similar amplitude considerable



constant, and the frequency of the other being varied between limits of about twice the amplitude, constant frequency. m—lower amplitude, varying frequency.

envelope distortion will be evident. This distortion is entirely distinct from that produced from rectification, although a square law type rectifier will tend to exaggerate the effect.

Beats at Harmonic Frequencies.

Besides the production of beats when two frequencies closely approximate, it is found that a similar phenomenon is also produced when one frequency approximates to a multiple or fraction of the other and some interesting features are to be found by studying the record of Fig. 23, which records the beat phenomena with two waves A and B of different amplitudes.

To obtain this record, on Fig. 23, the frequency of A was kept constant and the frequency of B varied from a top limit where B was more than twice the frequency of A, to a lower limit where B was less than one-third A. From examination of this figure it is seen that beating effects are produced at points where B approximates to twice, equal, half, and one-third, the frequency of A, that is to say at any harmonic, the points of zero beat at each stage being clearly defined. One frequency was not continuously varied at a constant rate, but changed in steps so as to show more clearly the more interesting stages. If observation is made of the record it will be noticed that as one recedes from either side of each "zero beat" point, beats quickening in frequency are observed, and at periods midway between two successive zero beat points the character of the envelope appears indeterminate and presumably at such periods no periodic beat frequency will be in evidence.

A further point observed is that at periods where B approximates to twice and half A, the beat produced is not symmetric, the crest of the envelope on one side coinciding with a hollow on the other. This means that the datum line varies with the envelope. On the other hand the beat at periods where B approximates to A and one-third A, the beat is quite symmetric, and thus the analysis suggests the rule that beats obtained with odd multiples in practice will be symmetric, and those obtained with even multiples will be assymmetric.

As in the case previously considered, the actual character of the wave is dependent upon the relative amplitude of the beating waves, A and B, although the general form of beat will persist.

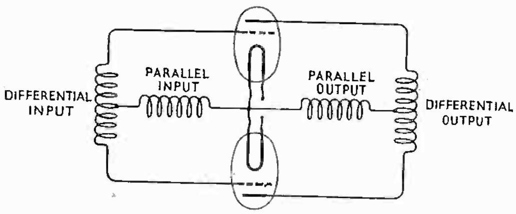


FIG. 24.

Consider the case of one frequency nearly twice the other. If the amplitude of the lower frequency is stronger than that of the higher, only a single note and a single beat is in evidence, throbbing at the low tone.

On the other hand, if the higher frequency has the stronger amplitude, frequency doubling occurs and two sets of beats will be observed. That is, a beat throb will be observed at the higher tone and a second beat throb of the same frequency mingling with it, at the lower tone.

To obtain the value of the beat the following rule can be applied. One wave will be either a multiple (or fraction) or approximate to a multiple (or fraction) of the other. Assume one frequency to be a fraction of the other frequency. Multiply the fraction by its denominator, take the difference of the figure obtained and the other frequency, and this difference will give the beat in terms of the fractional number and can then be reduced.

For instance a signal of frequency 1,000,000 beating with a local oscillator of 500,010. The latter is nearly one half.

Signal	..	1,000,000
Heterodyne 500,010 (multiply by 2)	=	1,000,020
		20

Thus the beat is 20 in 500,010 and reducing this one gets a beat every 500,010/20 waves or one beat in 25,005 cycles.

Section 4—A Mechanical Investigation of "Push-Pull" Circuits.

The name "push-pull" in wireless work is given to those circuits impulsed by two valves acting differentially. Of course it is not necessary to employ two valves to obtain a push-pull action, nor does the name adequately describe the circuit to which it is applied, for with this system it is possible to obtain a variety of effects, some of which are quite the reverse of push-pull.

Fig. 24 shows a general form of push-pull circuit from which it can be seen that input can be applied either at parallel or differential input, and output can be obtained from either parallel or differential output. Further, either valve may be set to the middle of its characteristic, or set to bottom or top rectifying point. Thus it can be seen that a variety of results may be possible with different settings, and it is a convenience to be able to study such a circuit mechanically.

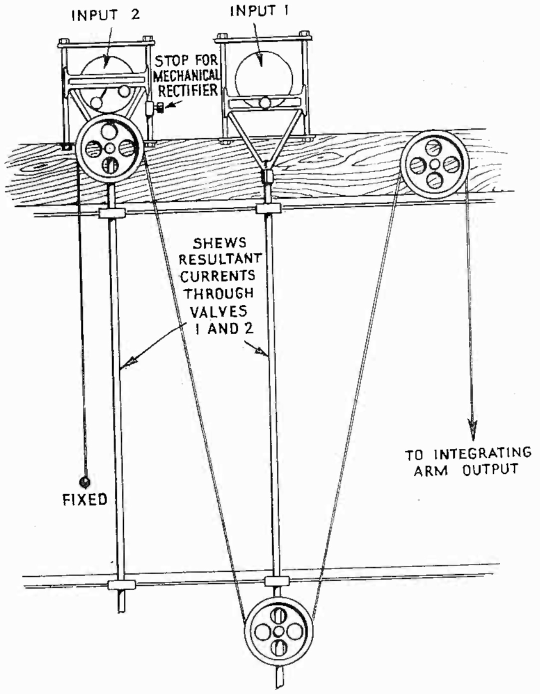


FIG. 25.

Before showing some of the results obtained, a brief indication will be given as to how the model can be set up to demonstrate the push-pull circuit.

The input sinusoidal voltages are obtained of course from the rotating cranks, say input to 1 being obtained from crank 1 and put to 2 from crank 2.

The valves are the crossheads, and should it be desired to set the valves at their rectifying point, this can be done by allowing the crosshead to operate only to such portion of the cycle as would be determined by the setting of the valve. For instance, suppose the valve is to be set to its bottom rectifying point. To do this the crank pin is lifted out of the slide block, and fixed below the crosshead so that the latter can only be impulsed upwards. The crosshead can then be prevented from moving below any predetermined point by a stop, and thus, for complete bottom bend rectification this stop would be set so as to prevent the crosshead moving below zero amplitude. If now any sinusoidal wave be applied to the input crank this wave is automatically rectified by the crosshead, this mechanical rectifier being, of course, a "perfect" device and not having a "square law" as is usually the case.

Thus the trace from a crosshead records plate current through that valve, and not input, and the output current from the two mechanical valves can be combined differentially as for an output 3, or in parallel as for an output 4. To arrange the valves to combine differentially, that is for a push-pull output, the integrating string must be changed from its usual order and fixed as shown in Fig. 25, so that movements in opposition add to one another, whereas for a common output 4, the usual arrangement of string is retained.

The various combinations of results obtained from such a circuit are interesting, and a few of them will be found in Fig. 26.

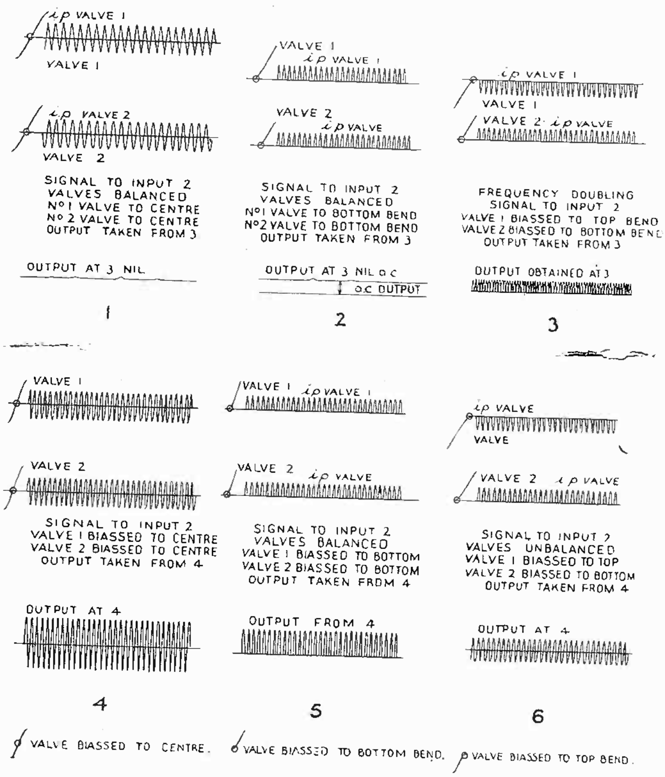


FIG. 26.

Section 5—The Synthesis of Alternate Current Waveforms.

It is well known that any periodic waveform can be analysed into a series of sinusoidal components, and although the machine is not reversible and capable of analysing, the investigation of a known series can be carried out and useful information obtained.

For instance, a square signal wave is represented by the expression

$$Ft = A \sin ft + \frac{A}{3} \sin 3\,ft + \frac{A}{5} \sin 5\,ft + \frac{A}{7} \sin 7\,ft \text{ etc. } \ldots \ldots \text{ to infinity}$$

Hence perfect reproduction of a morse signal should involve theoretically the transmission of this infinite series.

Obviously it is neither economic nor necessary to reproduce the complete set of harmonics, but it may be of interest to see how little one can transmit and still obtain a signal of sufficiently good formation for practical purposes.

Fig. 27A shows a signal with the third and fifth harmonic and Fig. 27B up to the eleventh harmonic, from which one can observe that after the fifth very little is gained in signal formation.

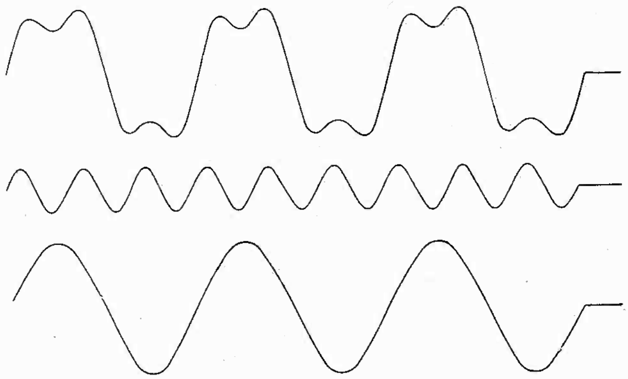


FIG. 27A.

