TELEVISION
Today and Tomorrow

by

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Foreword

TELEVISION!

Euphonious word, embodying within its syllables all, and exactly, the meaning of the ancient words from which it derived. Distance vision—physical and spiritual—epitomizing the unleashed imagination of the seers of old, the fantastic hopes of uninformed minds, who, ignoring natural laws, would create realities from nothing, the objective from sheer subjective.

Alluring will-o'-the-wisp—for the past fifty years it has led cloistered physicist, struggling inventor, endowed engineer steadily toward a miraculous goal.

To see from a distance details that defy telescopic vision; to have sight through barriers, to recreate in the home, in a million homes, not merely messages and music for the ear, but actual scenes as they transpire miles beyond the horizon, across continents.

To summon the apparition of loved ones far removed; to bring into one's room an athletic field, a race track, a ship sailing a far sea; in fireside comfort to meet and hear the nation's leaders as they counsel, instruct, and inspire; to annihilate space and separation, to enrich the home lives of modern millions through the medium of the mightiest miracle which science has ever yet conceived ——

This is Television!

One: Purpose of This Book

PRIMARILY, this book is for the lay reader. But, in this forty-first year of the twentieth century, thanks largely to the interest in things scientific which radio has awakened in the American mind, the average intelligent citizen is able to understand, and should have an interest in understanding, such matters of science and technology as television is made of.

When I was a boy one of my greatest delights on a half holiday was to visit the old school library, there to read in simple works on science—the Encyclopedia of Mechanics, even the Patent Office Gazette—chapters explaining laws of natural philosophy or intriguing experiments in physics; concerning ingenious inventions of almost any nature.

Especially inspiring were chapters describing the early efforts of scientists to unlock Nature's secrets; the lives and works of Faraday, Helmholtz, James Watt, Trumbull, Samuel F. B. Morse, and above all, young Thomas A. Edison.

From the lives and struggles of such pioneers, blazing the far frontiers of unfolding science, I derived inspiration, and a zeal to follow their courageous footsteps; an ambition to emulate, a resolute determination to let no thing or no obstacle stand in the way of similar achievement.

When, years later, I emerged from the university, equipped with an assorted fund of useful knowledge of more or less useless theory, my first care was again to haunt a library of science in Chicago, where I was at work; to scan everything I could find therein relative to the new science or art of wireless, then just beginning, in which I had determined to cast my life's lot.

It was not easy to do this, night after night. But there were no movies to lure one away; no radio to soothe the mind into unthinking indolence. I was too poor to attend the theatre, although I was most happy to set aside one night a week to listen to great music.

But the knowledge I sought lay scattered through fugitive brochures, and in technical journals, mostly foreign. Hard searching work was needed to find what I was after; hidden suggestions, blind clues, a sentence here, or a paragraph. Of inspiration in such reading there was little, of personal encouragement to further search, almost none.

Today, another great fascinating enterprise is beginning, and with these recollections in mind I propose this volume; that it shall not be too involved in thought nor too technical in expression, and yet shall be informative and clear. It is designed to provide an outline of the nature and scope of Television.

Such a book I believe will prove helpful, useful, save time and avoid perplexity for those who, even as forty years ago when I so eagerly followed the call of wireless, now turn inquiring minds to this new entity, promising another revolution in science and invention.

To the young—men and women, boys and girls—who intelligently are interested in the modern miracles amid which they live, have a desire to learn how scientist, inventor, and engineer have brought into actuality the most alluring, improbable vision ever conceived; to those who cleverly are curious regarding the texture of this wonder, soon to be commonplace, this volume is directed and dedicated.

Two: What Is Television?

TECHNICALLY, television consists of these three processes:

1. At the transmitter, analysis of scene or picture into a sequence of tiny elements of various light values; translation of these elements, one after another, into electrical impulses of corresponding values, and amplifying these tiny electrical impulses millions of times.

2. Transmission of the sequence of impulses in some manner, by wire or radio, to a distant receiver.

3. At the receiver, these now attenuated or weakened electrical picture-element impulses are absorbed, in like sequential order. Then they are again amplified millions of times, after which they are translated back into corresponding light elements, which are spread over the surface of a screen, in the same order and location as in the original picture. Finally, we view the integrated effect upon the screen.

Memory plays a vital part in television. At the transmitter there is physical "memory" or retentivity in the light-sensitive surfaces of the television camera, over which the fine pointing finger of the pick-up electron beam sweeps swiftly. At the receiver, physical "memory" is implanted in the fluorescent surface to retain the picture elements "painted" there by the invisible cathode beam, which sweeps back and forth with such incredible lightning speed. All this adds to the physiological memory of the retina of the human eye, which views separately each picture element as laid upon the screen, but retains them until all the elements appear to the eye as a complete, integrated picture, a reproduction of the distant original.

So much for the cathode beam system. But in modern mechanical systems physical "memory" also is used to retain for a brief time (in the form of density changes in supersonic waves in oil) the shifting record of a picture's electrical counterparts. The effect is to briefly "fix" upon a screen the beams of light which are swiftly pencilling the picture thereupon.

Thus is memory, or retentivity of light, an essential element in making possible television.

Three: History of Television

AT THE beginning of the seventeenth century a Dutchman, holding up two spectacle lenses, noticed accidentally that through them a weathercock in the distance appeared unusually large. Thus was born the idea of the telescope, and also of that incessant attempt to see distant objects as if near at hand. And from this has resulted the amazing method of seeing at a distance called television, now first coming to life as a commercial means of communication.

After the advent of the telegraph, or long-distance transmission of electrical signals by wires, the idea of sending whole images by means of these electrical impulses was conceived. Crude but ingenious, the first methods consisted of dividing a picture into small black squares of varying size, just as a modern newspaper picture is divided by screening.

The experimenters transmitted by wire telegraph the small picture elements, one by one, in the form of letters of the Morse alphabet. Each letter represented a different sized square, enabling the operator at the receiver to draw in the squares in their proper positions, the whole reproducing the picture sent from the transmitter. These images, necessarily, were very rough representations of the original objects.

Later workers avoided the human element. They made electricity itself control the movements of the pencil across the paper. Drawings traced with shellac on tinfoil proved successful only in sending over the wires the currents necessary to trace the picture. Line drawings, shaded by varying the width of the line, were transmitted by using a beam of light on a sensitive film, and controlled by a shutter regulated by signals from the transmitter. All these ideas had their day and were discarded.

But in men's minds persisted the dream of seeing distant objects in motion, at the moment they were transmitted, without waiting for the objects to be drawn on paper.

A magic element, selenium, later provided the key to the mysteries of light transmission by electricity. This element was first isolated by a Swedish professor, Jons Jacob Berzelius, in 1817. Not until more than a half-century later, however, was it known that this simple metal had unusual properties.

In a little terminal station for the Atlantic cable on the coast of Ireland in 1873, a telegraph operator named May was puzzled by the peculiar behavior of some selenium resistances with which he was working. For some unknown reason the current in the resistances varied, although he made no change in the circuit.

Investigating this phenomenon, May chanced to notice that, as the sun shone at intervals through the window on his apparatus, the moment more light fell upon the selenium the current increased. Thus, May accidentally discovered the unique property of selenium, by which it can vary the passage of a current through it as the light varies, and thus began a whole series of investigations from which emerged the present-day system of transmission of light by electrical signals.

The telephone, first electric carrier of the voice, was modelled, as far as the diaphragm was concerned, upon the construction of the human ear. Reasoning logically from this imitation of nature, Ayrton and Perry, in 1880, concluded that an electrical system of sight could be assembled, using the human eye as a model.

A study of the anatomy of the eye showed that a scene is focussed by its lens on the sensitive plate called the retina. The retina is composed of thousands of tiny light-sensitive cells, each connected with the brain by a separate nerve fiber, so that each small part of the scene observed is carried to the brain separately and there re-assembled into a composite picture.

Carey in Boston, and Ayrton and Perry in England proposed to build a large mechanical eye, using a plate of selenium cells as the sensitive retina. From each of these tiny cells led an electric wire, or nerve, to a corresponding spot on the receiver, or brain. As the image was to be focussed by the lens on the selenium plate, each separate wire was to carry its own electrical impulse, depending upon the amount of light shining upon its original selenium cell.

Magnets connected to each of the small sections of the receiver plate were to regulate the amount of light upon each section, according to the electrical current carried to it by its individual wire, and thus the identical composition of light and shade would be crudely built up at the receiver plate. Although made up of tiny spots of different light intensity, when viewed at a distance the eye would detect only the total effect, creating an intelligible picture.

This crowded mass of connecting wires, however, made the machine clumsy and cumbersome; impracticable for communication over great distances.

As long ago as 1884 a German scientist, Paul Nipkow,* built a television machine. He made practical use of May's early discovery by combining the light-sensitive selenium cell with a new device of his own design which he called a "scanning disk." As indicated by its name, this disk "scanned", or looked over the object to be transmitted, and sent the resulting dissected image over a wire to the receiver.

The disk used by Nipkow was perforated near its circumference with a single spiral of small holes, each hole a little nearer the center of the disk than the preceding one. When the disk was placed between a lamp and an object, then slowly rotated, the light shone through one hole at a time. Thus was produced a moving spot of light over the person or object to be televised.

The spiral of holes was arranged so that when the disk was rotated the first spot of light travelled across the top of the object. As this spot passed off at the

* Deceased, December, 1940.

right, the next spot appeared at the left of the scene, just below the path followed by the first spot. Each succeeding spot moved just below the one before it, and the last spot covered the base of the scene pictured.

When the disk had turned once, every small element of the object had been illuminated in turn by the narrow beam of light from the lamp.

As the scanning disk was turned faster and faster, the moving spot covered the image more rapidly, until the spot appeared as a series of lines across the scene. Because of the characteristic of sight known as "persistence of vision," the eye is unable to distinguish between individual stimuli unless separated by a certain length of time.

Thus, as the successive appearances of the spot become more rapid, they appeared to merge and take the form of a series of lines covering the object from top to bottom.

Even more rapid revolutions of the disk caused the lines themselves to merge, until the whole scene appeared to be illuminated by a continuous square of light.

Passing through the holes in the scanning disk and striking the object to be televised, the light next encountered a selenium cell. Each small element of the picture was to be received there separately, and because of the ability of selenium to vary an electric current with varying light stimulation, a stream of current variations was to be sent along the single wire to the receiver. Each current variation represented the shade of light intensity of a single element of the scene.

At the receiver, the sequence of current impulses, following each other one by one, was to be directed into a neon lamp, which was to vary in brightness according to the current flowing through it from the transmitting mechanism. Another scanning disk, identical with the first one, whirled in front of the neon lamp at exactly the same speed as the one at the transmitter.

Thus, for each hole in the disk and for each spot on the receiving screen, the lamp was to emit an amount of light corresponding to the same spot on the object. With the disk spinning so rapidly that the spots and lines became squares of light, the receiving screen was to be illuminated by a succession of light squares, one for each rotation of the scanning disk. If the transmitted object were moving the effect would be that of a moving picture, each rotation corresponding to one picture frame in a motion picture film, and an identical moving image of the original object was to be reproduced on the receiving screen.

But Nipkow's invention, brilliant and basic though it was, lacking the all-essential Audion amplifier, was doomed for forty years to remain merely an idea, clever but inoperative.

When it was first proposed to send pictures by means of the scanning disk, radio waves were unknown. Wires were the only carriers for the electrical signals, and the possibility of sending moving pictures through the air over distances of many miles was beyond even the most powerful imaginations. But Nipkow, with his perforated disk, forecast one phase of the limitless future of the wireless waves which were even then knocking on the doors of scientific discovery.

A different form of light on the receiver screen was used by a Russian professor, Boris Rosing, in his television tube patented in 1907. Instead of a beam of light from an electric lamp, he proposed to shoot a stream of minute electric bullets, called electrons, at a screen coated with a fluorescent material.

The electrons were to bombard the screen with a force depending upon the current received from the transmitter, and to follow the corresponding path across the picture as did the light beam through the scanning disk, which he proposed to use at the transmitter.

The fluorescent screen glowed with an intensity depending upon the force of the electron stream at its point of contact, producing the same intensity of light or shade as in the original scene. Since the electrons covered the screen in such a short time, it would be impossible to distinguish individual lines, or frames of the image, and a complete glowing, moving image would appear on the screen.

Rosing's electron apparatus was enclosed in an evacuated glass tube, originally invented by Crookes and developed and improved by Braun, Wehnelt, and Ryan, and called a "cathode ray" tube, because the beam of electrons was emitted from an electrical cathode within the tube. But here again, as was the case with the scanning disk at the receiver, through lack of the essential amplifier the entire scheme remained a physicist's dream, a vision of accomplishment to come.

For the next twenty years or so, television met a wall of obstacles, surmounted only with infinite difficulty. The action of selenium in indicating shades of light was much too sluggish, even for a coarse picture, and the effect on the receiving screen was so faint as to be practically useless. The necessity of wires for the transfer of signals from one place to another was another barrier to long distance or wide-spread television.

Waves which would travel of their own accord through space, unaided by wires or any other mechanical means of transportation, were observed and explained by Hertz in 1888. These miraculous Hertzian waves, which reduced time and space virtually to zero, were gradually harnessed for the use of wireless telegraphy, later radio, and finally for television broadcasting, by far the most intricate load yet carried by these electrical vibrations through the ether.

The fatal difficulty of insufficiently powerful reactions was overcome by a little three-electrode tube invented by the writer in 1906, and called by him the "audion." This revolutionary device, used as an amplifier, strengthened by astronomical ratios the ears of radio and the eyes of television, and made possible the clear reception over great distances which we have today.

A man of great imagination and foresight, A. A. Campbell Swinton, in 1911 saw the possibilities of television communication with variations of Rosing's cathode ray tube at both the transmitter and the receiver. The past few years have shown that Swinton actually predicted television apparatus as it is used today. Little progress was made with his suggestion, however, until almost twenty years after the idea was conceived.

The first actual television transmission was achieved in 1925, almost simultaneously, by an Englishman and an American. J. L. Baird in England, and C. F. Jenkins in America, in that year demonstrated wireless television silhouettes, or "shadowgraphs." The following year Baird succeeded in producing the first half-tone effect, or light and shade, in his television images, and demonstrated his new toy before the members of the Royal Institution. At about the same time, Baird and Jenkins both managed to project moving pictures on their receiving screens, and Jenkins invited several government officials to view the blurred but unmistakably real images which he was broadcasting from his transmitter.

Television was used commercially for the first time in 1926, when the William Morris Agency put an act on Broadway with the transmitter on one side of the stage and the receiver on the other. Even at that short distance, the image was poor, compared with the definition of modern television.

On April 7, 1927, Secretary of Commerce Herbert Hoover sat before a screen in Washington, D. C., and talked over a wire circuit to Walter S. Gifford, president of the American Telephone and Telegraph Company, at the Bell Telephone laboratories in New York. An audience in New York heard Secretary Hoover's voice and plainly saw his image on a screen. Then the New York audience was switched to Whippany, N. J., and the first convincing wireless television demonstration outside of England was there witnessed.

Important events followed rapidly. Outdoor scenes were first televised in 1928, colored pictures were transmitted in 1929, and in 1930 the first two-way television system was inaugurated. In 1938 the first American television drama, "The Queen's Messenger," was presented over WGY in Schenectady, and in 1930 the first television show was held in a theater. The action, originating in the General Electric laboratories, was shown by use of a giant scanning disk on a screen in Proctor's Theater in Schenectady. Up to 1931, pictures were made up of no more than 60 lines, making satisfactory reproduction impossible.

From the time of Jenkins' demonstration, scientists in several parts of this country were devising new methods and improvements. Ernst F. W. Alexanderson, of the General Electric Company, projected the above mentioned television image in 1930 on a six by seven foot theater screen. Herbert E. Ives was the pioneer in outdoor, color, and two-way television. U. A. Sanabria produced television images on a two-foot screen in 1931 and later on a 10-foot screen in public exhibitions in Chicago and New York City.

But meanwhile Jenkins and Baird had awakened active rivalry in Germany. That country's greatest contribution to mechanical television was perhaps the Muller polyfaced mirror drum, or drums, one small and rotating at high speeds to afford the horizontal line sweep, the other larger and slower, for moving the rapidly sweeping light beam more slowly up and down on the screen at the "picture-frame" frequency.

Then there appeared the "mirror screw," a rapidly revolving stack of narrow steel strips, assembled flatwise with polished light-reflecting ends. The picture here was received by looking directly at these mirror faces as they flashed by, each reflecting its own line portion of the picture light rays, picked up by each mirror from its own section of a vertically elongated, gas-filled glow tube, which fluctuated in response to each electric impulse as received from a similar image-scanning device, and photo-cell, at the transmitter.

In these and similar mechanical scanning systems, where mechanical accuracy and resourcefulness must be of the highest order of refinement, the German scientists and engineers clearly surpassed their British and American competitors.

In the initial development of the cathode-beam receiver the German pioneered with characteristic patience and skill, so that from 1930 to 1936 this cathode-beam type of television reception wrought its greatest advances in Germany. In fact, it was the Berlin demonstrations during the early '30's which, more than any other, convinced our own, the British, and French engineers that Television, if ever to be perfected and made acceptable to the public, must develop along the line of the cathode beam, rather than by mechanical systems.

Important work was done by the Dutch engineers, notably those of the Philips Corporation, especially in projection receivers. Concerning the development of the Television camera, or "pick-up" devices, the American, Philo T. Farnsworth, pioneered with his masterly "image dissector" principle. Dr. Vladimir Zworykin, with his disciples, has perfected to an amazing degree the old Campbell Swinton device and has set the pace for the world. In this field the British and German engineers have followed on.