A further point which is sometimes of interest, is the effect on the waveform, of phase shift of the different component frequencies and investigation of this point

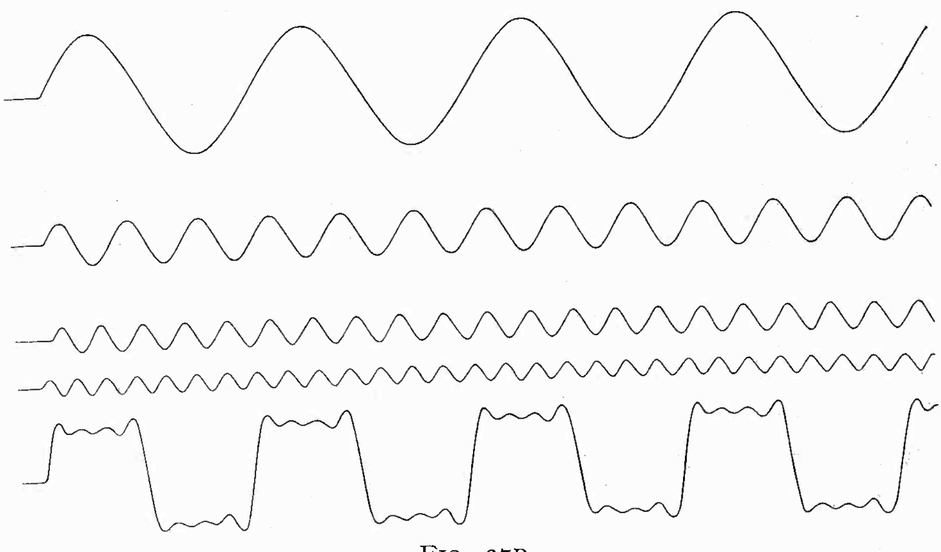


FIG. 27B.

can be carried out very quickly, an example of the use of this being given in the previous section of this paper dealing with single side band working.

A. W. LADNER.

AN AIRCRAFT DIRECTION FINDER

TYPE A.D.16

The A.D.16 aircraft direction finder, to be described in the following article embodies all the latest refinements in direction finding equipment, and combines great sensitivity with extreme lightness, simplicity of control, and interference due to the ignition and electrical systems of the aeroplane, is reduced to a minimum by suitable screening.

The weight and size of the instrument has been reduced to the minimum possible by the use of light-weight woods, metals, and the compact construction of the components.

The A.D.16 receiver operates on the Marconi Bellini-Tosi system and utilises a system of fixed frames in conjunction with a radiogoniometer.

The amplifier of the A.D.16 direction finder has been made extremely selective and sensitive in order to ensure the greatest possible range even when employing the very small frame aerials, the use of which is rendered necessary by the all-metal construction of modern aircraft.

THE type A.D.16 aircraft direction finder can be described conveniently under the following headings :—

(1) The aerial system.
(2) The radiogoniometer and tuning circuits.
(3) The amplifier.

1. The Aerial System.

A photograph of the latest type of screened aerial for use with the A.D.16 is shown below. It will be seen to consist of two rectangular loops, each consisting of several turns of insulated wire, completely screened by stream-lined duralumin tubes.

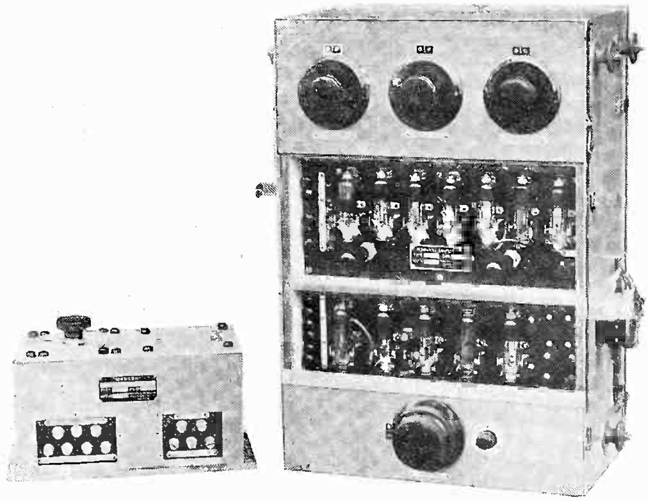
This type of aerial is similar in construction and principle to the F.g.6 type of aerial, a photograph of which was given in the MARCONI REVIEW, No. 8, page 6. The weight and air resistance of the frame has been reduced to the minimum consistent with necessary conditions, such as the pick-up area and maximum clearance from the metal structure of the aeroplane.

2. Radiogoniometer and Tuning Circuits.

The aerials are connected to the radiogoniometer in the usual way, calibrating chokes being placed in one or other of the aerial leads in order to make the receiving power of each equal. The chokes consist of two air core inductances of 50 turns provided with a number of tappings.

The radiogoniometer consists of two field windings at right angles to each other and a rotatable search coil movable by an external handle to which is attached a pointer moving over a graduated scale. The pointer is fitted with a "swing bisector " which enables the operator to take readings on the direction finder and to observe the compass course at the same time. The scale of the radiogoniometer is engraved every five degrees for the sake of clearness.

The two ends of the search coil are connected to the search coil tuning circuit of the amplifier, consisting of a search coil tuning condenser and coupling coil in series. This coil couples into a closed circuit which is connected to a twelve valve amplifier.



A.D.16 Receiver and Radiogoniometer.

3. The Amplifier.

The amplifier consists of six high frequency magnifiers, a detector, oscillator, two supersonic frequency magnifiers, a second detector, and one note magnifier.

The amplifier and tuning circuits are contained in a box divided into four compartments, the uppermost of which contains the search coil condenser, the coupling coil, and the closed input circuit of the amplifier.

The next panel carries the high frequency portion of the amplifier consisting of the six high frequency transformer coupled valves, and the first detector. The potential of the grids of all the H.F. magnifiers, with the exception of the first, can be suitably varied by means of a potentiometer.

The third panel contains the oscillator valve, the two stages of supersonic amplification, the second detector, and the note magnifier.

The bottom panel contains the oscillator condenser and filament resistance for the valves on the panel immediately above.

On the right hand side of the instrument box is the plug for H.T. and L.T. connection, an on-off switch, and a telephone socket.

The circuit diagram of the complete receiver is shown below. Fig. 1.

It will be seen from this that the input circuit is connected to the grid of the first H.F. valve. The six H.F. valves are coupled in cascade in the usual way and pass the received signal to the first rectifier. The grid of this valve is also coupled to the local oscillator which produces the supersonic note which is further amplified in the two stages of supersonic amplifiers. After this process the signals are again rectified by means of a second detector valve, and passed through the note magnifier to the telephones.

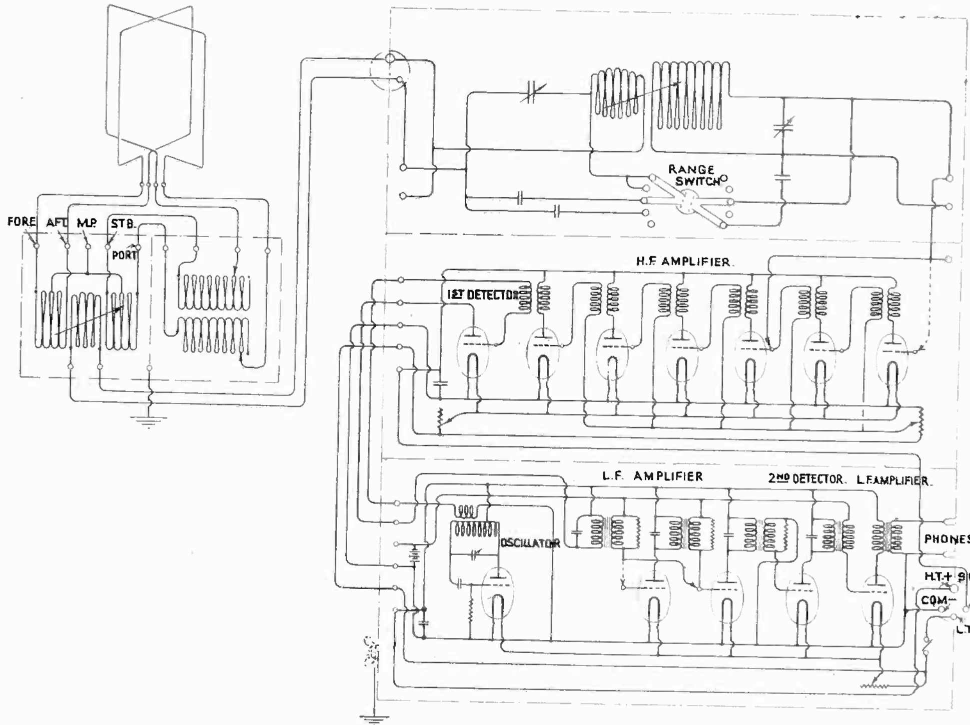


FIG. 1.

The primaries of the supersonic transformers are tuned to the heterodyne by means of a fixed mica condenser, and damping leaks are connected across the secondary windings.

Batteries and Valves.

Low tension current for heating the valve filaments is supplied from a 6 volt accumulator, and the high tension supply is taken from a 96 volt dry battery provided with tappings.

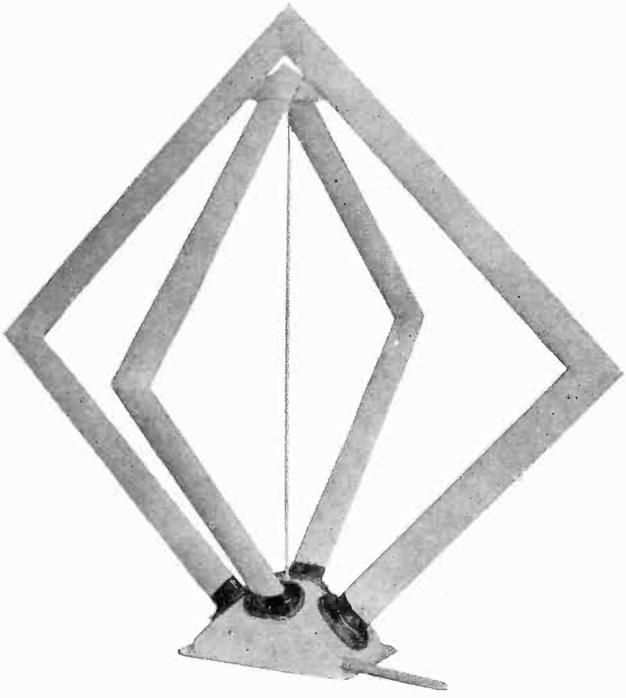
D.E.V. valves are used throughout with the exception of the two rectifiers which use D.E.Q. valves.

Operation.

The A.D.16 direction finder, as has been stated above, employs the Marconi-Bellini-Tosi method of directional reception, and this is so well known as to require no detailed description.

It will suffice to say that the point of minimum intensity of signals on the radiogoniometer is used to determine the direction of the transmitting station.

If it were possible to work under ideal conditions, an absolute extinction of signals could be obtained and bearings could be determined by actually noting the position of this zero. In practice, however, what is known as the " swing " method of taking bearings is generally used. Two points on either side of the minimum are selected such that the signals at these two points appear to be of equal strength. The mean of the readings of the pointer in these two positions will then give an accurate position of minimum signal strength and a correct direction for the received signal.



A.D.16 Frame Aerial.

It will be noted that in the A.D.16 no provision is made for a " sense " determination, *i.e.*, an ambiguity of 180° will always exist as to the direction of any signals, but this can nearly always be eliminated by the knowledge of the operator as to the direction of the aeroplane's flight, etc.

Installation, etc.

It is extremely necessary to screen the ignition system of the aeroplane if the efficiency of the receiver is not to be impaired, due to extraneous interference.

The main portions of an aeroplane ignition system consists of the sparking plugs, the ignition leads to the plugs, and the magneto. Each of these should be carefully screened, the essential factor to be borne in mind being that the electrical resistance of the screening system from plug to magneto should be as low as possible.

In aircraft of " all metal " construction it may be found that elaborate screening is not required, the metal construction acting to a large extent as a natural screen.

The amplifier requires careful suspension and is provided with special lugs and elastic supports.

COMMERCIAL SHORT WAVE WIRELESS COMMUNICATIONS

Part 1.—THE EMPIRADIO BEAM SERVICES

By H. M. Dowsett, M.I.E.E., F.Inst.P., M.Inst.R.E.

The following is a reprint of a lecture delivered before the Radio Society of Great Britain at the Institution of Electrical Engineers on September 27th, 1929.

The subject of international short wave communication possesses, at the present time, considerable interest, in view of the formation of the new organisation known as "Imperial and International Communications Ltd." which at the end of last month took over the control of the Empiradio, Via Marconi, and Eastern Telegraph Cable services.

The author, in the present article, first describes the working of the Empiradio Beam circuits—the precursor of all other short wave long distance commercial communications—and then proceeds to discuss the world network of short wave radio links of which the "Via Marconi" services form the British section.

THE subject of this lecture as chosen by your Committee may be considered appropriate at the present time, as the Empiradio Beam services of the British Post Office and the "Via Marconi" telegraph services come under the common control this month of the new telegraph organisation known as Imperial and International Communications Limited. Apart from this, the subject undoubtedly has special interest from the amateurs' point of view. The Washington Convention of 1927 drew up a chart of wavelength allocations which on short waves, that is, below 100 metres, provided for amateur working at various bands of wavelengths from 85 m. down to 5 m., and these bands are well distributed between those bands allocated for the use of fixed services.

The phenomena which are met with in commercial short wave working are therefore well known to members of the R.S.G.B., and on the basis of this common experience it may well be that the account I shall endeavour to give (1) of the manner in which the commercial services have applied the knowledge gained during the last few years to the solution of short wave propagation problems, and (2) of the operating technique which has gradually been built up, so that wireless traffic services are now well established between this country and all parts of the earth, on an economic and competitive basis, may prove of special interest to you.

THE EMPIRADIO BEAM SERVICES.

The Empiradio services provide the most striking example of successful commercial short wave working in the world, and we shall therefore consider them first.

The network involved has its imperial centre at the Central Telegraph Office, London, from which the transmitters at Bodmin are operated that communicate with Canada and South Africa, and also the transmitters at Grimsby that communicate with India and Australia.

The incoming signals from Canada and South Africa are received at Bridgwater, and those from India and Australia are received at Skegness, from which two stations they are put on the land lines to the Central Telegraph Office, London.

The call signs, transmitting wavelengths, and the dates when the Imperial Beam stations were opened for service after completing their acceptance trials are given in the following table.

EMPIRADIO BEAM SERVICES.

Transmitting Station.	Call Sign.	Wavelengths in Metres.	Receiving Station.	Date Service Opened.
Bodmin (England)	GBK	16·574 32·397	Yamachiche ... (Canada)	25th Oct., 1926.
Bodmin (England)	GBJ	16·146 34·013	Milnerton ... (South Africa)	5th July, 1927.
Grimsby (England) ...	GBH	25·906	Rockbank ... (Australia)	8th April, 1927.
Grimsby (England) ...	GBI	16·216 34·168	Dhond ... (India)	6th Sept., 1927.
Drummondville (Canada) ...	CGA	16·501 32·128	Bridgwater ... (England)	25th Oct., 1926.
Drummondville (Canada) ...	CFA	24·793	Rockbank ... (Australia)	16th June, 1928.
Klipheuval (South Africa) ...	VNB	16·007 33·708	Bridgwater ... (England)	5th July, 1927.
Ballan (Australia)	VIZ	25·728	Skegness ... (England)	8th April, 1927.
Ballan (Australia)	VYZ	24·958 16·286	Yamachiche ... (Canada)	16th June, 1928.
Kirkee (India)	VWZ	34·483	Skegness ... (England)	6th Sept., 1927.

Short history of Beam development.

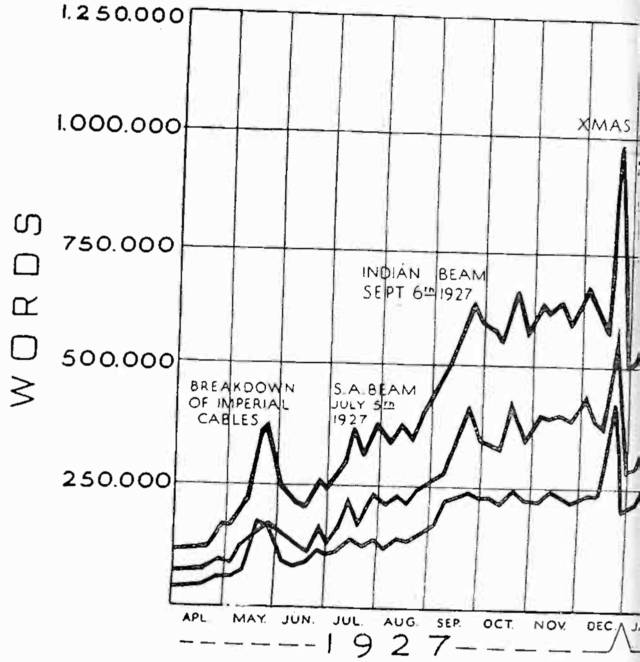
I need only refer briefly to the history of Beam development to remind you of the essential technical features embodied in the equipment of these stations.

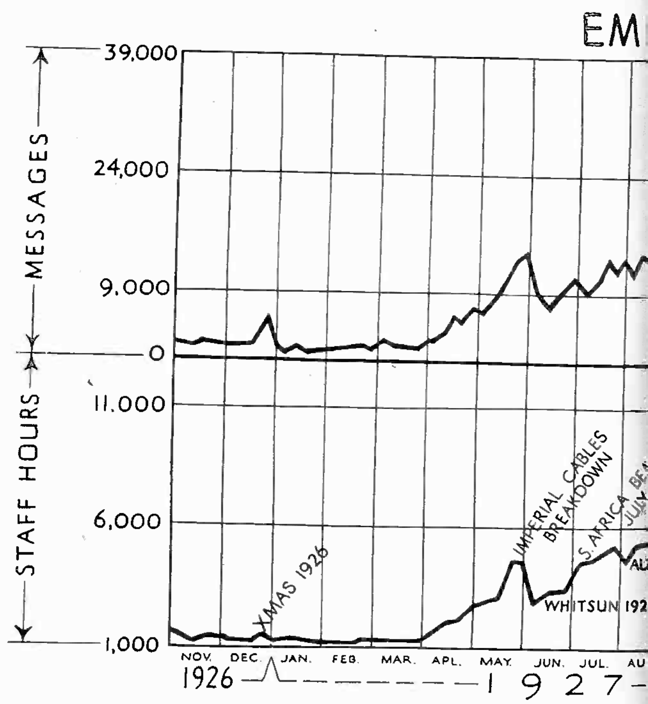
The researches of Marchese Marconi and his assistants on short wave directional wireless from 1915 onwards culminated in the proposal put forward by the Marconi Company to the British Government in 1924 for an Imperial wireless network based on the beam system.