At the height of its development, television is following Campbell Swinton's inspiration, using the cathode-ray tube at both ends of the system. At the transmitter, the image is focussed on a mosaic screen made up of tiny light-sensitive cells. A stream of electrons sweeps the image and each cell sends off an electric current impulse as it is hit by the electrons, the light and shade of the focussed image regulating the amount of current. This string of single electrical impulses, after amplification and transformation into ultra-high frequency currents, is thrown out into the ether, to radiate in all directions, to be picked up by any attuned receiver, where it is retransformed and rewoven into a moving picture in the cathode tube receiver. The transmitting tube, or camera, using the photo-electric mosaic surface, is now commonly known as the "iconoscope," and the receiver as the "kinescope."

From Nipkow's bulky and mechanically rotated scanning disk of 1884, television has evolved to the frictionless, inertialess electron beam of today. In the cathode ray tube there are no mechanically moving parts, the electron stream being guided entirely by electric attraction. From the crude, 60-line pictures of the early sets, we have progressed to the 525-line pictures now being broadcast. And the progress in refinement of picture detail has only begun.

Television has had an interesting and eventful past, but the seed has just begun to germinate, and the extent of its possibilities are beyond our powers of prediction.

Four: Economic Status of Television

COAXIAL CABLE NETWORK COSTS VS. TELEVISION BY FILMS; ATTITUDE OF FILM PRODUCERS REGARDING TELEVISION.

NOWHERE in the history of engineering science can be found another field of industrial endeavor or line of inventive research into which has been poured, through a decade of years, such intensive effort or lavish sums of money with so little of economic return, as that of television.

Hundreds of trained engineers in a score of superbly equipped laboratories, throughout a half dozen foremost nations, have been unstintingly backed by strangely optimistic and persistently courageous financiers, in their efforts to get around that fabled corner where lurks the realization of television.

By this I mean a commercially realistic, economically successful, self-sustaining television art or industry. From the viewpoint of the scientist and engineer, television arrived in England and Germany about 1936. In Europe, where maintenance of the transmitters and sustaining programs are the concern of government, the economic aspects are enormously simplified. They reduce merely to a factor of profit for the manufacturer of the receiver instruments.

The public demand, however, is yet too small to permit or to justify production methods of manufacture to any great extent. This situation is due primarily to three factors: (1) high cost; (2) pictures much too small; (3) mediocre entertainment value of the average television program.

But in America the economic problem must be far more difficult and complex. Here a present investment in inventive research well exceeding ten million dollars, and increasing each week, must be written off, as dedicated to industrial progress. Here the government helps not at all, save to allot and safeguard a few ether channels for "experimental" television. Here the unhappy corporation director must cudgel his brain to devise means for maintaining attractive television programs, nightly, month after month, or for years, while attempting to sell sufficient number of reasonably (perhaps profitless) priced receivers. This he must do to build up reliable audiences numerous enough to interest commercial sponsors in purchasing time on the pictorial air, at figures which finally will sustain the programs; and, eventually, to pay some rate of interest on the staggering, ever-enlarging investment.

Until that welcome day dawns television must "live on borrowed time" on the air. But before that time shall arrive two inexorable and opposing conditions must be satisfied: the received picture must be larger, and the price of the receiver must be smaller. Of the truth of this, I feel certain.

Yet these hard conditions can be met. The problem is by no means hopeless nor terribly difficult. In subsequent chapters the reasons for my statements are explained. The time when these conditions are to be satisfied, I am confident, is not distant. Science and inventive engineering now travel rapidly, with ever-increasing acceleration. Television with profit might be a reality within three years.

In the United States, television research and manufacturing are chiefly in the hands of five organizations: Radio Corporation of America, DuMont-Paramount, Farnsworth, Philco, and the General Electric Company. Each maintains a transmitter in which experimentation continually is carried on. Behind closed doors the problem is attacked from all angles.

Most notable today, from the public's viewpoint, is the RCA-National Broadcasting Company transmitter atop the Empire State Building, New York. There each night, and on certain afternoons, except during periods when alterations are being made, programs are regularly televised, radiated, and picked up satisfactorily in the metropolitan area and within a radius of fifty or more miles.

The Columbia Broadcasting System has installed in the steeple of the Chrysler building another equally elaborate transmitter, also the product of RCA engineering. With this latter in competitive operation, large potential audiences of New Jersey and Long Island, where the steel skeletons of Manhattan throw no obstructing shadows or no ghost reflections, will have the choice of nightly programs from two elaborately equipped television studios.

The tendency has been to wait and see how the New York metropolitan audiences will respond to the programs before other cities begin to equip their transmitters. This reluctance, while understandable, is a regrettable mistake. For in other sections of the country the public response to really entertaining programs may be quite different from that noted around New York. There the theater and cinema-fed populace seems to be more immune than elsewhere to modern magic. Myriads of tiny apartments offer little incentive to city dwellers to stay home evenings. Perhaps these folks are too sophisticated to become television-minded, at least for any less exciting program than a prize fight or a fireside talk by a President.

This disappointing reaction may not be found in centres farther west. Proportionately to population, it would seem that Los Angeles already owns more television receivers than New York City, although the present television program fare scarcely can be called a banquet!

For physical limitations easily understood, each metropolitan district must supply its own television studio and programs. Because, so far as we now know, network distribution of television programs is, and may continue, economically impracticable. Television video frequencies ranging from 60 to 5,000,000 cycles per second cannot be carried over telephone wire networks as are audio-frequency programs. A coaxial cable system will carry high frequencies, but such cables, including the necessary amplifier-relay stations, one of which is needed for each five miles of cable, cost upwards of $5,000 per mile.

A coaxial line from New York to Los Angeles representing about $15,000,000, would require, in interest and upkeep charges alone, far more than television sponsors would consent to pay for program transportation. But they can have all this, meticulously freed from all possible slips, memory lapses by actors, errors by camera men, lighting engineers or sound effect experts, with negligible cost of transportation and in defiance of all time zone differences. How? By the very simple and very sensible method of making television films and sending them from city to city in tin-can containers.

Few television executives, I find, will admit this fact. Mostly they emphasize the view that audiences will not turn on their receivers except for shows believed actually transpiring at that moment; they forget that each night millions flock to see films they well know were enacted days, months or years before, and pay handsomely for the ancient spectacles.

True, when the event is one whose outcome is uncertain—a horse race, ball game or prize fight—the suspense and thrill involved is always keener. But such events, at best, are only occasional. They cannot be had each night, or on demand at convenient viewing hours; they may occur by daylight when few men are at home and women are engaged in housework or cards, their rooms undarkened. Television, demanding concentrated attention and semi-darkness, is primarily suited to evening enjoyment.

And when it comes to entertainment: drama, vaudeville, even a lecture, who would not rather see a good play, flawlessly presented by skilled, properly trained actors, more or less renowned, than a piece being actually and badly (even if simultaneously), acted? Better, a thousand times, a good television motion picture than a bad stage act.

The motion picture can go to a thousand places inaccessible to the delicate television camera, with its heavy amplifier, transmitter and power-supply truck, to say nothing of the time element involved, nor that the scene to be televised is frequently a thousand miles from any audience.

Films will be vastly more necessary to commercial television than is the disk transcription to radio today. It will be found absolutely indispensable and invaluable, both from technical and economic considerations.

The film affords the television studio all the subtleties of today's motion picture technic—laboratory inserts; cut-backs, difficult camera shots, silent and process shots, with later sound dubbed in; a thousand tricks, theatrical and technical, which would be extremely difficult, or impossible to control in the television studio, to say nothing of the simplification in the problems of motion-picture lighting.

Today, notwithstanding the amazing progress in sensitizing the iconoscope surface, television studio lighting requirements still exceed those demanded for ordinary motion picture film.

When the scene to be televised is first reduced to film, the light required is less, and consequently is far less unpleasant and fatiguing upon the actors. For the later actual televising of that scene, through any of the new film projectors designed for the television transmitter, a far greater amount of light can be cast upon the mosaic surface of the iconoscope pick-up camera than the actors could tolerate. Hence, both in the shooting of the scene and its televising for transmission, the motion picture film offers tremendous technical advantages that should not be ignored.

And more important than any other consideration is the perfectly obvious fact that a television subject once reduced to perfected prints can be sent all over the world at negligible expense and broadcast wherever and whenever it is desired.

High-salaried actors, first filmed, may scatter, disband, fall ill, or go on a strike, but that perfected little act can be televised again and again.

Most emphatically the motion picture art will save television from the fate of the music box and the peewee golf game. It alone will enable this infant art, here in America, to survive these depression epochs and pay its own way in a hard-boiled, realistic world.

And what will television do, in grateful recompense, for the motion picture? In some ways it will aid the older, kindred art. Any development which will produce new writers having new and different problems to solve, or create new viewpoints, must aid the picture producer. New actors must be found and trained. The film producer will scout for and hire many a television "find," and vice versa, contracts permitting.

Television is certain to make the public even more picture-conscious than it now is. Incidentally, I can visualize such picture magazines as *Life* and *Look*, or effective new rivals thereof, spreading their startling stills upon a million screens, accompanied with engaging, entertaining or educational comment. Possibly this increase in picture-mindedness may serve to whet the appetite for more of the cinema screen.

The motion picture producer will be able to flash each week into the home a few teaser scenes from the latest film pictures, whetting the curiosity of the televiewer to see that picture tomorrow night. This, and many another advertiser's message, can be put over far more effectually and with more showmanship on the screen than by voice alone. Inoffensive ways will be found, and followed.

The insatiable demand for more and more films for televising will keep studios tremendously busy. Such demands may be seasonable, as in all studios at present, but it should help fill in the dull gaps of studio inactivity. Very probably the present producers will not take kindly to such new market demands for their product, even if specifically made for television and not so well suited for the cinema screen.

Indications are already pronounced that the "No Sale" sign will soon be up at most studio gates. There is precedent aplenty for such non-cooperation. The fear that television in the home will hold multitudes from the box-offices already prompts declarations that "none of their films can be bought or leased," no matter if out-dated and long ago vault-interred.

But I venture to say that some millions of feet of these retired films will yet go hurtling through the atmosphere. There lurks a possible new market for what the film producers heretofore have considered worth only the silver upon the celluloid. Once these capable tycoons realize that television is going to succeed, and will demand new millions of feet of films per year, they will not perpetually be blind to a profit, after one leader has succumbed to that lure.

In the past, motion picture magnates generally have not been easy to convince that they should risk an investment in an experiment, especially if that experiment seems to threaten their preserves. I should know this. For did I not besiege their doors from 1923 to 1926 while demonstrations of the Phonofilm were held daily in several theaters on Broadway, and scattered over the country? "The public doesn't want talkies; our technic and our artists are all against talking pictures. Many can't speak understandable English anyway. It's a novelty, nothing else." Such was the far-visioning encouragement I received!

So the upsetting revolution of their industry, finally precipitated by the instant success of Warner Brothers' "The Jazz Singer," caught them unawares, cost them hundreds of millions and earned them other hundreds of millions of dollars.

It was the same with radio and the phonograph industry in the '20's. Johnson, of Victor, simply could not see the finger writing on the etheric wall, or rather was deaf to the voices in the air. Finally he was forced to knock down "His Master's Voice" to the newly-fledged radio giant.

Thus, today it is not surprising if the movie magnates slant skeptical and hostile eyes towards television. With the exception of Paramount, they seem to have learned nothing from the lessons of 1926. Here Balaban and Zukor, hearkening to the preachment of the Morris Agency that television will be the mass entertainment of the future, have purchased an interest in the Allen B. DuMont enterprise.

"We're doing this by way of taking out an insurance policy," explains Balaban, who, I remember, with Sam Katz, showed unusual and encouraging interest in the Phonofilm in 1925. According to their present opinion, this new art eventually may displace the talking picture, as the talkies wiped out the silent film.

I can foresee no such complete calamity as this. The larger de luxe city theaters, with their "super production" pictures and stage shows, will always continue to draw large audiences. The human gregarious instinct will prevail.

But it would appear highly probable that in our suburban districts adequate television screen entertainment, nightly within the home, will withhold many thousands from the box offices of the smaller cinemas. This will mean definitely lessened demand for film from the present studio laboratories. It may entail the closing of hundreds of profitless theaters.

But, against this loss to such producer owners and their employees, will ensue a large new market for productions and films designed wholly for television audiences. In the succeeding chapter I shall consider further the statistics of film of Hollywood manufacture for nation-wide broadcasting in television.

Of one fact, however, we may reasonably be certain: The effect of television upon motion picture production and exhibition will be far-reaching and profound.

Five: Projection Tubes

SYSTEMS AND OPERATION DESCRIBED; HIGH-VOLTAGES REQUIRED.

A LARGE amount of theory, undoubtedly prompted by wishful thinking, is devoted to the contention that the present sizes of cathode ray pictures are adequate, optimal, or similar intellect-offending balderdash. For example, one German engineer argues at length to prove that the viewing of pictures larger than 8 by 10 inches is distinctly harmful!

"A picture which subtends a certain solid angle at the eye has the same appearance and entertainment value regardless of its size, within wide limits." One might as logically contend that it is as pleasing to view a toy church, as to survey the massive cathedral from which the miniature is modelled.

The eyes must be focussed upon the picture. If the picture is small, this means constant nervous eye strain, to refocus as the head is moved relative to that screen. Furthermore, to concentrate the eyes upon a brilliant small picture is markedly fatiguing to the retina. This effect increases notably as the picture dimensions are diminished. For physiological considerations alone, any dazzling effects must be avoided. A wholly engineering analysis of optimal picture size is so definitely inadequate as to become amusing.

The larger the picture, relative definition and light values remaining the same, the more satisfactory and pleasing it becomes, within reasonable limits. This statement is a truism, easily proved.

Before television really can arrive in the home—in millions of homes—we must learn "how to get the genie out of the bottle." The original image within the cathode tube must be sufficiently brilliant, and of so fine a texture or detail, as to permit its enlarged projection upon a flat screen of the order of four square feet in area (two feet square).

Serious efforts have been made, notably in England, Germany, and Holland, to project the cathode-beam image upon a screen. The original, most simple method, was to apply a very high voltage to the cathode beam, thus impelling the electrons at terrific velocity against the fluorescent surface. The resultant brilliant image was projected through a large lens upon a screen.

Before aggressive research was directed toward the development of the projection tube, engineers became fairly well convinced as to the impracticability of constructing cathode-beam tubes large enough to permit adequate sized screens directly upon their ends.

Inasmuch as the atmospheric pressure upon the highly exhausted tube is approximately 15 pounds per square inch, a limiting area is soon reached. For example, the pressure upon the end of an evacuated tube only 18 inches in diameter approximates two tons, a large load for a flattened dome of thin glass to withstand.

Even with cathode-beam tubes of considerable smaller diameters, a collapse or implosion is not at all infrequent. It is common practice thus to protect the viewer by the insertion of a plate of safety glass in front of the large end of the tube.

An 18-inch tube permits a rectangular picture area of less than 11 by 15 inches. In one attempt to procure an adequately sized picture for direct viewing, a 31-inch demountable tube, four and one-half feet long, has been constructed of arcwelded steel. Its end supported an air pressure of approximately five tons. The viewing end was of convexed pyrex glass two inches thick.

This tube was rendered gas tight by rubber gaskets between the glass and the metal flanges. Exhaustion of such a structure to one millionth of a millimeter of mercury required two days, and re-exhaustions were frequently necessary. The fluorescent screen was deposited upon a flat glass plate mounted to the tube wall. With such a tube, a potential of 10,000 volts on the second anode produced a picture having a brightness of 40 candles per square foot, and to secure this brilliance a beam current of six milliamperes was required. It is needless to emphasize that such means for producing large cathode-beam pictures, especially for the home, are utterly fantastic.

Projection tubes, however, offer some real encouragement, but only the fluorescent type is yet available. The required voltages range from 10,000 to 65,000. These high voltage tube circuits demand especial protection. The fluorescent material is bombarded essentially to its saturation point. Satisfactory life of such surfaces offers severe problems; yet claims are made of 2,000 hours of operation. The cathode "gun," in such tubes, must be most carefully designed and constructed in order to produce a minute screen spot, because the screen area itself may now be as small as 1½ by 2 inches.

It is better engineering to use larger areas even though this requires larger and more costly projection lenses. Light emission of the screen increases both with beam current and voltage, but in the interest of keeping the spot small (limiting effulgence), it is more satisfactory to increase the voltage. An average beam-current density of a few microamperes may represent amperes over a square centimeter. The ratio of light output to beam voltage varies with the screen material, or "phosphor," employed, up to the saturation point. For Willemite (it emits a pale greenish light) the output increases as the square of the applied voltage applied.

For calcium tungstate, or a fused layer of Willemite, this exponent is slightly greater than 2. The saturation-limiting voltage depends upon the layer depth of the particular "phosphor" employed; the thicker the coating the higher the permissible voltage.

Efforts of projection-tube engineers have been aimed mostly at large theater screens where box-office receipts thus far have constituted almost the total source of television's earnings. A few projection tubes have been installed in cabinets for home viewing. Ensuing years will see intensified effort along these lines, but before general public acceptance can be expected in America, the picture must be larger and the prices of equipment cut at least in half.

Two detailed examples of theater-screen television installations will be informative. The Baird projection system, installed for many weeks in several London cinemas, utilized an image 3.2 x 4 inches, a cathode spot less than 0.004 inches in diameter, and a beam current of one milliampere, produced by 40,000 volts on the final anode. The picture was projected by an exceptionally fast (f:1.4) lens upon a screen 12 x 15 feet in size.

Two complete projector units were installed, maintained continuously in operation, but only one image was projected at any time, the lens being arranged to be slipped into position before either tube as desired. A single high-voltage rectifier was provided, capable of supplying 10 milliamperes at 60,000 volts. The total electrical consumption was two kilowatts. All the equipment except the projector tube was located below the theater auditorium. The two long projector tubes and lens were placed in a safety cabinet in the center aisle of the theaters.

Quite similar results were obtained in theater installations by the Scophony mechanico-optical receiver system. Here the light beam from a high-intensity arc was projected through a highly ingenious super-sonic light valve (invention of J. W. Jeffree) which stores up in liquid form picture element images, projecting as many as fifty or more of them simultaneously along a single scanning line upon the screen.