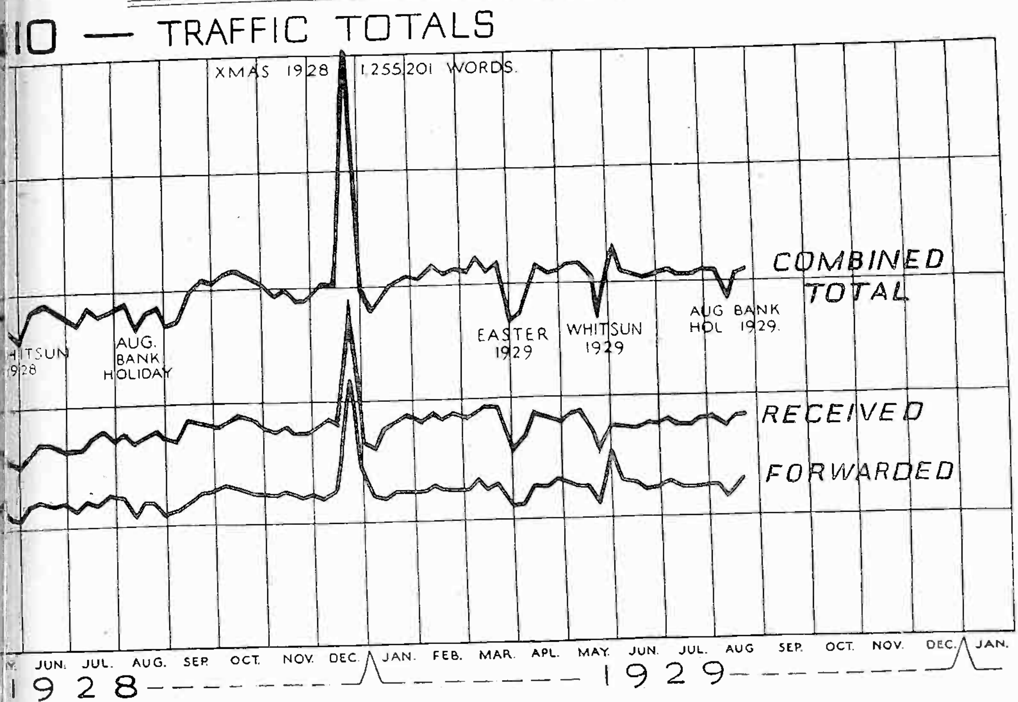
This proposal was accepted, and a contract for the erection of the necessary stations in Great Britain was placed with the Marconi Company by the Postmaster-General on the 28th July of that year.

This was followed by contracts in the various Dominions for the erection by the Marconi Company of corresponding stations in these territories. In the case of the British Government stations, acceptance was to be conditional on a continuous seven days test working duplex, at not less than 100 words per minute simultaneously both ways, and exclusive of any repetitions necessary to service accuracy, for 18 hours per day on the Canadian Circuit, 11 hours on the South African, 12 hours on the Indian, and 7 hours on the Australian circuits.

British Post Office Empiradio traffic charts, giving the number of words or messages sent and received per week from the opening of these services to the present date.






IO — TRAFFIC TOTALS
XMAS 1928 1,255,201 WORDS.
COMBINED TOTAL
RECEIVED
FORWARDED
HITSUN 1928
AUG. BANK HOLIDAY
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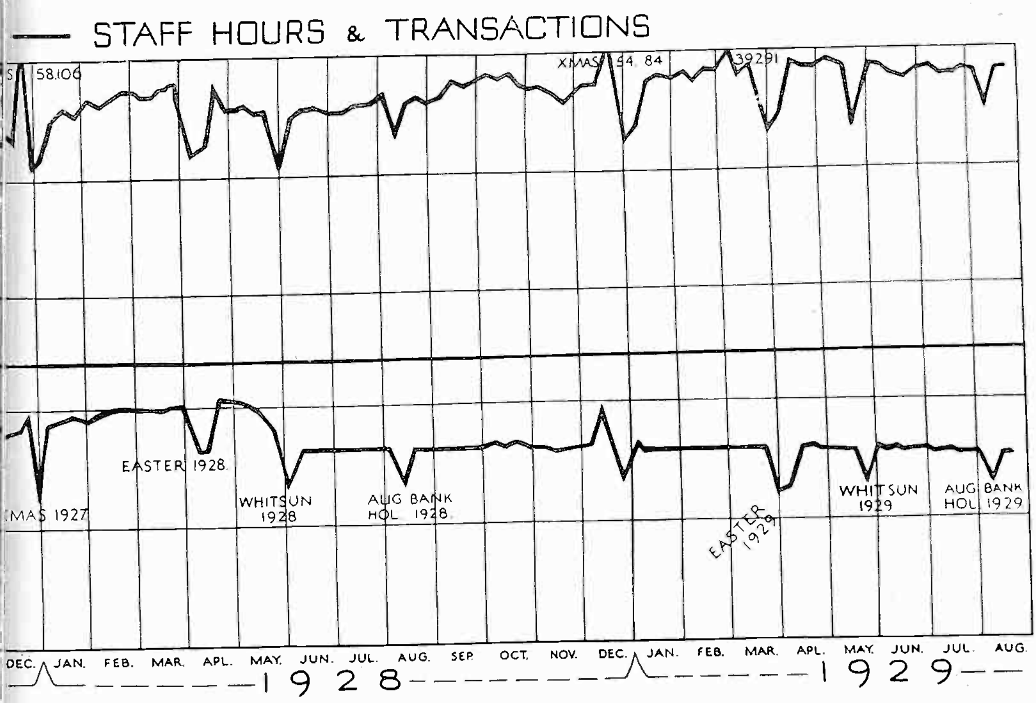
WHITSUN 1929
AUG BANK HOL 1929.
JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APL. MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN.
1928
1929

FIG. 1.


— STAFF HOURS & TRANSACTIONS
58.106
XMAS
54 84
39291
EASTER 1928
XMAS 1927
WHITSUN 1928
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DEC. JAN. FEB. MAR. APL. MAY. JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APL. MAY. JUN. JUL. AUG.
1928
1929

FIG. 2.

With a certain amount known, and a very great deal unknown of the behaviour of short waves, and of the beam method of propagation at great distances, the Marconi Company leaving the minimum to chance, erected plant suitable for delivering at the maximum distance, a strong high speed signal to the receiver on two optional wavelengths within the range of adjustment of a transmitter of standard design for all the stations, one wavelength for day working, the other for night working.

The best wavelengths for each service were finally settled by test, employing the complete equipment when the stations were actually put into commission. The transmitting reflector concentrates the beam of radiation within an angle of 11°. The transmitter itself is an elaborate design which gives great stability of wavelength, and with 20 kw. to the anode of the first magnifier, provides more than enough power for high speed working. The receiver is designed for strong signals, and the signals are not mutilated by short fade periods.

The generous design of these stations involved the Marconi Company in considerable financial loss, but the desired result was achieved, communications were established which more than fulfilled the guarantees.

Efficiency of Beam plant.

It is now three years since the first Imperial Beam service was opened to the public, and in this period several types of projector aerial have been evolved and employed for commercial working in different parts of the world, but nowhere will you find a concentration of beam radiation in both the horizontal and vertical planes equal to that provided at an Empiradio station ; also, although the number of short wave transmitters which can now be heard on the ether is very considerable, and many of them are crystal controlled, a careful watch will disclose that the Empiradio transmitter has a constancy of wavelength equal to the best of them, and that it is handling more traffic and continuing in service without "sticks" for more hours than any other type of transmitter.

As I shall show you later, rush periods on commercial circuits are generally provided for by bringing additional transmitters into operation, which work on additional channels. But the beam services have passed through several very heavy rush periods and have met all traffic demands without any alteration or addition to the original plant or increase in the number of wavelength channels used, and their capacity for traffic is still much above their present working load.

These are some of the facts which help to explain the astonishing commercial success of the Empiradio services.

British Post Office records.

The Post Office staff, which took over the stations, were both keen and capable, but it was the realisation by the business community that high speed, reliable, long distance transmission at a cheap rate had come at last that sent the traffic figures up by leaps and bounds. The Post Office organisation made a full response to the requirements of the service, and by the kind permission of the Controller of the Post Office, I am able to illustrate this point graphically in Figs. 1 and 2, which incidentally give the full traffic history of the Imperial Beams to date.

In a communications service the traffic must be sent when it is offered, the load may fluctuate rapidly, and the apparatus must be capable of handling at any time a great increase on its normal load without any sacrifice of readability, or else fail to satisfy the public.

At rush periods, the operating staff at the Central Office may require to be temporarily augmented, to be reduced again, and the men re-absorbed into other work as soon as normal conditions again prevail.

These conditions on a scale which was quite unexpected were satisfactorily met by the Post Office staff. With the Canadian and Australian beams both working the first severe test came when the Imperial Cables broke down in June, 1927. The incoming and outgoing traffic immediately doubled, rising to 50,000 words per day. When the South African service commenced working in June this figure was maintained and was increased in September, 1927, by the opening of the Indian service to an average for the four duplex circuits of 90,000 words per day.

The Christmas traffic averaged in 1927 140,000 words per day, and in 1928, 180,000 words per day. There is a seasonal dip during the summer, but the traffic on the Imperial beam services is still steadily increasing.

The significance of the staff hours curve is as follows: The amount of traffic attracted by the Beam services when they were opened to the public was much greater than had been expected or provided for. Men had to be employed whose experience was limited, and who had to make up in numbers what they lacked in expert speed. As the staff became more expert, the numbers were reduced, and it will be seen that at the present time, a gradually increasing traffic is carried with a staff which still shows a slight tendency to decrease.

Beam Station equipment.

The distinctive features of the Empiradio Beam equipment are :—

(1) The Aerial and Reflector.
(2) The Aerial Feeder system.
(3) The Transmitter.
(4) The Receiver.

A brief description of these essential parts is as follows :—

(1) The Marconi-Franklin Aerial systems at the Bodmin transmitting station are shown in Fig. 3.

There are two sets of five masts, one set supporting the two aerials of the Canadian circuit, and the other set supporting the two aerials of the South African circuit. The layout of each row of five masts is arranged so that the great circle bearing on the distant station with which that particular Beam aerial is designed to communicate, is at right angles to the line of the masts.

The masts are 287 ft. high with 90 ft. cross arms, and are spaced 650 ft. apart.

Each aerial occupies two bays between the masts, and consists of a parallel sheet of elements made up of a number of vertical doublets linked by phasing coils.

The aerial wires are spaced about one quarter wavelength from a screen of twice as many reflector wires.