An efficient split-focus optical system projects this complex beam of modulated light upon a screen 10 by 12 feet in size, placed about 20 feet in front of the projector, located on the stage behind the screen. The projector has a wide diffusing angle and is claimed to involve only a small loss of light. For such rear projection purposes a special sprayed acetate film screen made for motion-picture process shots by the Flat Screen Company, of Hollywood, has demonstrated astonishing efficiency.

Both Baird and Scophony cinema television pictures have been demonstrated in New York, and have received favorable public response. At London screen reproductions of such sporting events as the Derby and prize-fights, the SRO (standing room only) signs were at theater doors, day after day, despite fancy box-office prices.

With fluorescent screens deposited on glass, second or final anode voltages as high as 45,000 are practicable, but require special phosphors to endure the bombardment. Adequate secondary emission and electrical conductivity are requisite to carry away the excessive beam currents.

Phosphor-coated metal sheets used as screens permit anode voltages as high as 80,000 volts or more. Such construction introduces new problems, among them, electron optics for the "keystone" scanning thus required. But such screens are required when more than 50 watts beam power is used, and air or water cooling of the screen is necessary. The luminous efficiency of the screen material falls rapidly as voltages are increased; for example, five candles per watt with 6,000 volts, two candles with 20,000 volts, and only two candle-power with 40,000 volts. Still higher voltages increase the surface brightness, even with loss in efficiency. Furthermore, it permits better focussing of the cathode beam.

Both Baird and Scophony in England, as well as Phillips in Holland, have built relatively small projection tube television receivers for home installation.

For such tubes the following specifications are typical: 10,000 volts on the last anode, electron cathode current, 1 milliampere; beam current at the screen, 0.4 milliampere. The difference represents electron losses by diffusion and secondary radiation. As screen phosphor, zinc orthosilicate, of carefully controlled crystalline structure is used, and a scanning spot of .005 inches diameter. The screen picture within the tube is 1½ x 2 inches. The brightness of this small screen is measured at 280 candles per square inch. A f:1.5 lens enlarges this picture to a 18 x 24 inch rear-projection screen, having a brightness of 0.6 candles per square foot, a rather low value compared to that of the average 16 millimetre film home projector.

In one projection tube receiver a 14 x 16-inch picture required 15,000 volts. Magnetic deflection of the beam was employed, and a 2,000-hour tube life guaranteed. In such receivers the screen is customarily a part of the cabinet.

The trend in projection tubes, for major exhibition purposes, is toward higher anode voltages, even up to 50,000 volts, and beyond. In a demonstration of large-screen television in a theater in Europe, a 16-inch-diameter projection tube was used in which the 6-inch-wide picture was produced on a separate flat screen. The beam constants were 45,000 volts and 300 to 400 micro-amperes, with a stated normal screen power of 18 watts.

A projection lens of the highest available speed and a focal length of 14 inches was used to project a picture no less than 12 x 15 feet in size with an illumination of 10 lux. (This would be approximately 1 foot-candle on the screen and perhaps a screen brightness of 0.25 candles per square foot, which is decidedly below the motion-picture-theater screen-brightness range.)

A typical projection tube home receiver is that marketed by Phillips Lamps, Ltd., of London. Here the projected picture is reflected from a mirror in the lid of the cabinet on to a flat etched glass screen, the etched surface being protected from dust and dirt by enclosures between two sheets of glass. Considerable light is lost because of the number of glass sheets involved. The projection screen automatically rises into its correct position when the cabinet lid is lifted. A 25,000-volt supply operates the four-inch diameter projection tube.

Completely screened magnetically, the tube is mounted with the projection lens in gimbals to facilitate optical centering of the picture on the projection screen. Beam-focussing and deflection in horizontal and vertical directions are accomplished entirely by electromagnetic means, rather than electro-static.

The 25,000-volt supply (a "delightful" thing to have in one's parlor!) is obtained from a voltage-doubling rectifier unit. A gas discharge tube connected across the supply of the first anode of the cathode-beam tube prevents an excessive voltage from developing.

The video intermediate frequency, at 13.2 megacycles, is amplified by four stages using a single sideband system. Automatic volume control circuits are included.

Safety relay circuits are connected across the line and the frame deflection coils of the cathode tube. Should either of the scanning deflection means fail, from any cause, the tube which produces the deflection impulses will operate a relay in its anode circuit, cutting off the power to the high voltage transformer. This prevents damage by the cathode beam of the fluorescent screen.

In addition to television reception, normal broadcast reception is afforded by a high-fidelity all-wave receiving unit. Twin speakers are used in the cabinet. For this beautifully designed, intricately engineered job, the price is about $1,200.

I have here given rather complete details to afford the reader a fairly comprehensive conception of the vast amount of highly skilled, intensive engineering research required in developing cathode-beam television.

Too much high praise cannot be awarded to the brilliant and painstaking men by whose untiring efforts, through the past ten years, this new wonder art has been achieved. Likewise, all praise to the amazing courage of financiers, corporation directors, and investors who have had benefit of back-scene observation of the terrific difficulties encountered by the technical staffs, and who have continued to pour, year after year, unlimited funds into this venture.

Six: The General Television System

SOME of the technical chapters of this book may appear too involved for the average reader. For such, therefore, I shall attempt here to condense briefly the subject in such a manner that it can be more readily understood.

As pointed out at the beginning, television is the transmission of moving images either by wire or radio. It is of course today essential to transmit sound along with the picture in order to give complete entertainment. The modern television receiver, therefore, reproduces the sound as well as the images.

The television system as a whole can be resolved into three parts:

(a) Transformation of the moving picture into a sequence of varying electrical currents which represent the variations in brightness of the image as we dissect it line by line from top to bottom.

(b) Transmission through space of these varying electrical currents by means of a radio transmitter, and intercepting them in a receiver, very similar to the ordinary radio receiver. As far as the sound part of the transmission is concerned, it is exactly the same.

(c) Transformation by the receiver of the electrical currents back into a moving image thrown upon the viewing screen.

In television the moving image may be considered an infinite number of very small points or dots, each one having its own degree of brightness or darkness, which are continually varying from time to time. An ordinary radio system such as is used for sound would be capable of transmitting the variations in brilliance of only one such point of the picture, and could reproduce it by means of a neon light. The complete picture, therefore, would require an immense number of separate radio transmitters and receivers, which would of course be quite impractical.

The televisionist, however, avoids this by transmitting the picture dot by dot, spreading these in their proper position upon the viewing screen, and depends upon the persistence of vision of the eye to make the picture seem continuous. It is of course necessary that the analysis of the picture point by point at the transmitter be exactly reproduced in the same sequence at the receiver. Finally the whole process must be repeated so many times a second as to make the picture appear continuous.

In other words, the process can be analyzed as follows:

(1) Scanning the image to be transmitted.

(2) Translating the varying brightness of the picture elements into corresponding electrical currents.

(3) Generation of synchronizing signals to keep the scanning device at the receiver in exact step with the scanning device at the transmitter.

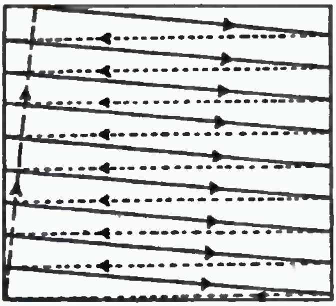
(4) Transmitting of the electrical currents by radio.

(5) Separating the synchronizing signals from the picture signals so that these do not mar the picture, and then causing the synchronizing signals to control a scanning light beam in the receiver.

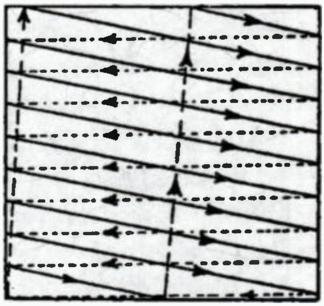
(6) Modulating this scanning light beam by the picture signal and thereby recreating the original moving image.

In the popular and standardized cathode beam television system now in use in America, the scanning process, both at transmitter and receiver, consists of causing an electron beam to travel across the picture area in a definite manner, while it picks up the picture point by point at the transmitter and recreates the picture at the receiver. The electron beam in the cathode beam camera, called the "Iconoscope," is caused to travel across the picture by two "sweep" circuits, one for the horizontal, and the other for the vertical sweep. The rate of travel along the horizontal line is much more rapid than that in the vertical direction. The cathode beam, having a definite width, or cross section, traverses the picture in a series of steps or lines as shown in Fig. 1.

The number of lines per picture will determine the amount of detail that can be transmitted, but obviously the diameter of the scanning beam can be but little wider than the distance between two adjacent lines, or we will have a *lack* of definition as we increase the number of horizontal lines, due to overlapping. The frequency of the vertical sweep of the cathode beam is called the "frame frequency" and determines



Progressive Scanning
FIG. 1



Interlaced Scanning
FIG. 2

the number of pictures per second, and thus the amount of flicker to the eye. In 1931 a 60-line picture was considered standard, and 24 picture frames per second, whereas today 525 lines is the temporary standard, with 30 pictures, or 30 frames per second. Already this number of lines is proving inadequate, and such organizations as the Du Mont and Philco Companies have advocated as many as 625, and even 800 lines, to the picture.

The accepted shape, or "aspect" of the picture is the same as that of the motion picture screen; the height is ¾ of the width of the picture.

It has cleverly been found that the amount of flicker can be reduced without increasing the total number of lines per second by causing the cathode beam to trace at first only the odd lines of the picture—1, 3, 5, 7, etc., and on the second scanning trace the even lines, 2, 4, 6, etc. This method is now called "interlaced scanning." This very ingenious and helpful idea originated with U. A. Sanabria in the days of the scanning disk. Sanabria styled this method "offset scanning."

By this process of interlaced scanning, therefore, the picture requires two vertical trips of the scanning beam from top to bottom for each complete picture frame. This type is shown in Fig. 2 on Page 57. Sanabria showed that it was possible to skip two or even three lines each time, which would require three or even more vertical sweeps to cover the picture. This method is advocated by some today.

So we see there is now a distinction between picture frequency, or frame frequency, and field frequency. By field frequency is meant the frequency of the vertical sweep oscillator, which may be two or more times the picture frequency. The RMA* standard picture frequency is 30, the field frequency 60, giving us interlaced scanning. The vertical-sweep oscillator therefore which controls the movement of the cathode beam up and down has a frequency of 60 cycles per second. The

* Radio Manufacturers Association.

horizontal frequency is therefore 30 x 441, or 13,230 per second (15,750 for 525 lines).

Today at the television transmitter, the "video" signal is generated by a camera tube enclosing a cathode ray or beam. This camera tube has been chiefly developed in this country by RCA and Farnsworth. The

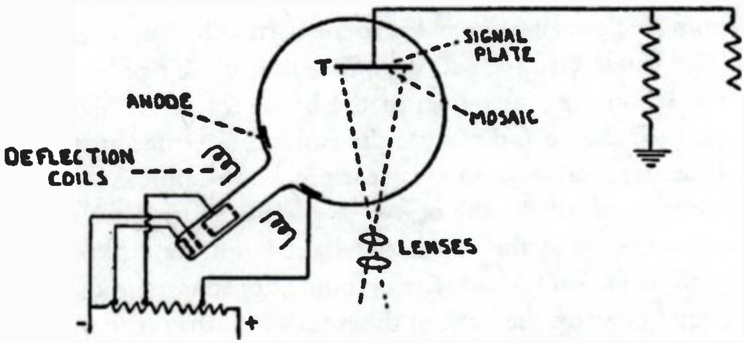


FIG. 3

former device is called the "Iconoscope," and its recent improved type, the "Orthocron." The Farnsworth camera is called an "Image Dissector." We will briefly describe here the operation of the Iconoscope. See Fig. 3.

The picture to be transmitted is focussed through a good camera lens upon the flat target, T. This latter consists of a perfect piece of mica covered by a "mosaic" of photo-sensitive material consisting of tiny globules of a silver compound made sensitive to light. Each globule is in reality a small photo cell and is insulated from its neighbors. On the back of the mica sheet is deposited a thin metallic coating which is called the signal plate. A wire leads from this plate to the grid of the first amplifier tube, and through a grid leak to the chassis of the amplifier.

When the image to be televised is projected on the mosaic target each of the photo-sensitive units will emit electrons in proportion to the light falling upon it. The anode electrode surrounding the tubular part of the Iconoscope, as shown in the figure, carries a high positive charge and attracts the emitted electrons away from the mosaic. In this way each mosaic globule is left charged positively, the degree of positive charge being proportional to the amount of light falling upon that globule at that instant. Each globule, together with the signal plate on the back of the mica sheet, thus forms a condenser, which is charged in proportion to the light falling upon it, and also proportionate to the time during which the light ray rested upon the globule.

The Iconoscope cathode-beam camera contains, like any cathode-beam tube, an "electron gun," the function of which is to project a beam of electrons upon the target. This beam is made to "scan" the target, line by line, from the top to the bottom, with the odd and even lines interlaced as described above. When this electron beam passes over the individual globules, each of which has been charged more or less positively by the light rays falling thereon, the electrons (merely units of negative electricity), by neutralizing the positive charges on the globules, enable the other plate of the condenser (the metallic plate on the back of the mica target) to discharge.

This discharge, or series of tiny discharges, rapidly following one after the other, flows through the grid leak of the first amplifier tube. It constitutes the video signal. So we see that the discharged current from this condenser represents at any time the amount of light which has fallen upon that particular tiny, microscopic photocell unit since it was last discharged. This system, which can be called the "light-storage" system, obviously is a great improvement over the scanning disk containing small holes arranged in a spiral, because, with the Iconoscope, we "save up" the charge due to all the light falling upon any picture element. This occurs during the time the cathode beam is traversing the remaining parts of the picture on the target.

After each horizontal line and after each vertical frame of the picture, the electron beam travels back to its original position; to the left hand side of the picture or to the upper left hand corner. The back sweep is made at a greatly increased speed. Notwitstanding this speed, the beam's path, nevertheless would produce a signal and mar the received picture. Therefore, at the end of each line and at the end of each frame a "blanking signal" is created to erase this effect from the Iconoscope during the return sweep, and sends out an impulse corresponding to black. Remember that in the American system of cathode beam television we use the "negative" signal system. In other words, the perfectly white portions of the picture send out no signal, but the darker portions send out one, the strength of it increasing with the degree of blackness of the part of the picture over which the cathode beam is travelling. Fig. 4 illustrates the signal in its various stages of formation in the Iconoscope and the radio transmitter.

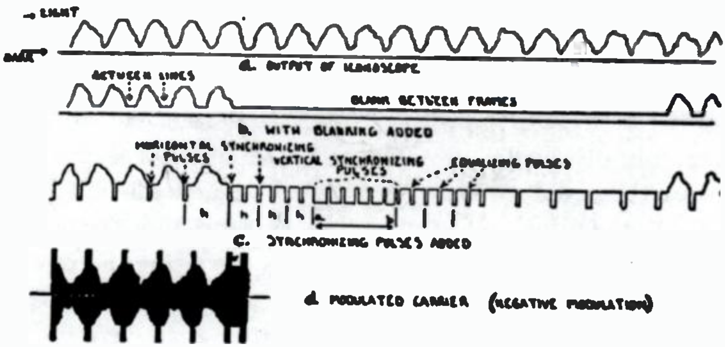


FIG. 4

In Fig. 4a the signal is shown as it leaves the Iconoscope. Fig. 4b shows the signal with the blanking periods inserted. It is necessary to send synchronizing signals along with the picture signals in order to keep the scanning oscillators at the receiver in step with the scanning oscillator at the transmitter. But the only period in which this can be done without mutilating the picture is the blanking period, therefore synchronizing signals appear at the end of each line and at the end of each frame.

These synchronizing signals are stronger than any signal representing the blackest part of the picture. Therefore the synchronizing signals represent "blacker than black," and are so-called. They do not interfere with the action of the cathode beam receiver, because all they can do to the cathode beam is to cut it off a little more (during that period) than is required to make the picture dark.

The horizontal synchronizing pulses consist of rectangular shaped waves sent out at the end of each line of the picture. But at the end of each picture frame these horizontal pulses last longer than after the other lines of the picture. Six of these longer pulses together constitute the vertical synchronizing signal.

You may be wondering how it is arranged that alternate vertical sweeps of the picture cover first the odd numbered lines, while the next vertical sweep traverses the even numbered lines. This effect has been very cleverly and simply obtained by causing the cathode beam to start its vertical trace at the *end* of the bottom line after one frame of the picture, and at the *middle* of the bottom line of the next frame. This results in a little complication in the synchronizing signals but the matter is simplified by the "equalizing pulses." Thus during the vertical synchronizing pulse, which consists of 6 of the longer horizontal pulses, for 3 lines before it and 3 lines after it there is a horizontal synchronizing pulse twice for each line. This is shown in Fig. 4c. This extra pulse, occurring half way along the bottom horizontal line does no harm to the horizontal sweep signal, but it does permit the vertical synchronizing pulse to start at the end of a half line as and when this is required. All of this complication of horizontal and vertical signal pulses is taken care of by rather complicated circuit arrangements at the television transmitter, but the receiver circuits are not complicated thereby.

At the receiving end the synchronizing pulses are filtered out from the combined signal, so that the picture signals traverse one circuit path while the horizontal and vertical synchronizing pulses traverse another circuit. In this latter circuit the horizontal and vertical pulses are separated from each other by circuits which discriminate against wave shape. The synchronizing pulses are then ready to be applied to the respective horizontal and vertical "sweep oscillators," keeping these oscillators in perfect step with the horizontal and vertical sweep of the cathode beam in the Iconoscope camera at the transmitter.

By this means the cathode beam in the Kinescope at the receiver is made to follow with utmost fidelity the sweep of the cathode beam, as it generates the picture signal in the Iconoscope at the transmitter.