The aerial arrangement is such that the currents fed into the parallel wires of the aerial are all in phase. Under this condition the energy radiated from the individual wires cancels out in the plane of the wires but adds in the direction at right angles to this plane.

The effect of the reflector is to cut off the back radiation from the aerial and strengthen it in front, and the total result is a strong beam of radiation confined almost entirely to one direction only and spread over an angle determined by the dimensions of the aerial.

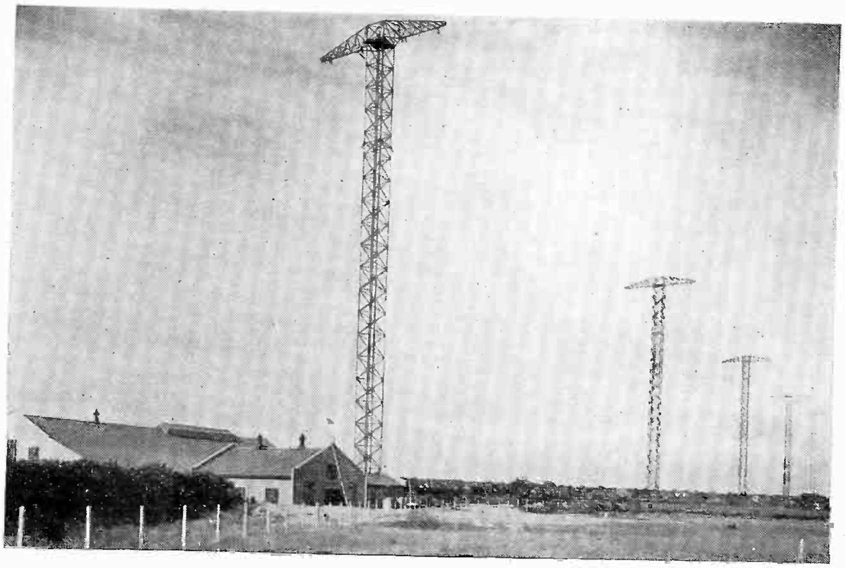


FIG. 3.

The aerial systems of the transmitting and receiving stations are identical.

The masts and aerial systems at Grimsby and Skegness employ a single reflector with an aerial on each side of it, so that by changing over from one aerial to the other the direction of the beam projected round the earth can be altered.

(2) Current is fed into the aerial from the transmitter or conveyed from the aerial to the receiver by means of a special feeder system of concentric copper tubes, the outer one of which is earthed, and so arranged that the length of feeder to each individual aerial element is electrically the same, which ensures that the currents in all the aerial wires are in phase.

(3) Fig. 4 shows the interior of Bodmin station, with the four panel Canadian transmitter on the left, and the South African transmitter which is similar on the right. The station precision wavemeters are on a bench in the centre. The rectifiers and the smoothing circuits for the H.T. D.C. supply to the valves are in another part of the building.

The Marconi Beam Transmitter.

The circuits of the transmitter are shown in Fig. 5.

Stability of wavelength is obtained in the first place by a control circuit, and in the second place by the extreme care taken in the construction of the set. The drive, or master oscillator which maintains the intermediate and main oscillatory circuits on its own frequency, is carefully screened from the other circuits except at the point where it is weakly coupled to the next stage known as No. 3 Magnifier. This is in part an amplifying circuit, and in part a stabilising circuit which by acting as a buffer between the drive and power circuits proper, helps to maintain the constancy of the drive wavelength when keying.

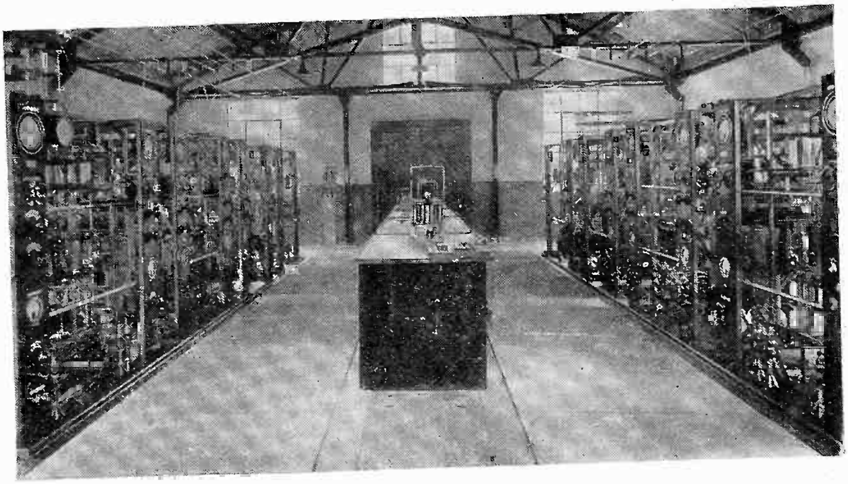


FIG. 4.

As in the case of the drive, the No. 3 Magnifier is carefully screened except at the point where it couples to the next stage known as No. 2 Magnifier, which in turn is coupled to the grid circuits of No. 1 Magnifier, the main power oscillator of the transmitter in which oil-cooled valves are employed.

The four panels of the transmitter comprise :—

No. 1 Panel.—The No. 1 Magnifier.

No. 2 Panel.—No. 2 and No. 3 Magnifiers and the Drive for the first optional wavelength.

No. 3 Panel.—No. 2 and No. 3 Magnifiers and the Drive for the second optional wavelength.

No. 4 Panel.—The main and sub-absorbing and keying circuits, which, by means of two oil-cooled valves in parallel, divert the H.T. supply through resistances during the spacing periods, and so keep a constant load on the generators.

When changing over from the day to the night wave therefore, Panel No. 1 is readjusted, Panel No. 2 is cut out, Panel No. 3 is switched in, and Panel No. 4 continues as before.

Time will not allow me to describe the transmitter circuit in more detail.

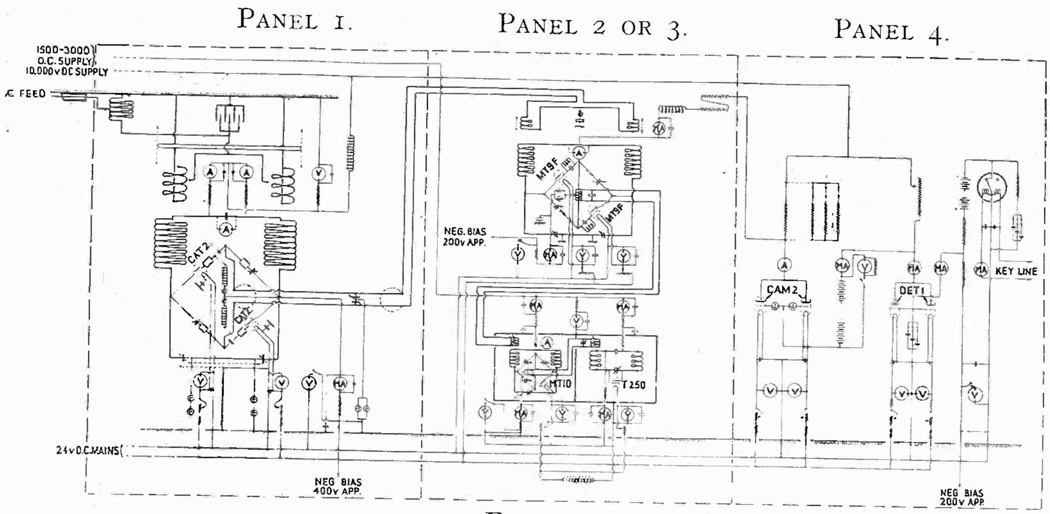


FIG. 5.

The Marconi Beam Receiver.

The receiver consists of a number of carefully screened stages mounted in a rack as shown in Fig. 6.

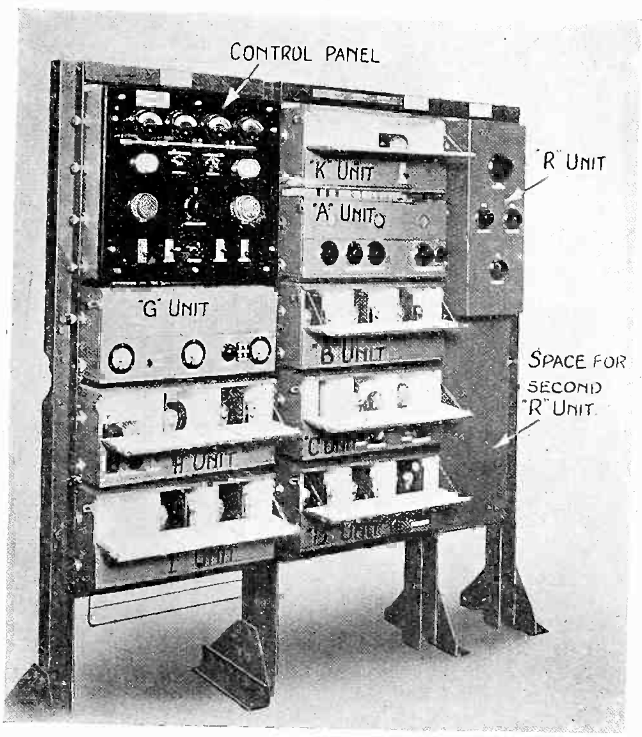


FIG. 6.

In addition to the switchboard, there are nine boxed units, the function of which, following the lettering on the photograph is as follows :—

R. Feeder Terminal Unit.
A. Intermediate Tuning Unit and First Heterodyne.
B. H.F. Amplifier and Filter Unit.
C. First Rectifier.
D. L.F. Amplifier and Filter Unit.
I. L.F. Amplifier and Filter Unit.
H. Second Rectifier.
G. Limiting Unit.
K. Modulating Unit.

The whole chain of operations from feeder to recorder is shown perhaps in a better general way in Fig. 7.