At the transmitter, the picture signal must now modulate the radio carrier wave continually radiated from the transmitter antenna. As stated above, "negative modulation" of this carrier is now the American standard. This means that maximum carrier signals represent dark parts of the picture, and minimum carrier signals represent light parts. Thus, Fig. 4d (Page 62) shows the carrier modulated both by the high amplitude synchronizing signals and by the lower amplitude picture signals.

This negative modulation might produce, at the receiver, pictures which would appear similar to those of a photographic negative; in other words, the dark parts of the image would appear light, and the light parts appear dark in the reproduced picture. The received picture, however, can be reversed simply by the addition of one video stage in the amplifier. Thereby, what otherwise would be a negative picture is inverted and made positive, as it should be.

At the receiver the picture signal passes first through a radio frequency amplifier, then through a superheterodyne tuner, again is amplified through the video amplifier, and finally is applied to the grid of the cathode beam picture tube. Meanwhile the two synchronizing signals have been segregated, or filtered out, and are utilized to maintain the cathode beam sweeping back and forth, and up and down, always in its proper position over the picture screen at the end of the cathode beam tube.

Assuming that our picture is to be one of 441 lines and that it shall have the same amount of detail along the horizontal lines as it does in the vertical direction, we might divide the picture into small squares, the sides of which are equal to the width of a picture line. Inasmuch as the dimensions of the picture are in the ratio of 4 to 3, we would have 4/3 x 441 x 441 of these tiny squares.* The greatest possible amount of detail of such an arrangement would result when these squares are alternately light and dark. Two such squares therefore, will represent a cycle. We would have therefore 2/3 x 441 x 441 cycles per minute and 30 times this number, or 3,889,620 cycles per second. This is the maximum picture or video frequency. The lowest frequency in which we are really interested can be taken as 60 cycles; therefore the video amplifier must be capable of reproducing without distortion frequencies ranging from 60 to about 4,000,000 cycles.

These difficult conditions require that great skill be used in the design of a video amplifier. Using amplitude modulation (the only type of transmission yet proven practical for the wide bands demanded by television), the side bands would extend 4 megacycles on each side of the carrier, and require 8,000 kilocycles for just one television transmission channel. Moreover, the radio frequency and the intermediate frequency amplifiers of the receiver would then have to be wide enough to pass this enormously wide band.

It is perfectly obvious, therefore, that only in the ultra high frequency regions can we find enough space for such television signals. In consideration of this situation it has been found highly desirable to use single side-band transmission, rather than the double side-band method.

* Actually, this number is only approximately correct, a certain number of lines being omitted for the synchronizing periods, as above explained.

In single side-band transmission the lower side band of frequencies has been partially suppressed at the transmitter, so the receiver circuits employed are designed for a 4 megacycle frequency band. This is illustrated in Fig. 5.

The audio or sound signals accompanying the picture are transmitted on a separate carrier which is

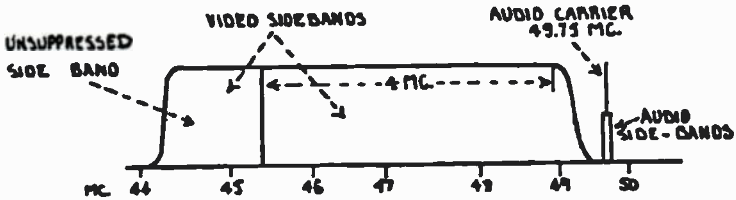


FIG. 5

always 4.5 megacycles higher than the picture carrier frequency. Thus it is easy to design a receiver in which both the picture and the sound circuits are tuned by a single dial, a really great advantage, for then the viewer can tune his receiver by sound for the maximum signal and he also will be correctly tuned to receive the picture. Without this arrangement it would be quite difficult to properly and exactly tune the picture part of the receiver because of the broadness of the picture frequency channel.

The Federal Communications Commission some years ago assigned special wave bands for television service. At the present time all such television service is classified as experimental, although it will not be long before certain stations will be permitted to engage in commercial telecasting, but still confined to the present allotted television frequency channels. You will note by inspection of Fig. 6 that each such channel is 6 m.c. wide, and that picture carrier, side bands and the audio carrier are located within these channels, and always in the same manner. Fig. 6 covers the radio frequency spectrum from 50 to 108 megacycles.

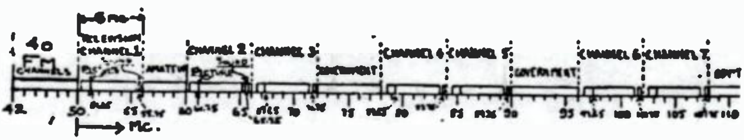


FIG. 6

Details of No. 1 to 7 Television Channels, in megacycles

Television receivers manufactured in the United States today comprise both sight and sound receivers, having different sized pictures ranging all the way from 3 inches to 18 inches and cathode beam tubes from 5 inches to 20 inches in diameter. Some television receivers have been designed to utilize the regular "all-wave radio" set as part of the sound receiver, by means of a converter for the sound part. This is attached to the complete picture receiver. There is one receiver on the market which includes an all-wave set in addition to television.

The block diagram in Fig. 7 on Page 70 shows the various essential parts of a combined television and sound receiver as constructed today. Therein a single

50– 56—	TELEV. 1
56– 60—	AMATEUR
60– 66—	TELEV. 2
66– 72—	TELEV. 3
72– 78—	GOVT.
78– 84—	TELEV. 4
84– 90—	TELEV. 5
90– 96—	GOVT.
96–102—	TELEV. 6
102–108—	TELEV. 7

Regular television channels Nos. 1 to 7, inclusive, interspersed with other services.

ULTRA HIGH-FREQUENCY CHANNEL ALLOTMENTS

162–168—	TELEV. EXPERIMENTAL
168–180—	GOVT.
180–186—	TELEV.
186–192—	TELEV.
192–204—	GOVT.
204–210—	TELEV.
210–216—	TELEV. EXPERIMENTAL
216–224—	GOVT.
224–230—	AMATEUR
230–234—	GOVT.
234–240—	TELEV.
240–246—	TELEV.
246–258—	GOVT.
258–264—	TELEV.
264–270—	TELEV. EXPERIMENTAL
270–282—	GOVT.
282–288—	TELEV.
288–294—	TELEV.

High-frequency television channels, and other service assignments for government, amateur and television experimental work.

radio frequency and superheterodyne mixer section, together with an oscillator, accepts both picture and sound signals. The oscillator causes the picture carrier and the sound carrier to remain 4.5 megacycles apart, as they were at the transmitter. The picture

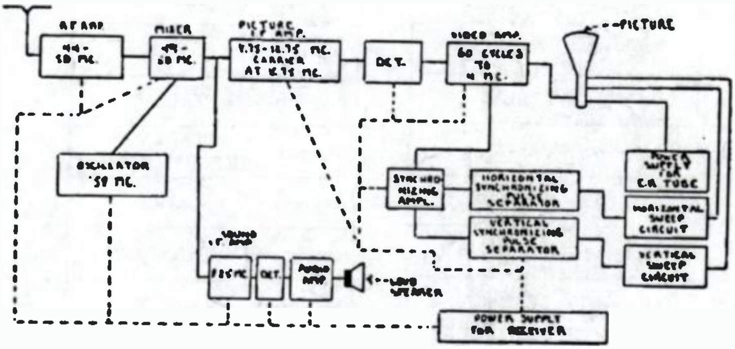


FIG. 7

intermediate frequency is usually 12.75 megacycles, with the single side band extending to 8.75 megacycles. The sound intermediate frequency is 8.25 megacycles.

Fig. 8 illustrates the progress of the video signal as it traverses its part of the receiver circuits. As shown in Fig. 8a, the picture signal as delivered by the detector, corresponds to that shown in Fig. 4c, with the exception that it is here inverted. Fig. 8b shows the signal re-inverted, and with the amplitude of the synchronizing signals somewhat diminished. Fig. 8c shows the synchronizing signal after it has been filtered out from the combined picture-synchronizing signal, leaving only the synchonizing pulses, those at the end of each line of the main part of the picture, and the double frequency synchronizing signals, with first sharp and then broad tops, which bring about the vertical synchronizing pulse.

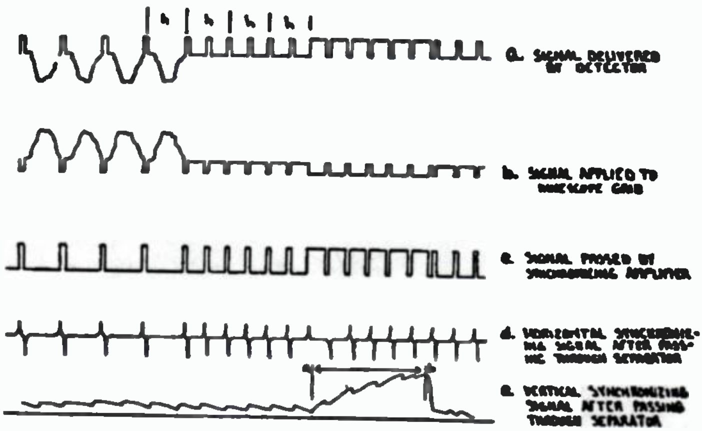


FIG. 8

Fig. 8d shows the horizontal synchronizing signal after passing through the separator circuits. Here the shape of the signal has been materially changed so that each positive peak is immediately followed by a corresponding negative swing. These peak signals are best adapted for "triggering" the horizontal line sweep oscillator.*

* The DuMont 500 kc. vertical synchronizing pulse offers certain genuine advantages over the RMA synchronizing signals here described. (See Chapter Seventeen.)

Fig. 8e shows the vertical synchronizing signal after it has passed through the separator circuits. You will note that between points a and b the signal rises to a high amplitude, which is represented by the charging of a condenser, which at point b suddenly discharges and thereby acts to swing the cathode beam suddenly back from the bottom to the top of the picture screen.

Seven: Cathode Beam Systems

DISCOVERY, ELECTRON OPTICS, ABERRATION; MECHANICS OF DEFLECTION; THE PHOSPHOR.

FROM the discoveries of the Cathode beam by Sir William Crookes, and by Professor Braun, using the fluorescent surface for tracing its path, and the Wehnelt coated cathode, development of the tube has progressed slowly. First an interesting scientific phenomenon, it now is one of the most significant tools in the armentarium of the physicist, communication and industrial engineer.

Rosing, very many years ago, first suggested the cathode beam as a means for tracing upon the fluorescent-coated end of the Braun tube the details of electrically transmitted images in television. Lacking the all-essential three-element amplifier tube, this brilliant suggestion was doomed to remain unrealized for many years.

The electron beam or ray in cathode-beam tubes is a narrow pencil of negatively charged particles or electrons, which, under the influence of heat, exude from the outer surfaces of the hot cathode. For this reason these electrons are sometimes called "thermions." The exact nature of the substance of which the cathode surface is composed determines the number of electrons emitted. A tungsten filament placed within a tiny cylinder, or button, of some ceramic, akin to porcelain, coated with the electron emitting layer, e.g. oxides of calcium, barium, and strontium, or a fine ribbon of nickel with this coating baked directly upon its surface, makes the most efficient type of cathode for use in the cathode-beam tube.

The number of electrons emitted from a unit area (square cm.) of such surface in a unit of time (one second) depends upon its chemical make-up, temperature, and also (up to saturation point) upon the difference in potential between this negatively charged cathode and a positively charged electrode, or anode, located somewhere in the highly evacuated cathode-ray tube.

The velocity with which the electrons travel from cathode to anode also depends upon the voltage applied across the cathode and anode electrodes. The velocity of this electron stream, inasmuch as the electrons are being constantly subjected to this attractive force from the anode, is not constant, but is an accelerated velocity. But in a typical small cathode beam tube where the impressed potential is of the order of 4000 volts, this velocity exceeds 30,000 miles per second. In high voltage tubes this speed may become very comparable with that of light, 186,000 miles per second.

The discovery by J. J. Thompson of the electron, of electron emission, and the development of means for their control (notably by the grid electrode) opened the way to present-day radio broadcasting and communication systems. Similarly the development of means for concentrating electrons into narrow beams and for focusing and controlling the direction and intensity of these beams is responsible for the development of today's high definition television systems.

ELECTRON OPTICS: In the cathode-ray tube electronic method of television scanning for image reconstruction, in the cathode-ray oscillograph for radio servicing and for analyzing electric currents in general, it is important that an intense, small-diameter electron beam be directed on the fluorescent screen. To secure sufficient electrons from the emitter there must be a large cathode surface in the "electron gun," but this naturally gives a beam of large cross section with electrons taking many paths besides those in the desired direction.

By making use of the electronic optics principle of electrostatic focusing, it is possible to bundle these emitted electrons into a small-diameter beam and make them form a small bright spot on the screen. "Electron optics" also plays an important part in the design of regular grid-controlled tubes, making possible such special ones as the beam-amplifier tube.

The underlying principles of electron optics are not difficult to understand. An electron is always attracted to a positively charged electrode, but the path which the electron takes in reaching the anode is quite important. Electric lines of force exist between any two differently charged bodies; it is along these lines of force that the electrons travel.

"Equipotential surfaces" is a term applied to imaginary surfaces which are at every point perpendicular to the lines of force passing through the surfaces. Such surfaces represent positions of equal potential, or equal energy level. It is easier to predict how an electron will move by reference to such equipotential surfaces. The electrons travelling from cathode to anode will travel along the radial electric lines of force and will therefore move at right angles to the equipotential surfaces. When an electron moves from one equipotential surface to another having a greater potential, the velocity of the electron is increased. If an electron moving at high speed is directed towards a surface of lower potential, its speed will be progressively reduced.

Consideration of the above simple principles enables the tube engineer to design electron guns and deflecting surfaces whereby the direction and performance of the electron stream can be made to comply with various requirements. Reference to the diagrams of an electron gun showing in section the equipotential surfaces and travel of the electron streams at right angles to these surface make the principles readily understandable.

The facts can be summarized as follows:

1. An electron meeting an equipotential surface at right angles is not changed in direction, but speeded

up if it enters a zone of higher equipotential, and slowed down if it enters a zone of lower potential.

2. When an electron enters the lower equipotential surface at an angle its path is bent away from the normal.

It is comparatively simple to trace the path of an electron through an electric field produced by symmetrical electrodes when the positions of the equipotential surfaces are known.

Such surfaces can be calculated mathematically by a long and tedious process, but only for the simpler shapes of electrodes.

A practical procedure for tracing the electron paths, or rather the equipotential surfaces, involves making a large, accurately scaled model of the electrodes, immersing this model in a conducting liquid, and applying appropriate voltages to the electrodes. A test probe which is completely insulated except for a tiny metal point at its tip is connected to a vacuum tube voltmeter, and the probe moved around in the liquid between the electrodes to determine points of equal potential.

These points are then plotted on a cross-section diagram of the electrodes and connected together by smooth curves to give the equipotential lines for that arrangement of electrodes. The path of the electron stream relative to these equipotential surfaces can then be directly plotted. If these paths prove to be not what the engineer desired, a different arrangement of electrodes must be constructed and the same process repeated until the desired effects are obtained.

Behavior of electron streams in a cathode-beam tube is quite similar to rays of light passing through trans-

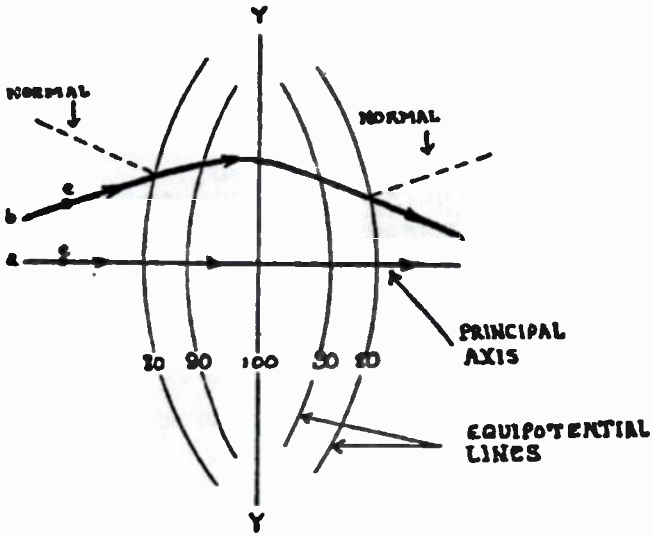


FIG. 1

parent refractive substances. Hence the term, "electron lenses," is applied to various electrode structures in the cathode beam tube.

Thus the electron lens shown in Fig. 1 can be approximately reproduced by using two open cylinders, one larger than the other, placed end to end as shown in Fig. 2, and applying higher positive voltage to the larger cylinder than to the small one. The electron lens formed by the equipotential surfaces near the junction of the two cylinders progressively bends the electron paths toward the principal axis. If point S is the focal point of the electronic lens, the final beam will be a bundle of rays parallel to the principal axis; if S is to the left of the focal point, the emerging beam will be converged to a point. These effects can be attained by

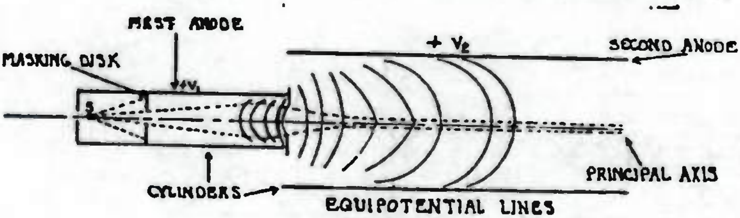


FIG. 2

varying the ratio between the voltages applied to the two electrodes.

Electrons passing through an electronic lens are subjected to the effects of chromatic and spherical aberration, just as in the case of glass lenses. Chromatic aberration in an electrostatic lens is due to the different velocities of the electrons in the stream, just as chromatic aberration in a glass lens occurs because light of different colors (different wave-lengths) travels through the lens at different velocities. In electronic optics, the effects of chromatic aberration are reduced by making the electrons leave source S with as nearly the same speed as possible.

Spherical aberration results because the shapes of the equipotential surfaces depart from the true spherical form in actual practice; this defect is more apparent at points farther away from the principal axis, as is shown in Fig. 2 (Page 79). Spherical aberration in an electronic lens is corrected by making the cone of electrons leaving S as small as possible and by placing a mask near S, to block electrons which are too far away from the principal axis.

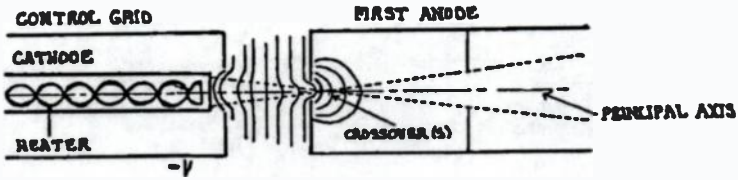


FIG. 3

Although a cathode of large area is needed to obtain the necessary number of electrons, a cylindrical electrode surrounding the cathode with a masking disk, as shown in Fig. 3 produces the desired focusing effect. This electrode is called the control electrode, and is given a negative bias potential with respect to the cathode. The resulting electric field produces equipotential lines as shown, which progressively bend the electrons into a cone-shaped beam having a minimum diameter at point S, sometimes called the cross-over point, or focus. The electrons then continue on to the right of S in a diverging beam, part of which is blocked by the second masking disk, while the remaining electrons pass into the second cylinder.

The control electrode provides a means of varying the number of electrons which leave the cathode; the more negative the potential on this electrode, the fewer electrons there will be in the beam. Large negative potentials result in greater chromatic aberration, however, for electrons emitted near the edges of the cathode will

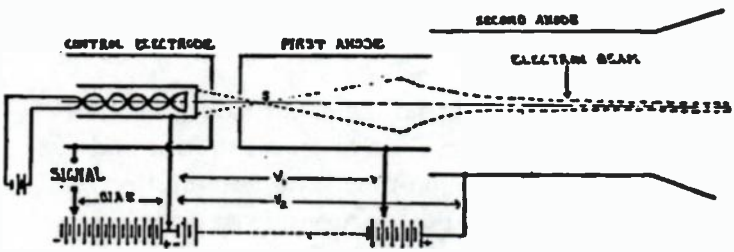


FIG. 4

then be slowed up more by the control grid than the electrons emitted from the center of the cathode. With small values of negative bias, the electrical field is positive near the greater part of the cathode, and all electrons enter the beam at practically the same speed. The effects of chromatic aberration are further reduced by the masks at the end of the control electrode and in the first anode. Since the number of electrons reaching S can be varied by changing the potential on the control electrode, it is customary to apply the beam-modulating voltage (such as a television signal) to this electrode.

The electron gun for a cathode-ray tube, shown in Fig. 4 (Page 81), contains the electronic lens systems given in Figs. 2 and 3. The signal voltage applied to the control electrode determines the intensity of the electron beam and therefore the brightness of the spot formed on the fluorescent screen, while the ratio of voltages V_2 and V_1 controls the focussing and therefore the diameter of the spot on the screen. Deflecting plates (or magnetic fields) located to the right of the second anode are used to control the position of the spot on the screen.

We can now understand the construction and function of the "electron gun" in the small tubular end of a cathode beam television tube. This gun must first of all provide the projectiles (electrons) from the hot cathode with which to bombard the fluorescent screen target at the opposite, enlarged end of the tube. One element of the gun, the control electrode, sometimes called the "grid" electrode, as in any radio tube, acts to control the intensity of the beam in accordance with the received video signals. The coaxial cylinders in front of the gun act, as we have above described, to focus the electron beam to a fine spot on the screen.

Then the beam passes between two parallel, vertical plates upon which opposite electrical charges are alternately impressed. These cause the beam of negative electrical particles, or electrons, to be deflected in a horizontal plane, from left to right when the left hand plate is negatively charged, the right hand plate positively charged, and vice versa. This action produces the horizontal sweep of the cathode beam across the screen.

Further along the axis of the cathode-beam tube is located another pair of plates in horizontal position, either parallel, or slightly flared away from each other. Their function is to displace the beam in vertical planes. The polarity impressed upon these plates is reversed at "picture frame" frequency; that is, during the

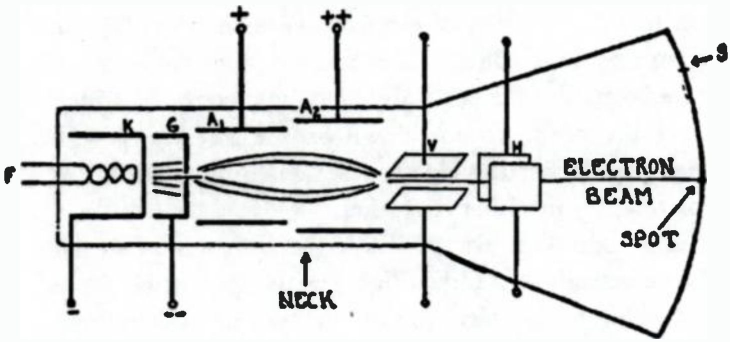


FIG. 5

projection of one picture upon the screen the lower plate is charged positively, attracting the beam downwardly, the upper plate negatively, repelling the beam, while at the termination of that picture's scanning, the plate charges reverse, deflecting the beam once more to the topmost line of the picture on the screen.

In Fig. 5 we see how the various elements above described are finally assembled in a television cathode-beam receiver tube, or kinescope, as it is now frequently called. In this figure the essential elements are:

K—the cathode, which emits electrons when heated; F—the filament, which heats the cathode; A_1 and A_2—anodes which accelerate the electrons and focus them into a narrow beam; S—the fluorescent screen, which glows when hit by the electron beam; G—the control electrode (commonly called the control grid even though it looks entirely different from the grid of an ordinary vacuum tube—and I should know), which controls the number of electrons entering the electron beam and thus controls the brightness of the spot on the screen; V—the vertical deflecting electrodes, which move the beam up and down on the screen; H—the horizontal deflecting electrodes, which move the beam horizontally in either direction.

Electrode A_2 is always at a higher positive potential than electrode A_1. These high positive potentials serve to accelerate the electrons in the beam, giving them greater speed; at the same time, the difference in potential between A_2 and A_1 serves to focus the electrons into the desired narrow beam. Control grid G is always negative with respect to cathode K; the value of this negative potential determines the number of electrons which the cathode can force into the electron beam.

When proper voltages are applied to the various electrodes in a cathode-ray tube, with all electrodes located symmetrically with respect to the central axis of the tube, the spot will be in the exact center of the screen. Increasing the negative voltage on control electrode G reduces the number of electrons in the beam and thus reduces the brightness of the spot. The negative bias on the control grid is usually set so that the screen is dark when no television signal is present. The television signal must be applied in series with the negative grid bias in such a way that the spot will be dark each time a "pedestal" is transmitted. Video signals must make the control grid more positive than the cut-off voltage, thus varying the brightness of the spot on the screen. Synchronizing pulses must make the control grid more negative than the cut-off voltage, so the screen will be dark during the very short intervals of their duration (these intervals are, of course, too short to be noticed by the human eye).

The spot is in the exact center of the cathode-ray tube screen only when there are no voltages on the vertical and horizontal deflecting electrodes. The spot must not remain stationary, or screen will be destroyed.

Horizontal sweeping of the beam by applying to the horizontal deflecting plates of a cathode-ray tube a voltage having the characteristics shown in Fig. 7 can be secured; this is known as a saw-tooth a.c. voltage. This voltage is zero at points 1, 2, 3 and 4, is positive at

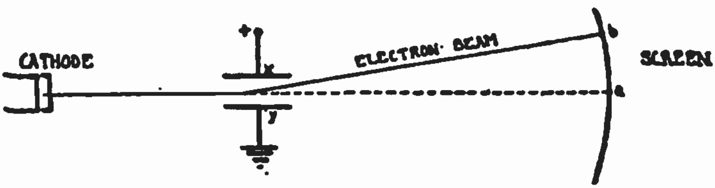


FIG. 6

points 8 and 9, and is negative at points 5, 6 and 7. If this voltage is applied to plates x and y in Fig. 6, and plate y is grounded, plate x will be positive when the voltage is following path 1-8-2, and plate x will be negative when the voltage is following path 2-6-3. Plate y will always be at zero or ground potential. We can think of the voltage wave in Fig. 7 as showing variations in the charge on plate x.

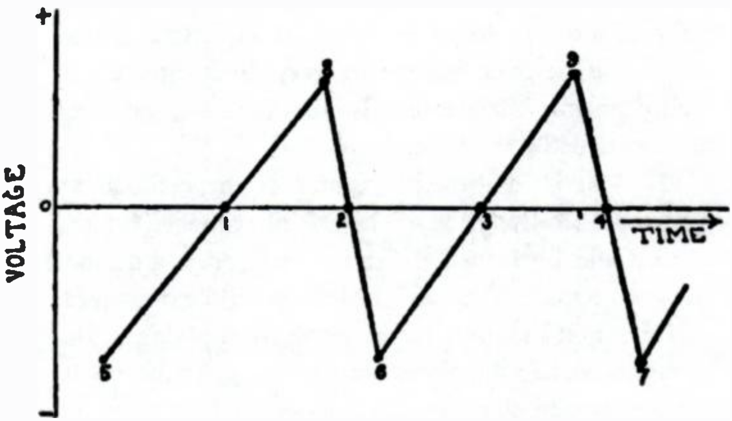


FIG. 7

When this charge is at point 1, the deflecting plates will have no effect upon the electron beam and the spot will be in the exact center of the screen. As the charge on plate x approaches the positive value at point 8, the electron beam will be attracted gradually and uniformly toward plate x. As the charge drops to zero again at point 2, the spot will move rapidly back to the center of the screen. From point 2 to point 6, plate x will become increasingly negative, repelling the beam and bending it toward plate y. From point 6 to point 9 the beam will move *gradually* from plate y toward plate x, and from point 9 to point 7 the beam will move *rapidly* back toward plate y again.

We have seen that a saw-tooth voltage of the form shown in Fig. 7 will produce the desired sweep of the electron beam. If this saw-tooth voltage is applied to horizontal deflecting plates H in Fig. 5, it will cause the spot to sweep *slowly* from left to right across the screen, then return *rapidly* to the left again. If this voltage is applied to the vertical deflecting plates V in Fig. 5, it will cause the spot to move *gradually* from top to bottom and return *rapidly* to the top again.

There is a practical limit to the angle at which electrons can leave the first focal point and still be focused to a point on the screen. Stray electrons would cause undesirable spreading of the beam. To overcome this, one or more electron baffles (each a disk with a hole in its center) are used in a cathode-beam tube to block all electrons which do not converge to the desired narrow beam along the principal axis.

There are two electrostatic lens systems in a cathode beam tube. The first one is near the cathode and is used to bring the emitted electrons to a more or less sharp point which can act as a source of electrons for the second lens. The first lens is essentially produced by the control grid, which is a "Wehnelt cylinder" located in front of the cathode. This first lens is known as the cathode lens. The Wehnelt cylinder surrounding the cathode is usually given a negative bias with respect to the cathode, and is excited with the television signal; it thus serves as the control electrode.

When using two parallel charged metal plates to deflect an electron beam, one plate is sometimes connected directly to the second anode. The other plate is fed with a saw-tooth a.c. sweep voltage which makes this plate first above and then below the potential of the second anode, causing the beam to be deflected to one side of the principal axis and then to the other.

It is customary to ground the second anode in a cathode-beam tube and make all other elements in the tube negative with respect to this second anode. If the anode requires a positive potential of 4,000 volts with respect to the cathode, this can be secured by making the cathode 4,000 volts negative with respect to the anode. This practice *eliminates the danger of shock* to a person touching the glass envelope of the cathode-beam tube, for this envelope assumes the potential of the second anode. The power supply which provides this high negative voltage is carefully insulated from the chassis, and the high-voltage secondary winding of the power pack transformer also must be properly insulated from the grounded metal core.

The sweep voltage makes the ungrounded deflecting plate alternately positive and negative with respect to the grounded plate, and alternately higher and lower in potential than the second anode with respect to the cathode. For example, if the sweep voltage swings positive and negative by 250 volts, the voltage at the ungrounded plate with respect to the cathode will vary between 4,250 volts and 3,750 volts when there is 4,000 volts on the second anode.

Electrons enter the region between the parallel deflecting plates with a definite velocity determined by the potential of the second anode. When the ungrounded plate is positive with respect to the second anode, it will attract the electrons in the beam and consequently pull the beam up toward it, and conversely.

The amount of bending will depend upon the voltage difference between the two plates, upon the distance between the plates, and upon the time the electrons are between the plates. The greater the voltage difference, the greater will be the bending or deflection. The closer together the plates are, the greater will be the deflection. The longer the electrons take to travel between the plates, the greater will be the deflection.

The time for electrons to pass through this space depends upon the electron velocity (upon potential E_1) and upon the length of the plates along the principal axis (L). The higher the velocity, the shorter is the time an electron is between the plates. A high-velocity electron beam is classed as "stiff," and hence is more difficult to bend. For a given bending angle the spot movement on the screen will depend upon the distance between the deflecting plate and the screen, increasing as this distance is increased.

The deflection sensitivity of an electrostatic deflection system can be expressed either in terms of the deflecting plate voltage required to move the spot on the screen a unit distance (the lower the deflection voltage the greater the sensitivity), or the distance which one volt will move the spot on the screen.

Increasing the velocity by raising the potential of the second anode with respect to the cathode will reduce the deflection sensitivity. Increasing the velocity without increasing the sweep voltage will reduce the height or width of the picture on the screen.

The deflection sensitivity is dependent upon the lengths of the deflecting plates and upon their separation. For a given electron speed, there is an optimum length and optimum separation, but deflection sensitivity can be increased by keeping the beam close to the plates without actually hitting them. Curved plates which flare outward meet this requirement. We find plates of this type used extensively in large cathode-beam tubes, for they permit a closer spacing at the cathode end and still do not intercept the beam when it is bent a maximum amount.

It has been assumed that the equipotential lines in between the deflecting plates lie parallel to the plates. However, these plates have limited lengths, so that equipotential lines will curl around the front and rear ends of the plates. In a sense, this gives at each end an electrostatic lens which will defocus the electron beam, for only lines which are parallel to the electron beam have no effect upon focusing.

The balanced connection of electrostatic deflecting plates as shown in Fig. 8 has two important advantages, in that it reduces pattern distortion and minimizes defocusing of the beam.

FLUORESCENT SCREENS: Dimensions of square-cornered images for various useful face diameter values are given in the following table:

Face Diameter..........	3"	5"	9"	12"	14"
Width..................	2.4"	4"	7.2"	9.6"	11.2"
Height.................	1.8"	3"	5.4"	7.2"	8.4"

A special chemical material deposited on the inner face of a cathode-beam tube will produce light when bombarded with a stream of electrons. The explanation usually offered for this phenomenon is that the energy of electron impact disturbs the electrons in the atomic structure of the chemical material, thereby making the material absorb energy. In returning to their normal state, the electrons in this material give off light. Any material which behaves in this manner is known as a "phosphor." The production of light by a phosphor while being excited by an electron stream is called fluorescence.

The preparation of phosphor material for cathode-beam tubes is a highly specialized branch of chemistry.

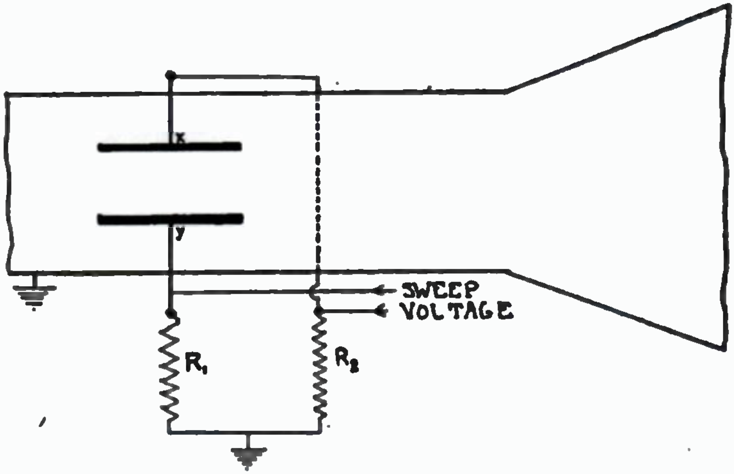


FIG. 8

The most commonly used materials are willemite and zinc sulfide. Willemite is a chemical made up chiefly of zinc, silicon and oxygen, and gives a green to yellow fluorescence when bombarded with electrons. Zinc sulfide phosphors are available under various trade names, and normally give a blue fluorescence. When used with small portions of other materials known as activators, the fluorescent action is increased and the color of the light is changed. By properly combining the different materials, it is now possible to secure an almost white fluorescence.

Candlepower of a Screen: The intensity of light given off from the viewing side of a cathode-beam tube screen can be expressed in terms of candlepower. It is not possible to measure directly the amount of light given off by a spot on a cathode-beam tube screen, for a stationary spot would ruin the fluorescent material. It is therefore customary to sweep the spot over a desired area on the screen, measure the total amount of light given off by this area, then compute the candlepower of the screen.

The electrical power which is supplied to the fluorescent screen in a cathode-beam tube depends essentially upon the voltage and the current of the electron stream. For practical purposes we can say that this power is the product of the current of the stream and the voltage supplied to the final accelerating anode.

Only a small percentage of the power in an electron beam is transformed into light, visible from the outer face of the screen. With the phosphor materials now being used, when converting electrical power into light in a cathode-beam tube, an efficiency of about two percent can be expected.

The effectiveness of a screen in converting electrical power into light power is measured in terms of the total candlepower produced by the screen per watt input. A value of two candlepower per watt is typical of modern cathode-beam tubes. If a cathode-beam tube has a second anode voltage of 7,000 volts and a second anode current of 100 micro-amperes (.0001 ampere), the total beam power will be 7,000 x .0001, or 0.7

watts. The screen will deliver about 0.7 x 2, or about 1.4 candlepower.