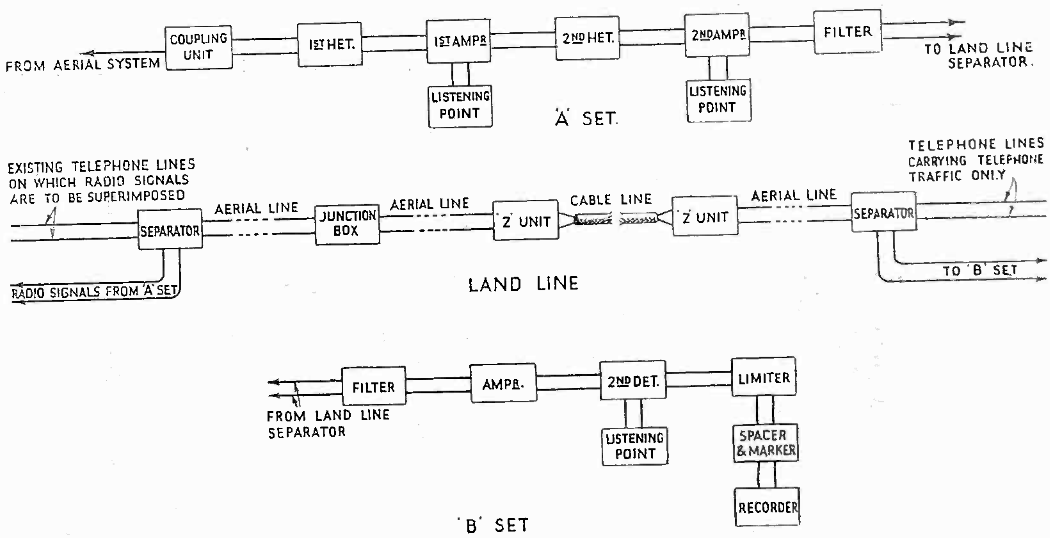


FIG. 7.

This indicates the progress of the signal through the various stages of the " A " set apparatus at the receiving station, whence it is put on to the air-line, then possibly through buried cable to the " B " set apparatus at the Central Telegraph Office where it makes its final appearance on the recorder tape.

(The actual circuits are shown in THE MARCONI REVIEW, No. 4, on page 26.)

The feeder connection is made at the " R " unit which according to the wave-length received may either be a simple tuning circuit, or a tuned valve circuit to magnify the input signals.

The " A " unit includes an intermediate tuning circuit and first stage heterodyne which produces a beat wave of about 1,600 m.

The signal then enters the " B " unit which includes a 3-stage amplifier and filter which gives uniform amplification over a frequency band of 5,000 cycles.

The "C" unit contains the first rectifier, the second heterodyne which converts the signals to a wavelength of 10,000 metres.

The "D" unit is a second amplifying filtering unit for the 10,000 m. signal, limiting the band width to 3,000 cycles.

There are two further amplifying and filtering stages in the "I" box, and the "H" box contains the final push-pull rectifiers and second "listening" circuit.

The "G" unit comprises a limiting valve and two valves for operating the recorder.

The "K" unit contains a modulating valve and circuits to allow the H.F. oscillations generated by the first heterodyne to be modulated at 1,200 cycles, so that the operator can listen in at the first stage of the receiver.

Bridgwater Receiving Station.

In the view of the receiver room at the Bridgwater Beam station, Fig. 8.

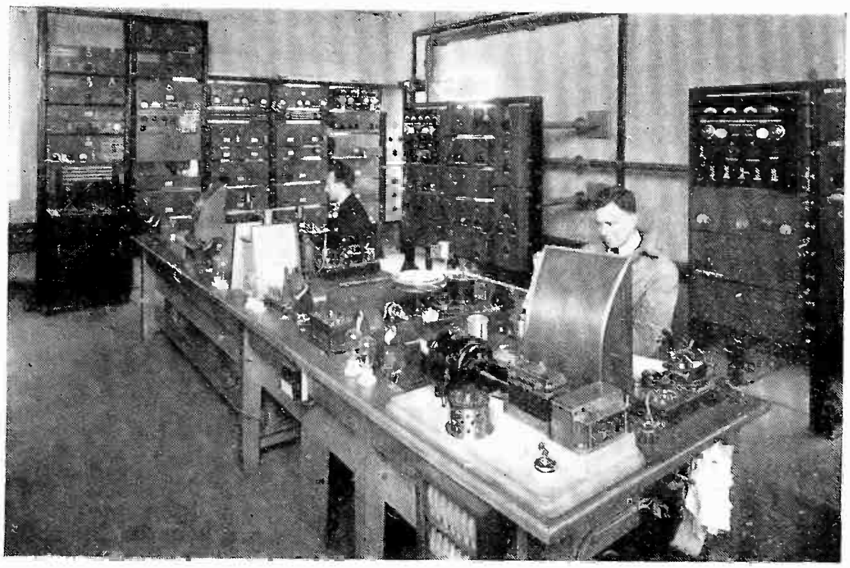


Fig. 8.

the two receivers for the Canadian and South African services occupy the middle of the picture, and in front of them are the undulators of the monitoring circuits with line apparatus to enable the operators on watch to communicate with the Central Telegraph Office or the Transmitting Station at will.

The Multiplex apparatus is in the rack on the left. This is not yet part of the standard equipment, but is at present receiving all the beam telegraph traffic from Canada in place of the usual receiver, and its second channel is employed for beam telephony tests as and when required.

The third channel is used for telegraph traffic when necessary

Propagation Characteristics.

It may be as well now to discuss briefly the conditions of propagation which exist in the communicating medium between the wireless transmitting and receiving stations, and which periodically alter according to whether the great circle path through the two stations is in daylight, twilight or darkness, or is in a combination of all three states.

A careful systematic study extending over a considerable period has been carried out by the Marconi Research Department at Chelmsford on the strength of signals received from a large number of stations at various distances and on various wavelengths, during the day and during the night, and on the basis of these observations, the signal strength attenuation curves shown in Fig. 6, for all daylight propagation have been prepared.

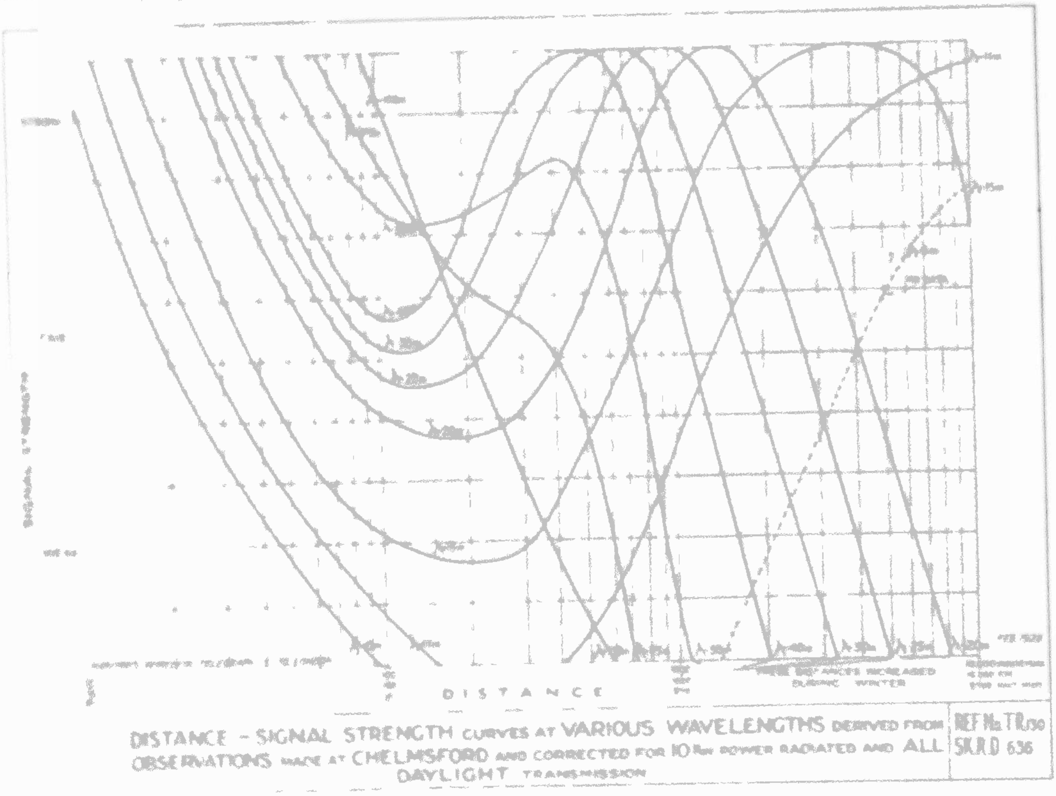


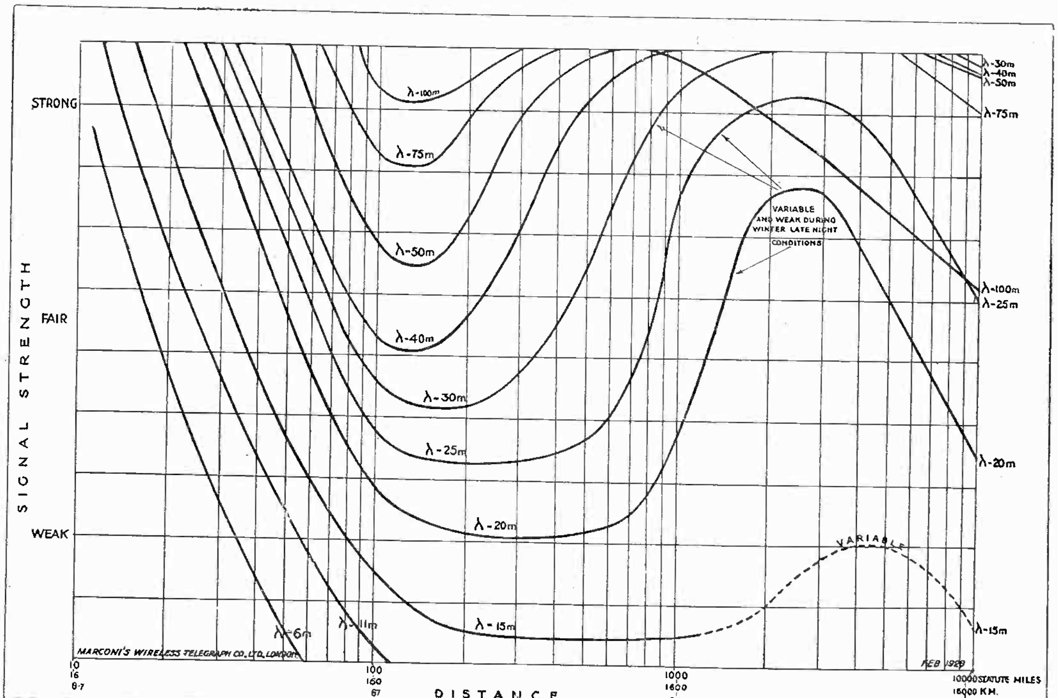
Fig. 6.