Thus it is readily seen why the ordinary cathode tube picture cannot be projected through a lens upon a large screen. The light from the picture surface is wholly inadequate. Yet a highly efficient electron gun will deliver as much as 80 percent of the total electronic emission of the cathode into the active electron stream, and cathode beams carrying as high as 10 milliamperes have been claimed. In projection tubes of the incandescent screen type voltages as low as 5,000 to 7,000 volts may be used, it is said, so that 50 to 70 watts are expended in the beam. This relative large amount of power is manifested in heating the screen. However all such highly efficient projection tubes are yet in the laboratory stage.

Once a fluorescent material is bombarded by an electron stream, it will continue to glow even after the electron stream has moved away or stopped. It is possible to make phosphor materials which will glow as long as one minute after excitation, but these materials would obviously be unsuitable for cathode-beam tubes. In television it is desirable to use materials which will fade out quite rapidly after the excitation has been removed.

The glowing of a screen after removal of excitation is referred to as the persistence of the screen, and the time it takes to reduce the glow a certain amount (say to one tenth the original brilliance) is known as the decay time. By selecting a decay time which will give a reduction in brilliancy to a negligible value in 1/30 of a second (the time for one frame), one image will be almost completely dark by the time the following image is produced, and there will be no overlapping of images. This complete extinction is not necessary except for very fast motion scenes. The persistence characteristic of a fluorescent screen is highly desirable in that it aids the persistence of vision of the human eye, thereby reducing flicker and helping to maintain screen brilliancy.

Importance of a Spherical Face on the Tube: For viewing purposes a flat cathode-beam tube face is the most desirable, but on a flat screen it is very difficult to maintain sharpness of focus. The focusing system in a cathode-beam tube is designed to bring the beam to a spot of a definite area at a definite distance from the focusing electrode structure. Thus, with proper adjustments the spot will be focused at a point in the center of the screen. The spot will also be focused properly anywhere along the arc, for all points along this arc of the tube's face are the same distance from the focusing system, as at points a and b, Fig. 6.

If the face of the cathode-beam tube is made with a curvature corresponding to an arc of the proper radius, the spot will be in focus on the screen at all times. If a screen has too short a radius, the image will be noticeably out of focus near the edges. It is possible to make the screen slightly flatter than the optimum curvature if the beam need not be focused too sharply. Shorter tubes are more conveniently accommodated in receivers and are widely used in spite of the increased face curvature which they require.

In large cathode-beam tubes, a curved face is essential from the standpoint of safety. A cathode-beam tube has almost a perfect vacuum inside, and consequently the normal atmospheric pressure of about 15 pounds per square inch is pressing against the glass envelope at all points, tending to collapse it.

A flat surface bends far more easily than does a curved surface. If a flat screen were used on a tube of this size, a slight jar or blow might be sufficient to cause collapse at the face, Under this condition the glass flies inward (an implosion) and then outward again, with sufficient force in the case of the larger tubes to cause serious personal injury. The use of high-strength glass such as pyrex, carefully annealed so that there are no strains, and the construction of the glass envelope in such a way that there are curves rather than flat surfaces at all points, minimizes the danger of collapse.

Notwithstanding, practically all large television receivers have a safety-glass window over the viewing face of the cathode-beam tube. This window prevents accidental damage to the tube by objects falling on it and protects viewers from flying glass if an implosion occurs.

HALATION: Only a portion of the light produced by electrons bombarding the screen is visible from the outside. That point at which the beam strikes the fluorescent material becomes a source of visible light. Being more or less a point source, it produces light rays which spread in all directions. Most of the light in the forward direction goes directly through the screen and the glass envelope.

But light rays at a large angle to this direct path are reflected back and forth between the inner and outer surfaces of the tube face. Some rays from this point source go directly to some other point on the screen, causing excessive brightness. Much lost light from the point source is radiated backward toward the inner surfaces of the funnel. It will be observed as a complete lighting up of the inside of the cathode-beam tube.

Since, at its best, the cathode-beam tube emits very little light, to make the contrast between dark and bright elements in an image more noticeable it is wise to operate a television receiver in a completely dark room. When this is not desirable for any reason, room illumination should at least be dimmed by drawing the curtains and shades during the daytime and by using a minimum of general room illumination at night.

And this characteristic of present small area cathode-beam pictures emphasizes the fact that eye-strain or irritation is produced by continued viewing of a small, brightly-illumined picture, where the eye has no field for roving. Such concentrated effort produces strain in the muscles directing vision. The smaller the picture the more pronounced becomes this physiological effect. It is another weighty consideration calling for enlarged, screen-projection of the television picture, a development already in the offing.

Direct viewing of a cathode-tube image has certain advantages, including somewhat increased picture brightness with no need for cleaning the picture-reflecting mirror. A disadvantage of direct viewing in the larger picture sizes is the fact that the tube length then controls the size of the cabinet which may therefore protrude further from the wall than is generally desirable. Mirror viewing of the picture has the advantage that it is easy to locate the reflected picture higher than the top of the cabinet, thus enabling it to be seen above the heads and shoulders of other persons.

In home receivers of the "projection type" the screen is arranged to come out into position in the front of, or just above the front edge of the housing cabinet, as in the Scophony or the Phillips designs. Translucent projection is used—that is, the source of light is at the rear of the screen, as viewed by the observer.

FLUORESCENT-SCREEN MATERIALS: The phenomena which result in visible light when certain crystalline phosphor materials are agitated by a stream of electrons from a cathode are of a complex nature. This effect, if vanishing immediately the cathode bombardment ceases, is called "fluorescence." If it persists for a noticeable period thereafter, it is called "phosphorescence."

Originally willemite and calcium tungstate were the principal elements used in cathode beam tubes. Today the wide variety of available fluorescent materials and their characteristic colors include:

zinc orthosilicate—green light
zinc beryllium silicate—orange to green
zinc sulfide (silver activated)—blue
zinc cadmium sulfide—red to blue
cadmium tungstate—white or light blue.

All such materials must be prepared with scrupulous care, but a certain definite amount of foreign matter must be added to obtain the maximum light efficiency. Experimental screens are made by suspending the extremely finely divided phosphor in acetone and gently agitating the supporting surface while the acetone is evaporating. Materials for binding the phosphor firmly upon the glass surface of the cathode beam tube are added, containing, for example, sulfur or borax.

Brightness of the spot on a fluorescent screen increases with the cathode-beam current up to the saturation point. The saturation point varies with different materials, being highest for willemite and zinc sulfide.

As the potential of the cathode beam increases, secondary emission of electrons also increases, acting as a limitation. Thus, 5000 volts is said to be the useful voltage limit for a screen of calcium tungstate. Up to their saturation points the luminous output varies approximately as the square of the voltage. Zinc cadmium sulfide gives maximum light output at 8000 volts. With some of the sulfides it is practical to use voltages in excess of 10,000.

The current density of such a beam is of the order of 10 micro-amperes *per square centimeter*, which means an exceedingly small current in the actual beam. The light efficiencies of such fluorescent surfaces as here considered are poor at best, being of the order of 1 to 3 candle-power per watt in the cathode beam.

The sulfides ordinarily have a persistence, or afterglow period, of the order of one thousandth of a second. But, as stated in a later chapter, DuMont has purposely added phosporescing materials to his screen for the purpose of producing a luminous persistence of the order of 1/30 second, or even considerably longer. By so doing he is enabled to reduce by one half the number of picture frames per second, thus halving the width of frequency band required (for a given number of lines to the picture). Upon the circular end of the cathode tube must be outlined the oblong picture dimensions. It is now standard practice to make these coincide with those of the standard-motion picture, that is, having a vertical to horizontal ratio of 3:4.

The manufacture of cathode-beam tubes has today become so perfected that the best ones have a life comparable to that of a good radio tube. The fluorescent material, given cathode-beam voltages for which it is intended, has a useful life of a thousand hours or so.

However one limitation to the useful life of a tube thus far has been the formation of the so-called "black spot," a small darkening or discoloration in the center of the screen. This may appear shortly after the tube is put into service, or after many hours. Its existence is primarily due to undesirable impurities in the fluorescent screen. The spot shows up more quickly where higher voltages are used. It is probably due to the impact of heavy negatively charged particles (not electrons) on the screen, notably chlorine and cyanogen. In the best and most carefully made kinescopes on the market however the occurrence of this black spot is exceedingly rare.*

It is obvious that the electron beam should never be permitted to play upon the screen when a picture is not being received, as this will very quickly produce a dull or inactive spot in the fluorescent area at the point where the beam impinges. Automatic means are usually provided for preventing such an occurrence.

Cabinet Controls: In a typical television receiver the usual controls are for tuning, brightness, contrast, beam focusing, power switch, and a volume control for sound. Some receivers have in addition a sound-tuning control whereby the audio receiver in the cabinet can

* Black spot occurs only when electro-magnetic deflection of the beam is employed.

be used for receiving short and ultra-short wave sound transmissions.

The pre-set or factory-adjusted controls usually include a horizontal-sweep frequency, vertical-sweep frequency, horizontal-picture width, vertical-picture height, horizontal-positioning or centering, vertical-positioning or centering, and an additional horizontal-positioning control for effecting minimum "astigmatic" aberration of the electron-lens system.

Eight: Cathode-Beam Synchronization

STANDARD RADIO MANUFACTURERS ASSOCIATION SIGNAL, MODULATION, ETC.

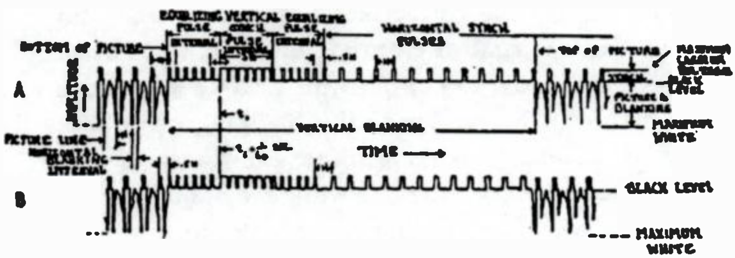
THROUGH synchronization, the transmitting and receiving mechanism in a television system are held exactly together or in step with each other—the speeds of operation of the two scanning elements are identical. Of old, when the scanning disk or similar mechanical systems were in use, only one synchronizing signal was needed to keep the receiver disk rotating at exactly the same speed as that of the transmitter. The transmitted synchronizing pulse, received and amplified, was applied to a phonic wheel motor at the receiver, causing this motor to speed up if it began to lag, and to slow down if it began to exceed the speed of the transmitter disk.

The two disks might be running at the same speed, but like points upon the disks not in the same relative position. This would result in the received picture being displaced on the viewing screen, perhaps showing the right and left halves of two successive picture frames simultaneously upon the screen. So it was necessary to have the receiver disk not only running in exact synchronism, but also exactly *in phase* with the transmitting disk.

In cathode-beam receiving tubes, the same conditions must obtain, the beam in the receiver tube must not only sweep horizontally in perfect synchronism with the transmitter-iconoscope beam, but must also follow down the screen, line after line, in keeping with the downward course of the iconoscope beam. And in addition the two beams must begin their journeys from the upper left-hand corners of their respective screens at exactly the same instant. Here the received image is pencilled upon the fluorescent screen by means of constant-speed unidirectional scanning, always from left to right and from top to bottom, with the beam cut off (or essentially so) during the very brief periods of "fly back," from right back to left, and from bottom back to top.

The Radio Manufacturers Association (RMA) standards call for "negative transmission" as the norm for America. This means that a decrease in light intensity at any point of the scene to be transmitted shall cause an increase in the power radiated at that instant. They further have ruled that if the peak amplitude of the radio-frequency video signal be taken as 100 percent, then between 20 and 25 percent of the total amplitude should be reserved for the synchronizing signal impulses.

This means that for extreme white the modulation of the carrier wave shall be zero percent; 75 to 80 percent shall be full black, i.e., that the cathode-beam is totally cut off, and that the region between this level and 100 percent be reserved for the synchronizing signal pulses. The disproportionately large part of the carrier energy thus devoted to synchronization is one of the imperfec-



RMA STANDARD T-111
TELEVISION SIGNAL
FIG. 1

tions of this type of television transmission. It is reasonable to expect that improved synchronizing methods will appreciably reduce this energy, enabling it to be more usefully devoted to the video signals.

Fig. 1 illustrates the form of the standard synchronizing pulse advocated in the RMA report—the idealized wave forms of horizontal "blanking" and synchronizing signals near the occurrence of two successive vertical blanking pulses. Blanking, it will be remembered, means the time interval during which the cathode-beam is returning from the right end of one line to the beginning or left end of the next succeeding line; or, for vertical blanking, from the bottom of the picture back to the top of the screen.

On account of interlacing the location of the corresponding lines at the bottom or top of the picture (as shown at A and B) lie adjacent to each other. Notice that during the blanking interval of fly back at the bottom of a frame the "black level" is transmitted. This means that the control electrode of the cathode-beam gun is then biased to cut off, which avoids a spurious path across the screen during this blanking, or fly-back interval. Likewise blanking pulses are transmitted at the end of each horizontal line while the beam is sweeping back to the left to begin a new picture line.

For a 441-line picture the duration of a horizontal line is about 75.5 micro-seconds. Fifteen percent of this interval, or only 11.3 micro-seconds is reserved for the blanking impulse. But the vertical blanking pulse endures for 7 to 10 percent of 1/60 second, or an average of 13 ten-thousandths of a second, approximately 125 times as long as the horizontal blanking pulse. Now during the horizontal blanking period the horizontal synchronizing signal is produced by modulating the transmitted carrier waves into the "blacker than black" region (from the 75-80 percent to 100 percent modulation).

This horizontal or line synchronizing signal is filtered out from the other portions of the carrier wave train and caused to trigger the horizontal sweep generator, so that this sweep of the beam will be initiated exactly at the proper instant, in synchronism with the corresponding sweep of the beam in the distant pick-up camera.

During the relatively long vertical blanking period these horizontal synchronizing pulses continue to be transmitted as shown in Fig. 1, on the supposition that these shorter interval signals must be continued in order to control the line-frequency generator.

A quite different method of synchronization control from the transmitter will avoid many restricting complications now necessitated by the RMA standard methods here described. But here the vertical synchronizing pulses as shown in the diagram, consist of a strong signal to the 100 percent modulation level, but which is "serrated," or notched so that the horizontal line pulses may continue even during the vertical pulse. The larger area under the vertical pulse constitutes a sufficient difference to permit of its segregation from the other signals being transmitted.

The television transmitter must, at the end of each line, send a signal impulse which will serve to swing the reproducing device back to the start of the following line in synchronism with the television camera. With this requirement met, we know that the transmitting and receiving devices will start each line at the same instant, even though they may vary in speed a certain amount during a given line. The impulse which is sent at the end of each line for reproducer-controlling purposes is called the line-synchronizing impulse or the horizontal-synchronizing impulse. In a practical transmitter this impulse is produced by an impulse generator in the transmitter which directly controls the travel of the scanning eye and which, by means of the connecting medium (wire or radio carriers), controls the travel of the reproducing device.

To provide means for returning the reproducing device from the lower right-hand corner to the upper left-hand corner at exactly the right instant, the transmitter must send an end-of-the-picture impulse to the receiver along with the varying-line signals and the end-of-the-line impulses. This end-of-the-picture impulse is called the picture-synchronizing impulse, the frame-synchronizing impulse or the vertical-synchronizing impulse.

Therefore the three important signals which must be transmitted on the picture carrier in an electronic television system are:

1. Picture or video signal, obtained by breaking up the view into a number of elemental areas and scanning each of these in an orderly sequence.

2. Line synchronizing or horizontal synchronizing impulses;

3. Frame synchronizing or vertical synchronizing impulses.

Actual Television Transmission: During the transmission of a television signal, the line impulse exists for an instant after each line has been scanned, and the frame (picture) impulse exists for a longer period after each frame has been scanned. The video signals need not exist while these impulses are being transmitted; in fact, it is wise to stop them entirely during these periods. The line and frame impulses must be sufficiently different in character so they can be readily separated at the receiver and each applied to the proper control circuit. In actual television systems, this difference usually involves making one type of impulse last a longer time than the other.

The three essential components of a television signal may be transmitted in a number of different ways, but the signal arrangement shown in Fig. 1 comes nearest to satisfying the requirements of the television receiver. The r.f. carrier is not shown in this diagram.

For a rather complete, detailed explanation as to just how the synchronizing impulses, pedestals, shown in Fig. 1, are segregated from the video signals after passing through the video i.f.* and demodulator circuits, consult the chapter on Television for Amateurs.

* "Intermediate-frequency," characteristic of all superheterodyne receiving circuits.

Nine: Use of Film in Television

COSTS, FILM LIBRARIES, STATION SERVICE, ETC.

ANY intelligent consideration of television, or approach to its economics, must involve (what I construe to be) its foundation. We must, therefore, examine radio and motion pictures, the inter-relationships of which with television will become more and more apparent as we proceed. In the following analysis and forecast I am looking a long way ahead. But the acceleration of technical advances in our generation should abundantly justify such forecasting as I shall here make.

Radio has grown to a dominating position as a medium of public entertainment during the past ten years. So startling has been its growth that today the presentation of a radio program of universal appeal, if put on the air simultaneously over all the broadcasting stations, envisions the startling possibility of zero attendance at the motion picture theaters, at least for the duration of the "ideal program."

Purely visionary? Possibly. But consider the facts. Look at the radio statistics. Recently NBC's chief statistician reported to the Federal Communications Commission that there are thirty-seven and two-thirds millions of radio sets in the United States alone. That means there are 290 sets per thousand of population.

With the average audience of four persons per set, excluding automobile radios, there is radio coverage of the entire population of this country. Such blanketing of the nation by radio is something which motion pictures cannot disregard. It comprehends something that Hollywood should scrutinize closely.

Further, in the United States there are more than 880 stations licensed to broadcast. The capital invested in radio stations in 1936, exclusive of real estate, was $19,300,000. The maintenance cost, including interest on the investment and depreciation, was $20,001,000 in that year. These figures are from the Department of Commerce. The gross investment in broadcasting, including talent, contracts, good will, studios and real estate, approximates $150,000,000. This latter figure is my estimate. (As January, 1941, ended, there were 882 broadcasting stations operating in United States.—EDITOR.)

Paid-time figures for broadcasting, supplied by the Department of Commerce, are:

	1935	1936	1937
Chain	$51,178,425	$ 60,300,000	$ 68,872,140
Non-chain	$36,345,513	$ 45,400,000	....
	$87,523,938	$105,700,000	$125,000,000

From the same source, talent costs of $36,600,000 for 1936 and $40,000,000 for 1937 are cited.

Thus we learn that the broadcasting gross income is increasing at a rate of about 20 percent per year. It is also obvious that the strictly apparatus investment in the broadcasting stations is less than 10 percent of the total capital in these stations. I might add that the public is purchasing about $300,000,000 worth of radio sets and parts each year.

All of this vast yearly expenditure is carried directly and indirectly by the public, and competes directly with the dollars this public might otherwise spend in the motion picture theaters. With these basic facts before us, try to imagine the serious additional competition to pictures, which will grow out of the introduction of motion pictures on reasonably large screens in the home.

The stage is set. A comparatively small investment will alter the present sound broadcasting studios to sight and sound broadcasting. The system for the distribution of television sets exists. The factories for their manufacture exist. The public is television-minded and familiar with the adjustment of home equipment.

Television is capable of broadcasting two general types: from films, and from live subject matter. But it is the opinion of many television men that film programs will constitute the bulk of broadcasting, for the following reasons:

(1) Duplicates with sound on film can be made cheaply.

(2) Film duplicates will provide an inexpensive chain-system, and save the charges now paid by radio to the telephone company.

(3) The programs can be edited.

(4) Much of the technique and production apparatus

of the motion picture production companies can be used, thus cutting program costs.

(5) Letter-perfect productions, requiring enormous rehearsal time and expense, can be eliminated.

(6) The talent need not be forced to rigid schedule.

(7) The production can be made at the most suitable or convenient location.

(8) Subject matter of programs can be extended to include educational subjects such as travelogs, science, musical technique and the like.

(9) Program libraries can be created. A good business can be established in renting features such as classical plays and other timeless items to the various television broadcasting stations.

Naturally in attempting to estimate the magnitude of the probable film production we must use figures that are subject to challenge. However, assume a program period of three hours a day per station, with two hours of film subject matter and one hour of live program. Assume also that only 200 of the present-day radio stations will be equipped with sight and sound broadcasting. And also that at any moment only 100 stations are broadcasting the same program from film duplicates.

Thus we arrive at a possible production of 200 hours of *new* film a day. Allowing only 20 hours in production for each hour of usable film, means 4,000 film-hours of production per day and 200 hours of duplicate prints per day. This means 250 additional sound studios just for television. It is further estimated that on a continuous basis some 10,000 people would be employed, exclusive of writers, film processing and distribution staffs, scenery and costume staffs and administrative workers.

From the broadcasting angle, logically it is possible also to assume that the stations broadcasting aural, plus sight and sound entertainment, would be returned a substantial increase over their present income. It is estimated that a possible revenue of $27,000,000 annually might be realized from commercial television on the basis of plausible figures.

Assume that broadcasting stations operate on an average of 12 hours a day. Let us then cut off one fourth of the talent and time expense, or $12,000,000, which will be applied against the portion of the program retained for the nine hours of sound alone. On the balance of three hours of television let us assume, because of its terrific power as a selling medium, that the advertizers will pay two times what they now pay for sound alone, or a total of $18,000,000 income to 200 television stations.

Since the cost of wire networks is eliminated by the use of film duplicates, we can figure a saving of some $10,000,000 to the stations. Whether the stations exchanged one fourth of their present sound hours for television hours, or maintained both services simultaneously from separate studios, the station return would represent a very substantial increase over their present income.

This $18,000,000 will be spent in large part for film production. This is the target at which the motion picture producers should aim. If the producers do not seek this business aggressively, the television companies themselves will have to do the job, for there is an essential difference between theater and special home programs that makes this undertaking logical. That difference is the utter simplicity of the subject matter and setting, which, as radio experience has shown, is ideal for the home.

On the other hand, there exist many millions of feet of film still useful for homes, covering history, travel, education, plus stories presented years ago which yet are good and interesting material. The leasing of such represents an entirely new and additional potential profit for existing film producers and distributors.

Translating some of these figures into feet of film per day, and feet per year, assuming 90 feet of film per minute, we obtain 200 hours of positive film per day—or more than one million feet of film per day.

To this must be added 11,000 feet of cut and finished negative film per day for the chain features, or an additional 20 million or more feet of negative film per year. The grand total would then be nearly 400,000,000 feet of film per year.

Assuming the above figures approximately correct, as conservatively based on 1937 statistics, indicated is a gross income for 200 television stations, plus network charges saving: $37,000,000; studio operating and film costs: $25,000,000; net annual profit: $12,000,000.

Ten: Transmission Through Space

NETWORKS BY SHORT-WAVE RELAY SYSTEMS; TELEPHONE WAVE GUIDES 441-LINE PICTURE, ETC.

As HAS been already explained, high-fidelity television breaks down a picture or scene into a very large number of picture elements, then rearranges these elements and restores the scene at a distance.

With the former RMA standard of 441 horizontal picture lines it is fair to consider that each single line comprises a similar number of picture elements. Therefore in each picture frame we have elements amounting roughly to the square of 441, or 194, 481 elements. And since the picture is completely scanned 30 times each second, approximately 6,000,000 picture elements must be transmitted per second. At least, the transmitter should be one capable of transmitting this maximum number.

Each picture-element represents a complete cycle of the video-frequency current. In other words, as the cathode beam scans or sweeps over the mosaic surface of the iconoscope camera, on which is projected the image to be transmitted, any change, say from a tiny black spot to an adjacent white spot causes a plus electrical charge, followed by a minus electrical charge (or vice-versa), to flow over the output cable conductor. These two alternate charges flowing through the wire represent, therefore, a single cycle of the so-called "video" current, the maximum frequency of which will be one-half of the maximum number of picture elements, i.e., 3,000,000 cycles. This is called the video modulating current, because it is caused to modulate or control the intensity of the much-higher frequency radio-carrier current in the transmitting antenna.

The frequency of this carrier current must be many times greater than that of the current which modulates it, of the order of 10 to 15 times, to obtain smooth modulation of the carrier. Consequently, the radio frequencies involved in modern television transmission are of the order of fifty to sixty million cycles, or 50 to 60 megacycles. They may run much higher, of course. Therefore, it is easy to understand that to transmit television signals over the usual broadcast frequency channels would require six times the ether space in the entire present broadcast band of about 1,000,000 cycles (500,000 to 1,500,000 cycles).

So it is obvious why television radio transmission demands carrier channels in the high-frequency and ultra-high-frequency (above 30 megacycles) bands. Thus the Federal Communications Commission has wisely set aside for television several bands in the extremely high-frequency spectrum. Tomorrow we may be using frequencies still higher, and come to regard present channels as decidedly "low" frequency. In other words, television may use still shorter and shorter waves.

We have seen why high frequencies, or short wavelengths of the order of five to ten meters, are demanded for television transmission. But these short waves behave very much as do light waves. They tend to travel in straight lines and are not readily refracted or bent around small conducting obstacles. (They are like high frequency sound waves in this respect.) Such quasi-optical electric waves, properly called, do not follow the contour of the earth, as do longer broadcast waves, therefore they should be limited by the horizon. But, as a matter of observed fact, even seven-meter waves are sufficiently refracted by the atmosphere, or sufficiently conducted by the earth's surface, to be picked up at points well below the optical horizon. The exact theory defining how far a definite fraction of the radiated energy may be received at definite angles below the direct line of sight to the transmitter antenna has not yet been worked out, and perhaps cannot be very definitely calculated. Too many variables will show in the equation.

A recent experiment made in an air-plane 21,000 feet above Washington, 200 miles from the Empire State Building television transmitter in New York, showed that at such altitudes where the receiver and transmitter are in direct lines of vision, strong reception is afforded. As the plane descended and the earth's horizon intervened the strength of the signals fell off rapidly.

Hence, the necessity for locating television transmitters upon a lofty height, for example, atop the Empire State Building and the Chrysler steeple.

But nature, in certain places, laughs at lofty-minded architects. In Hollywood, a range of hills much higher above the southern and sea-ward plains than the Empire State, affords a television transmitter site from which to reach a present population of nearly 2,000,000 in 400,000 homes of wood, frame and stucco, with scarcely a steel frame throughout the entire vista, outside of downtown Los Angeles; truly a paradise for television.

Inasmuch as we have seen why picture broadcasting demands short waves, lofty towers and has limited service ranges, it becomes clear why each metropolitan area densely populated district must establish its own individual television units, transmitters and studios. Especially does this hold true in as large a land as America, where populated clusters are widely scattered. Coaxial cable costs to link the cities, therefore, would usually be prohibitive.

Long-range television transmission by means of a chain of relay stations has been successfully demonstrated between New York and Philadelphia. A relay receiving station installed at Arney Mount in New Jersey, 63 miles from the Empire State transmitter, passes the amplified signals through a short cable to a directional transmitter, which beams these on their journey 25 miles further to a receiver atop of the RCA Building, at Camden, thence via 1500 feet more of coaxial cable to a transmitter tower on the roof of the manufacturing plant. The again-reinforced signals then travelled four miles further to the Collingswood, New Jersey, test house. Much intensive investigation and experimentation along this line is in progress, and will continue. But even with frequency modulation the hazards of interference, or interruption, from various causes may make this method of aerial-linked relay stations unreliable at times for television service.

There may be a solution to this fascinating problem of long-range telecasting, in utilizing as the carrier channel the "long small-bore holes in the free ether" represented by the existing masses of closely grouped parallel copper wires of the telephone and telegraph lines which now stretch from city to city all over the United States.

On the outside surfaces of these small copper "bores" thus grouped, there is, in the aggregate, a large conducting surface affording a perfectly good "wave chute." The efficacy of these trackside wires in carrying over great distances radio-broadcast electric waves is abundantly demonstrated by the strong signals from distant stations picked up aboard the club cars of our transcontinental express trains.

I think perhaps I was the first to observe this interesting phenomenon back in 1903, when engaged in demonstrating the possibilities of wireless telegraph communication between Toronto and Hamilton, Ontario. Our Hamilton station was located near the railroad, with its usual stretch of thickly clustered trackside wires. We had a fairly tall mast for our antenna, but the unexpected strength of the Toronto signals prompted the suspicion that these wires were carrying the signals, and playing possibly a large part in the then new marvel of wireless transmission. So, equipped with my small, untuned wireless detector and head phones, I went down the tracks to a point about a mile nearer Toronto, tied a length of antenna wire between two telegraph poles as high up as I could reach, made an earth connection to the scraped trunk of a small bush nearby, and put on the phones. Sure enough, the reproduced characteristic sounds from our 60-cycle spark transmitter signals at Toronto, 70 miles distant, were coming in loud.

Later, in the summer of that year, we had a wireless station on Block Island for securing news from another on the mainland at Point Judith, Rhode Island. A severe storm blew down the tall ship-mast on the island, putting the transmitter out of service. Not so the receiver, however. The two-wire telephone line extending for seven miles across the island in a straight line with Point Judith was hooked up through a blocking condenser, to the receiver tuner. Thereupon the wireless news flashes from the Providence Journal were received even more strongly than with the 125 feet upright antenna used before.

Again in New Haven, in June 1906, I repeated these experiments, with an antenna wire lying on the bare earth, pivoted to the receiver. When this wire lay underneath and parallel to the overhead telephone wires, strong signals were received. But when this wire was placed at right angles to the telephone lines, the signals were very faint.

Based upon these observations I then took out a basic patent covering the use of receiving and transmitting horizontal antenna wires parallel with, and located near, existing long wire conductors such as telegraph, telephone, or power lines. Since the World War this latter application, radio antenna inductively associated with power transmission lines for telephonic inter-station communication, has proved of much value. However, here was just another example of a pioneer patent having been born too early, expiring before the art had grown up to an appreciation of the value of the discovery.

And so I say, it *may* be that we have here, ready made, a solution for long-distance television chain transmission. So far as I know, no tests yet have been made to determine the value of these overhead massed wire channels as "wave chutes" for conducting to great distance short, or ultra-short, electric waves, when inductively or capacitatively applied to such filiar media.

What then are the losses through resistance, leakage or radiation, and to the underlying earth? What by-passing devices will be necessary to shunt these gliding wave-trains around intervening towns and cities where the overhead conductors are cabled or scattered, again to be applied beyond the town, probably after reinforcement by local amplifier-tube relays, for the next link in the transmission?

Certainly this use of existing wire lines need not interfere in the slightest with their present uses. And the tolls to be charged by the public utilities for this additional use of their wires should not be comparable to those now exacted for long distance toll service. Here is perhaps an opportunity for a gratuity (if such can be imagined) to a new and deserving enterprise. In any event here lies an opportunity among the various transmission utilities for competition—something heretofore non-existent so far as radio net-work services are concerned!

But in the meantime, as I have explained, there is a superabundance of work to be done in installing 200 or more television transmitters in some 75 American cities, which should be adequate to supply entertainment and education on good strong signals to the homes of 50,000,000 citizens—largely made possible, economically practical and profitable, by means of the "Can-carrier" system. Or if this medium jars the artistic sensibilities of certain directors, the television film may be encased in modernistic, streamlined bakelite containers, rendered fire-proof.

But what about local transmission, assuming lofty sites for the radiators and abundant wattage to put out a 10 m.v. (millivolt) signal at 50 miles? While using wavelengths of the order of 10 meters or less, quasi-optical electric waves, we are doomed to suffer from shadow losses from objects which are more or less "transparent" to the longer waves; and to reflections, not merely from steel frames and other metallic bodies such as passing airplanes, but from brick and stone masonry, even from stucco surfaces, if the angle of incidence of the waves be sufficiently oblique.

Shortly before the present war the British Broadcasting Company was preparing plans for piping their Alexandria Palace television signals seventy miles to Birmingham by buried coaxial cables. Following the satisfactory completion of this first link, coaxial networks were contemplated to Manchester and other cities. All such plans, of course, are now indefinitely postponed. But England is a snug island. Distances are relatively short. More important, as a factor making possible this type of television distance transmission, is the fact that the British Government's tax on all radio receivers makes it possible for BBC to finance such costly installations and service.

From what we have seen regarding the advantage of elevating as high as possible the television transmitter, it is clear that the receiving antenna also should be high, as nearly as possible providing a direct line of sight between the two. Thus we should place the receiver di-pole antenna, horizontal or vertical, in order to match the position of the transmitter, atop of a small pole or tower on the roof, or concealed in the attic beneath a high wooden roof. To reinforce the received signals a duplicate or reflecting dipole may be placed one-quarter wavelength behind the receiving dipole, in direct line from the transmitter. Such a reflector not only materially increases the strength of the signal but helps shield the receiving antenna from unwanted signals reflected from neighboring or distant surfaces, and interferences from behind.

Dual reception of direct and reflected signals is one of the major difficulties facing the television installing engineer or service man. How to point or aim the receiving dipole to avoid (as far as possible) such reflected signals is often a problem. Sometimes several screening antennae or netting may be cleverly located to gain this end. Sometimes, however, the architectural arrangements at the receiver practically prevent such shielding.

Reflected signals arriving at the receiver, even a few micro-seconds behind the direct wave, produce more or less pronounced "ghost" images upon the cathode-tube screen.

How to isolate the receiving antenna from such reflections in certain locations will prove one of the knottiest problems facing the television engineer, especially when multiple reflections from several scattered reflecting bodies are involved. Quite obviously it is impracticable to segregate direct from reflected signals once these parasites reach the antenna, because they are all of the same wave length. Shielding the antenna system, as well as the transmission line to the receiver, appears the only hope.

A complete solution of this and a lot of other problems might be found if there existed above us, not too high, an almost totally reflecting layer for the television frequencies. Then we would need only "point" a strong transmitter beam vertically upward, spray the radiations outwardly, and receive the waves only from above. Then, with the receiving antenna in a cup or trough screen to protect it from all horizontal or oblique radiations, we might sit complacently before our televisor and gaze upon pictures from "heaven"—yet without "ghosts."

Impossible, alas! But there's no harm in supposing.

Reflecting layers exist in the upper regions of the atmosphere by which we explain occasional reception of television signals over enormous distances. These layers long have been recognized. Years ago, television pictures from the early Baird transmitter in London were received, in more or less fragmentary condition, in the United States. I believe also some claims of Australia pick-ups have been made. Obviously, when such extreme distances are attained, multiple reflections are involved from the upper rarified or ionized layers down to earth, then up again to the same or different reflecting layers and back, perhaps many times repeated, before the final destination is reached or the wave energy dissipated.

The elevation of this "Kennelly-Heaviside layer," as it is called, varies from one hour or moment to another. Another variable is the angle of its lower surfaces. Thus, reception of signals depending upon such reflections necessarily must be of a freakish nature and utterly unreliable. Furthermore, the coefficient of reflection, or the ability of such ionized atmospheric surfaces to reflect electric waves depends to a large extent upon the exact wavelength of the arriving radiation. Similarly, the color of the blue sky is due to the power of fine particles or molecules in the upper atmosphere to reflect blue rays from sunlight, but not those of other portions of the solar spectrum. And it is this selective reflection and absorption quality of moisture or fog-laden atmosphere which gives us the inspiring displays of rich coloring during sunrise and sunset hours.

So, with short-wave radio, and especially television signals, where the frequencies are continually varying through rather wide limits, we can expect reception of messages, voice and pictures reflected from upper layers to be variable, distorted, or fragmentary.