It will be seen that on all wavelengths within the range 15 to 100 m., the signals fall off in strength up to 100 miles, but below 60 m. there is a recovery of signal strength with increase of distance, the extent of the recovery being greater the shorter the wavelength used, 15 metres for instance producing a strong signal at 9,000 or even 10,000 miles during daylight.

The accepted explanation of these effects is that at distances within a 100 miles or so of the transmitter, propagation depends mainly on the direct rays which leave the aerial at low angles, the energy from which is soon absorbed, whereas at great distances, the received energy is obtained from the radiation leaving the transmitting aerial at higher angles which enters the Heaviside layer and travels along it with minimum absorption and is finally bent down earthwards again, the actual angle incident to the ground at which the rays reach the receiving aerial being about 15°.

The signal strength attenuation curves compiled from the records for all night propagation conditions are shown in Fig. 10.

It will be seen that 15 m. is a bad night wave for long distance, and that in general there is improved working up to 30 m. with some falling off in range again above that value.



DISTANCE-SIGNAL STRENGTH CURVES AT VARIOUS WAVELENGTHS DERIVED FROM OBSERVATIONS MADE AT CHELMSFORD AND CORRECTED FOR 10 KW POWER RADIATED, AND ALL DARKNESS TRANSMISSION | REF. No. T.R.130 SK.R.D. 635

FIG. 10.

Now these two sets of curves are just average propagation characteristics for daylight and darkness. There are, in addition, seasonal changes to be allowed for, and different parts of the earth at the same distance from the transmitter show local differences in signal strengths received, which can only be definitely determined by actual tests between the stations concerned. How these effects are likely to influence communications is indicated in the following charts.

Beam Station reception characteristics.

The first one, Fig. 11, shows the mean signal intensities for 24 hours for the 34 metre wavelength used on the Cape Town—Bodmin circuit as measured at

Chelmsford. The three curves give the different values for summer, the equinoctial periods, and winter.

It will be seen that this wavelength is no good for transmission from 8 a.m. G.M.T. to 8 p.m. G.M.T.

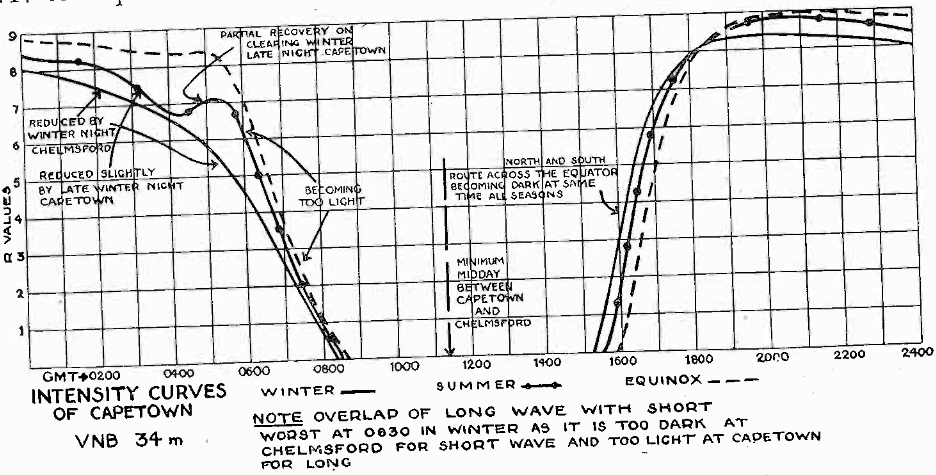


FIG. 11.

A day wave of 16 m. is therefore used which allows traffic to be sent during the whole of what would otherwise be a blank period, and by this arrangement, the circuit is able to provide a 24 hours service.

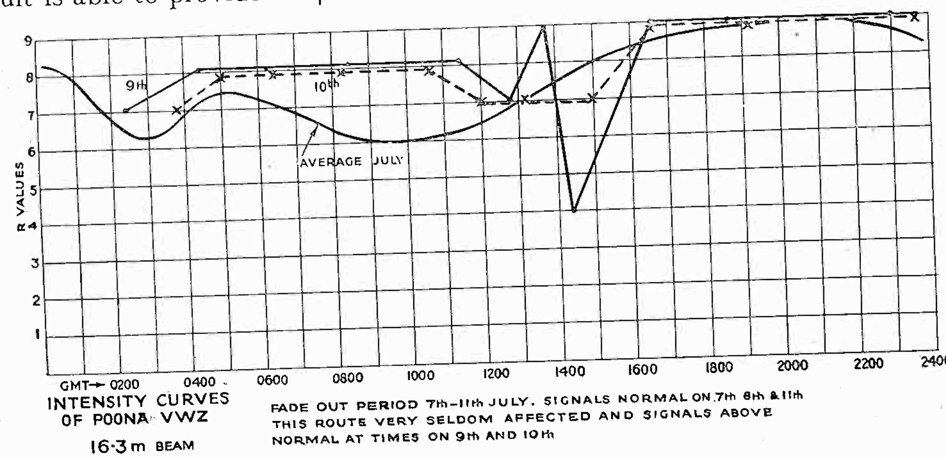


FIG. 12.

I can show you a 16 m. record taken on another circuit, the incoming beam signals from Poona, India, Fig. 12. This chart first of all shows the average signal strengths for the 24 hours during the month of July, and it will be seen that from 8 a.m. to 8 p.m. G.M.T. the signal strength was quite good enough for commercial working. But there are other points of special interest peculiar to the Indian beam service which are brought out by this record.

You are aware that during periods of great sunspot activity, pronounced fade-out of signals may sometimes be experienced on Short Wave circuits.

The Indian beam service is remarkably free from serious perturbations of this character.

One such fade-out period occurred from the 7th to the 11th July, 1928, yet during that time as stated on the chart, signals were normal on the 7th, 8th and 11th, and on the 9th and 10th the signal strength curves show that communication was at no time interrupted, and the worst period lasted only a couple of hours.

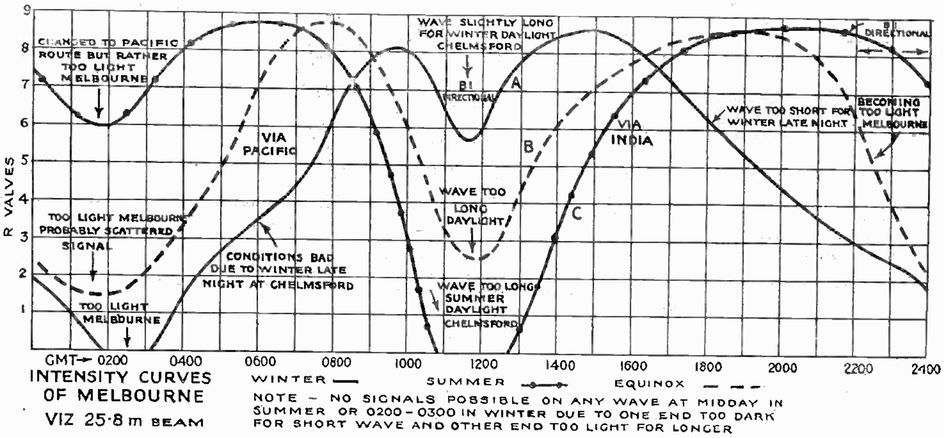


FIG. 13.

Signal strength values measured on the Melbourne beam are shown in Fig. 13. This chart is of particular interest because the circuit is worked for the whole 24 hours on one wavelength. The reason for changing the wavelength as you know, is because the propagation conditions alter. But at the antipodes, the propagation characteristics for the first twelve hours of the 24 can be kept approximately the same for the second twelve hours by reversing the direction of the beam, and this is what is done. Aerials are fitted in front and at the back of the beam reflector. For twelve hours or thereabouts, traffic is sent to this country via the Pacific, and when signals commence to fall off, a change-over of aerials takes place, and traffic then reaches this country with increased strength via India.

Traffic Speed Charts.

All the wireless apparatus in the Beam stations is capable of working at 300 words per minute if necessary.

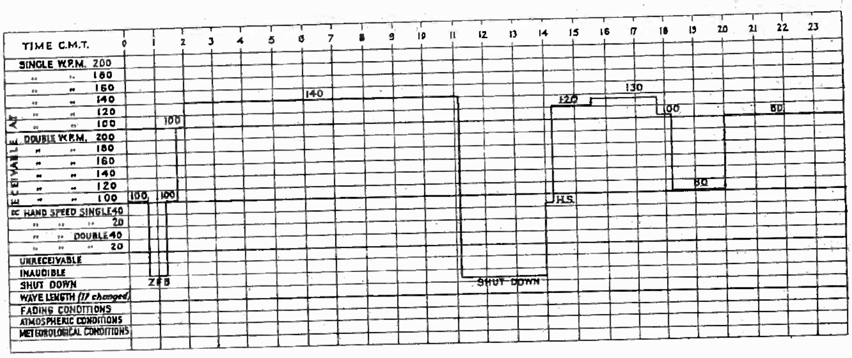
In practice, the reception conditions are indicated in a general way by the traffic speed charts which are compiled for each service. These charts give the number of words per minute at which traffic is received during the 24 hours, with remarks on operating conditions. The speed and number of working hours are of course affected by the amount of traffic on hand, but on the beam services there is always sufficient traffic offered to keep the circuit busy for 24 hours.

Taking the results obtained on the Indian beam service as typical, Fig. 14 shows the traffic conditions on one day in July this year at Dhond, India, receiving from

Grimsby. The service was working on 16 m. wavelength for 20 hours out of the 24, during nine hours of which traffic was received at 140 words per minute, and for various periods at lower speeds down to 80 words per minute.

Traffic the other way is indicated in Fig. 15, which shows the traffic conditions at Skegness for a day in July this year, also on one of the 16 metre waves.

LOG OF RECEPTION CONDITIONS AT DHOND, INDIA, FROM GRIMSBY GBI. *7th July,* 1929.



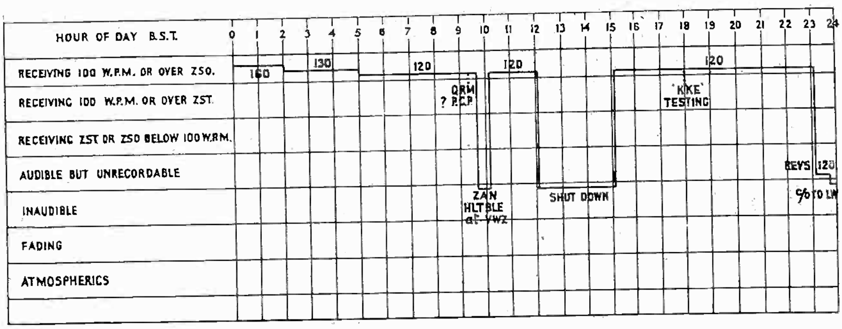
Wavelengths 16·216 m. and 34·168 m.

FIG. 14.

The stations were in communication some 20 hours, the maximum speed was 160 words per minute falling to 120 words per minute. There was a change-over to the 34 m. wave at midnight.

From the speeds of working at the times of shut-down and starting-up again, it is clear that if necessary on these two days, the stations could have been passing traffic for twenty-three out of the twenty-four hours, and such conditions are normal on the Indian beam service.

LOG OF RECEPTION CONDITIONS AT SKEGNESS, ENGLAND, FROM KIRKEE, INDIA VWZ. *14th July,* 1929.



Wavelengths 16·286 m. and 34·483 m.

FIG. 15.

Transmitting Station Routine.

The routine at the transmitting stations is to start up the plant and keep it going.

Two monitoring undulators, one on the line from the Central Telegraph Office, the other on a pick-up circuit from the transmitter, indicate the quality of signals passed into and out of the transmitter on to the aerials.

When no messages are being sent, a reversal slip is used on the Central Telegraph Office Wheatstone, to keep the line occupied, and the distant station advised that the circuit is still alive and likely to send traffic at any time.

The change of wavelength is usually done after advice has been received from the other end that signals are failing. If this advice is not given, there is usually a programme time when the change-over is effected.

It may take half-an-hour to effect a change of wavelength, and this is carried out when possible at both terminal stations at the same time. If one station changes over while the other is still sending traffic, as sometimes happens, the first station is sending blind with no means of knowing, until the other station starts up again, whether its messages have been properly received, and this is undesirable.

Receiving Station Routine.

The receiving stations at Bridgwater and Skegness are the actual control points of the four Empire Beam services.

A continuous monitoring watch is maintained on both the incoming and outgoing signals, and according to the conditions prevailing, the receiving station advises the Central Telegraph Office when to change the operating speed, the route, or the wavelength.

Communication by one route or on one wavelength is continued until signals one way or the other fail, when the route or wavelength is changed, and in practice, it is difficult to start the traffic service, incoming or outgoing, until fairly good touch each way has been re-established.

In the case of Australia and Canada, as these stations are in wireless communication with each other, by utilising the station with which London is in communication, it is possible to advise the other as to the possibility of reception, etc., or to use any of the three to pass advice to the other, an arrangement which has been used.

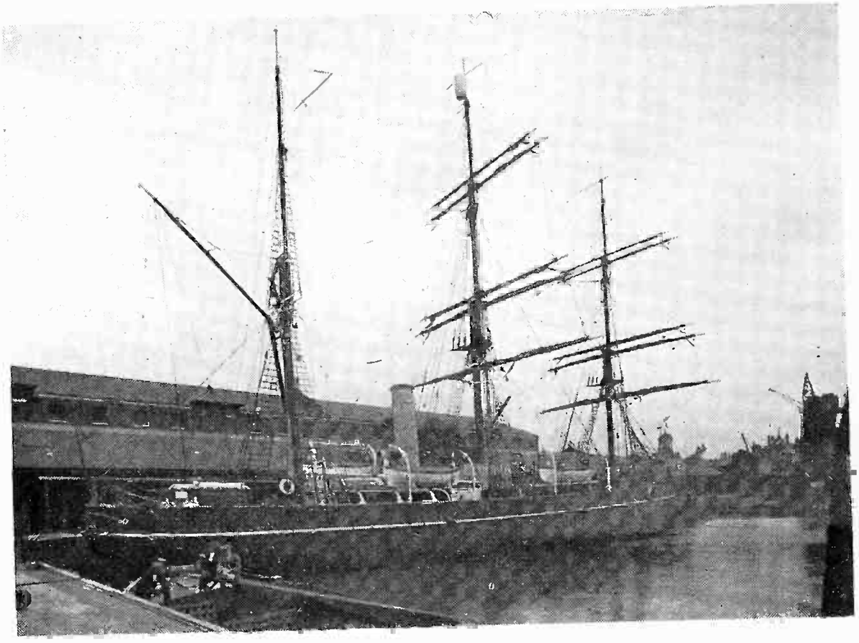
In the event of the beam stations having been out of touch with each other during the period proceeding the anticipated time of change of wavelength or route, the change is made at the normal time and communication established on the new route or on the new wavelength.

(*To be continued.*)

MARCONI NEWS AND NOTES

WIRELESS FOR ANTARCTIC EXPLORATION

THE barque "Discovery," which is now on its way to the Far South for a new voyage of Antarctic exploration, is equipped with Marconi wireless apparatus that will enable it to maintain constant communication.



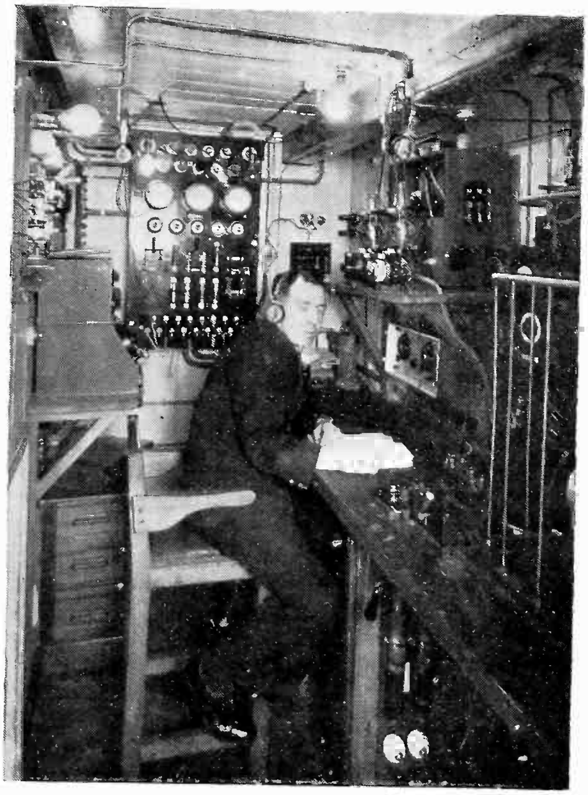
The "Discovery."

The expedition, which is under the leadership of Sir Douglas Mawson, the famous Australian explorer, has been specially equipped for scientific and survey work in the Antarctic to the South of Australia, and the comprehensive wireless equipment of the "Discovery" will play an important part in keeping the party closely in touch with the scientific world.

For ordinary ship-to-ship and ship-to-shore communication, a Marconi 1½ kilowatt Quenched Spark transmitter and a ship's receiver of the latest pattern are installed. For special messages from the heart of the Antarctic, many hundreds of miles from the nearest point of civilisation, a Marconi short wave telegraph transmitter is to be used for communication with Australia and Great Britain. In conjunction with this transmitter a new Marconi short wave receiver is fitted, so that the explorers will be able to "listen-in" to civilisation.

Direction Finder for Navigation.

A Marconi wireless direction finder also forms part of the navigation equipment. The direction finder has already proved of great value in Arctic and Antarctic navigation, and is widely used by whalers and other vessels engaged in the Far Northern and Southern Seas.



Wireless Cabin of "Discovery," showing Marconi Direction Finder, Short Wave Transmitter and Receiver, and Quenched Spark Installation.

The Moth aeroplane to be carried by the expedition is also being equipped with Marconi apparatus. The aeroplane is to be used for scouting purposes within a range of 100 miles of the "Discovery," and it is being fitted with the new Marconi transmitting and receiving set for light aeroplanes, specially adapted for Morse working. During his scouting expeditions the pilot of the aeroplane will thus be able to keep in touch with the base ship, which, by means of its Marconi Direction Finder, will at the same time be able to locate the direction of the aeroplane. In case of a forced landing, an emergency aerial can be rigged on the aeroplane and the generator normally driven by airscrew can be operated by hand. With the power thus supplied, a special automatic code sender will enable messages to be sent from the aeroplane to the ship.

Wireless Men's Accuracy.

A well-deserved tribute to the accuracy and efficiency of wireless operators on Atlantic liners is contained in the annual report of the Director of the Meteorological Office. He says that, although all messages relating to weather are sent in figure code, and frequently during the busiest traffic periods, 4,476 reports, each consisting of eight groups of five figures were transmitted during the year, only two mistakes in every 1,000 figures were made.