Eleven: Television for Amateurs

APPARATUS EXPLAINED; CIRCUIT DETAILS

RADIO has swept ahead to its present position, sparkplugged by two important factors. The first was the general interest in radio developed by the young men who joined our fighting forces in the World War, and the second was the availability of radio parts designed for home assembly of sets shortly after the War terminated. Back of all this was a general amateur interest in radio, extending to the early days of this art.

In the first few years of radio after the war, the more efficient sets were those constructed by the amateur. Gradually, however, the radio manufacturing industry succeeded in embodying the later developments into their products, so that it became possible to purchase a radio set superior to one that could be assembled by a talented amateur. Since that day, mass production has made superior radio sets so inexpensive that usually it is sheer folly for an amateur to construct his own set, except he be an artisan who delights in this kind of work.

A television set is a much more complex instrument than an ordinary receiver. In the first place, it is designed to be used on ultra short waves and a difference of ½" of wire more or less is an important factor in a resonant circuit. Amplification of short waves is a rather difficult technical problem. Furthermore, very high voltages often are employed in certain types of television receiving sets and, in addition to the wave that produces varying light intensities over the successive spots that form the screen picture, other waves must be dealt with to control the vertical and horizontal scanning of the picture. In addition to these three controlling currents, a sound channel must be provided for, also on short waves.

The television industry, naturally, has sought to enlist the interest of the amateur, for there is no advertising medium as loyal and thorough as he, with the set he has built. He goes out of his way to invite his friends and the lay public to see a performance. His enthusiasm is contagious. The television industry has made some effort to design equipment suitable for assembly by amateurs lacking professional experience, and the equipment offered is accompanied by very detailed drawings and instructions to assist toward successful assembly of the instrument.

Proportioning of the parts of a television receiving set is an exact matter, and unless properly performed the set will not function. A large and expensive array of measuring instruments are required for this work, and it is hopeless to expect the average amateur to buy and construct from parts all these "tools," to be used only in constructing a television receiver. This is recognized by manufacturers of amateur television equipment. Generally they have overcome the problem by supplying matched units for certain portions of the assembly.

In his leisure time an amateur might put together a radio set from parts in about a week. A television set would require several times that period. When the assembly is complete, the power connected and the switch closed there will be only a few moments of breathless waiting before he knows the answer—success or failure. Some vital element may have been misplaced; the set may refuse to function. There can be no compromise in television.

No greater nor more disappointed individual can be found than an amateur who has spent some eighty to a hundred dollars for parts for a receiving set, and given a month of his leisure time, only to find that the set will, for some mysterious reason, not work. This has been foreseen by the makers of television parts, hence they usually maintain a department in their organization for the free service of home-built sets. Experience has shown that most faults are relatively minor, and can be corrected quickly by the service men engaged in this work.

In the present state of the television art, to take advantage of all the fun connected with its technique and construction, it seems more logical for a *group* of amateurs to assemble a set. The time required per person could be reduced and the expense shared. Furthermore, since television is a new art, models will change rapidly and fundamentally, and the group could keep abreast of the latest technique without burdening any single man.

The antenna problem for television is quite different from that of the ordinary radio. Since the waves are short and optical in character they stream out at the most unusual angles with respect to the line of transmission. The antenna problem, however, has been simplified so one can purchase an outfit adjustable to all angles, with reflectors suitable for this particular service. All sorts of oddities are found. A water tank may be found the apparent source of your picture show. You may even find that the antenna turned to the position of zero reception with respect to the line of transmission works best. The very fact that such unpredictable oddities exist in television makes it a happy hunting ground for the future of the amateur.

To aid in understanding details of the various circuits of this chapter let us proceed with a brief summary of the elements involved in a complete television receiver.

In brief, a complete television receiver today should include two superheterodyne receivers, one for picture, and one for sound; circuits for selecting and controlling the synchronizing signals, deflection and picture contrast; means for inserting a direct-current component in the signal, also controls for the cathode-beam tube and loud speaker, and automatic gain controls for both picture and sound.

At the transmitter the video signals are produced by the camera, after which blanking signals at the end of each line and frame are inserted to define the "reference level" for the "black" of the picture. Synchronizing signals for controlling the sweep circuits at the receivers are then added before the complete transmitted signal is delivered to the power amplifier and to the antenna.

Referring again to the television receiver, we first have the receiving antenna or "dipole," which is connected to a preselector system and radio frequency amplifier, followed by a heterodyne circuit to produce an intermediate frequency for the picture signal and also a second intermediate frequency for the sound signal. These intermediate frequencies are then amplified, each in its own amplifier circuit, which terminates in a second detector to produce the complete television and complete sound signals.

The television signal is then split into portions. The video frequency modulation is amplified and applied to the control electrode of the cathode-beam tube after the direct current component has been inserted into the signal. This is for the purpose of controlling the background, or average brightness, of the picture.

From the second detector, a filter discriminates between amplitudes of the signal and produces two outputs: horizontal deflection impulses, and vertical deflection impulses. These impulses are fed into appropriate deflection circuits to control the horizontal and the vertical sweep of the cathode beam.

Obviously the antenna and preselector circuits of the system, while being selective to frequency, should be broadly tuned to admit the complete television channel of video and audio modulated carriers. The intermediate frequencies used for video and audio reception are of the order of 10 megacycles.

The Federal Communications Commission has assigned several television channels, each six megacycles in width. The lowest of these is 50-56 megacycles; the highest 102-108 m.c. So far New York is the one city where there has been access to several regularly operating television transmitters, those of the NBC, CBS and DuMont. These three transmissions are of course on different allotted frequencies. In the near future there will be additional regularly operating transmitters in the New York area. The prospects are excellent that four other transmissions soon will be in operation in the Los Angeles section, where the Don Lee television station has been on the air for the past three years.

In the following it is assumed that the reader is acquainted with the fundamentals of radio—that he understands the meaning of such words as diode, triode, pentode, superheterodyne, resistance, impedance, reactance, capacity, and mutual inductance.

For brevity, the following designations usually will be employed: d.c. for direct current; a.c. for alternating current; m.c., megacycles, or million cycles; k.c., kilocycles, or thousand cycles; r.f., radio frequency; i.f., intermediate frequency; v.f., video frequency; a.f., audio frequency; a.v.c., automatic volume control, etc.

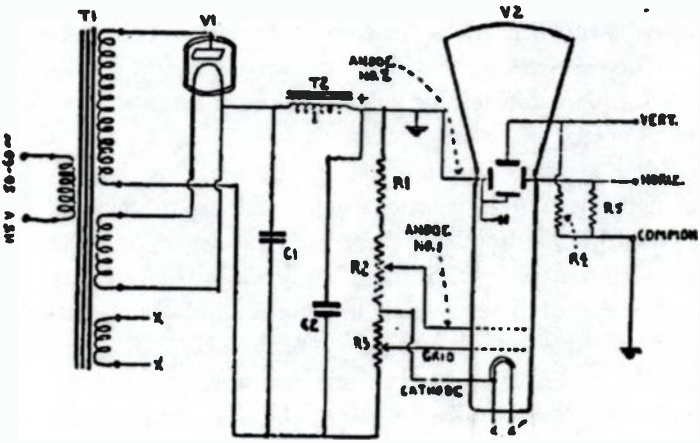


FIG. 1

T-1	Power transformer	R-2	200,000 ohms—Potentiometer
T-2	Impedance coil	R-3	20,000 ohms—Potentiometer
V-1	81 type rectifier	R-4, R-5	10 Meg. ohms—½ watt
V-2	RCA 906 or Equivalent	C1	.25 mfd—1,500 volts
R-1	500,000 ohms—1 watt	C2	.25 mfd—1,500 volts

R2 and R3 should be insulated for 1,000 V.D.C. from chassis and from control knobs.

It is possible to operate this circuit with the cathode of the cathode ray tube grounded provided choke T-2 is placed in the negative leg of the filter instead of the positive as shown.

An easy way to become familiar with the essential circuits involved is to begin with the circuit and details of a 3-inch cathode-ray tube power supply (Fig. 1). This looks very simple. But you may not assume that the balance of the television receiver (sight and sound) is equally easy, hence we look now at a complete block diagram (Fig. 2).

The Radio Frequency Amplifier: The first section of a television receiver is the radio frequency amplifier.

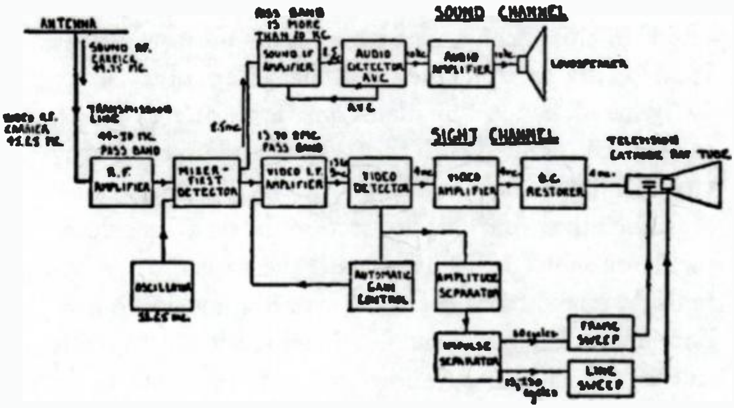


FIG. 2

This section increases the amplitudes of both the sight and sound radio frequency signals without changing their characteristics in any way, and hence must pass all frequencies between 50 and 56 million cycles, or 50 to 56 m.c. In addition, the radio frequency amplifier must reject any other outside carrier or wave outside the 50 to 56 which might cause interference. The amplified sight and sound radio frequency signals are fed into the first detector section and there are combined with the unmodulated radio frequency signal produced by the local oscillator. A video intermediate frequency or i.f. value of somewhere between 10 and 15 m.c. is favored by television engineers, since it permits the use of simple preselector or antenna tuning circuits, while still providing a reasonable degree of selectivity.

Let us assume that the video intermediate frequency or i.f. in this receiver is 13 m.c. This means that the local oscillator frequency will be 51.25 plus 13, or 64.25 m.c. The local oscillator delivers a sine wave output, which is mixed with the incoming radio frequency currents to produce the desired intermediate frequency.

In the mixer-first detector section the 64.25-m.c. local oscillator signal will "beat" with the 51.25-m.c. video radio frequency carrier and its side frequencies to produce a video carrier signal of 13 megacycles, along with side frequencies ranging down to 9 m.c. and up to 14.25 m.c. At the same time, the 64.25-m.c. local oscillator signal will beat with the 55.75 m.c. radio frequency carrier of the sound signals and its side frequencies to produce an 8.5 m.c. sound intermediate frequency signal, with side frequencies extending for 10 kilocycles or k.c. (ten thousand cycles) in either direction. These intermediate frequency signals will have essentially the same characteristics as the original signals.

The video signals are separated from the audio signals by the two intermediate frequency mixer-first detector tube circuits from which they feed into an audio intermediate frequency or i.f., and a video intermediate frequency channel.

THE SOUND INTERMEDIATE FREQUENCY AMPLIFIER: This amplifier section must pass the complete 20-k.c. (kilocycle) wide range of frequencies associated with the 8.5 m.c. sound intermediate-frequency carrier, and must be enough wider to permit passage of the entire sound intermediate-frequency signal, despite any normal frequency drift of the local oscillator circuit.

THE AUDIO DETECTOR: This should be a diode, so as to serve also for a.v.c. (automatic volume control) purposes. The output circuit of the audio demodulator or detector should have a simple radio frequency filter to reject intermediate frequency signals.

THE AUDIO AMPLIFIER: The signal, if originating in a high-class, high-fidelity television sound transmitter, will have at the output of the audio demodulator a maximum frequency of 10 k.c. (10,000 cycles). This audio signal is fed into a conventional audio amplifier, where it undergoes power amplification before being converted into sound by the loudspeaker.

THE VIDEO INTERMEDIATE FREQUENCY AMPLIFIER: The video "i.f." (intermediate frequency) amplifier must have a pass band of from 9 to 13 megacycles and a frequency response characteristic which will suppress the undesired side frequencies (those above the 13 megacycle frequency of the intermediate frequency carrier).

The amplified video i.f. signal passes into the video detector section, where its envelope is "stripped" from

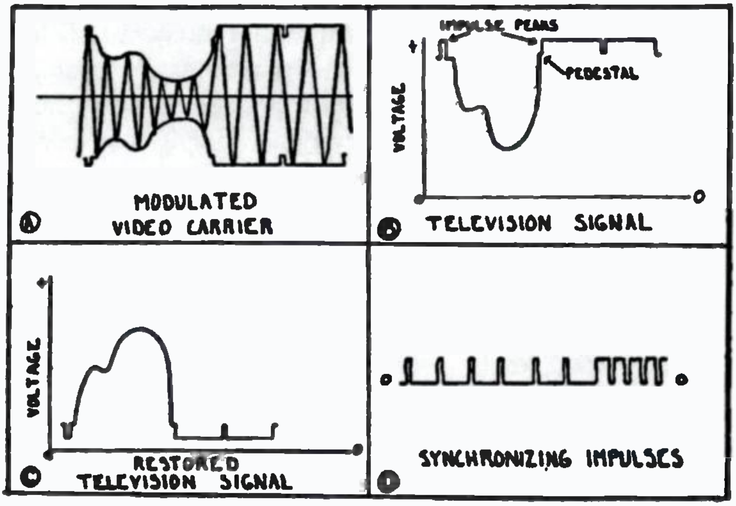


FIG. 3

the carrier. Fig. 3A shows the modulated radio frequency video carrier, while Fig. 3B shows the resulting demodulated, or "detected" video signal. The video detector circuit will usually employ a diode tube for rectification, followed by a condenser-coil filter circuit which rejects all i.f. components while passing the entire television signal ranging from 10 cycles to 4 megacycles, or higher. This demodulated television signal, consisting of the synchronizing impulses and the video signal, is actually a pulsating d.c. (direct current) signal. The signal voltage across the load resistor of the diode video detector is therefore a pulsating d.c. voltage, with the pedestals all lined up at one d.c. voltage value and the impulse peaks lined up at another d.c. voltage value. Automatic gain control circuits are used in professional video receiving but are not described here.

THE VIDEO AMPLIFIER: The phase of the television signal applied to the image-producing cathode-beam tube must be opposite that of the signal in Fig. 3B. Now each video amplifier stage reverses the phase, and consequently both the phase and the amplification requirements must be considered when designing the video frequency amplifier. One stage will give sufficient amplification for small cathode-beam tubes; this will usually be a d.c. amplifier stage, but passing both the alternating and direct current components of the television signal. When more than one video frequency amplifier stage is required, resistance-capacitance coupling will be used between the stages, but this passes only the a.c. component.

A good video frequency amplifier must amplify equally well over a range extending from about 10 cycles to about 4,000,000 cycles. Its successive stages must not introduce "phase distortion,"* for any distortion of this

* Phase distortion: the slight shifting along the line of scan of the picture elements from their proper position.

type will cause elemental impressions of gray, white or black to be shifted either ahead of or behind their proper positions along a line.

Removal of the direct current component (which results from repeated amplification) throws the pedestals of a television synchronizing signal out of line. We have remaining only an a.c. signal. This means that when resistance-capacitance-coupled video frequency amplifier stages are employed, a d.c. restorer section must be used to restore the lost d.c. component and re-align the pedestals. This section adds to the a.c. television signal a direct current voltage to make the pedestals line up again. The restored television signal with the correct phase is shown in Fig. 3C.

We have seen that the two anodes in the cathode beam tube serve to focus the electron beam to a small point on the screen. The application of a television signal to the control grid of this tube serves to modulate the beam, in other words varying the brightness of the spot on the screen. Since the impulses are more negative than the video signal (see Fig. 3C), the impulses and the blanking level prevent retraces from being visible during the fly-back period.

We have also seen that while the electron beam is being modulated by the television signal, it is simultaneously being swept back and forth both horizontally and vertically by saw-tooth shaped voltages, produced by the line and frame sweep generator sections. In accordance with present RMA standards, the horizontal sweep will have a frequency of 13,230 cycles per second, and the vertical sweep will have a frequency of 60 cycles per second. In time, as larger pictures become practical in the home this line frequency will undoubtedly be substantially increased.

The line and picture synchronizing impulses are sent along with the video signal. These impulses must be separated from the video signal, after which the horizontal synchronizing impulses must be separated from the vertical impulses. Finally, each type of impulse must control the start of its own "saw-tooth" sweep circuit.

THE AMPLITUDE SEPARATOR: If we pass the demodulated television signal shown in Fig. 3B through a triode tube which has a high negative bias, only the positive peaks of the signals (the impulses) will cause variations in plate current. We thus have only these peak impulses in the plate circuit of this triode. Since this separation of impulses from video signals is dependent upon the amplitude of the television signal, the section containing this triode tube is referred to as the amplitude separator. The signal at the output of this section will appear as in Fig. 3D. It now contains only the horizontal impulses, the serrated vertical or field impulses, and any equalizing pulses transmitted along with them.

Now the next problem is the separation of the serrated vertical impulses from the line and equalizing impulses. This is accomplished in the impulse separator section of the block diagram, which also converts the serrated vertical impulses into single impulses by an integrating action. These separated impulses are now fed into the frame (vertical) sweep oscillator and the line (horizontal) sweep oscillator, where they control the starting times of these horizontal and vertical sweeps.

THE RECEIVING ANTENNA: A doublet type antenna with twisted two-wire transmission line is generally the best for the purpose. Better results are obtained with a doublet which is resonant or tuned at a middle frequency in the entire range to be received. Such is called a half-wave-length antenna. This calls for resonance at 79 megacycles, which is about midway between 50 megacycles and 108 megacycles. An antenna approximately 2 meters (6.6 feet) long will furnish signals to the transmission line on all television channels. Each half of the doublet is only one meter long; thus television receiving antennas are considerably shorter than ordinary broadcast or short-wave antenna. This antenna does not become the inefficient full-wave doublet until about 150 megacycles is received, considerably higher than any regular television channel in Group A.

A transmission line leading from the doublet down to the television receiver, and having a surge impedance of about 100 ohms, is satisfactory for a television receiver. With this line, no antenna matching transformer will be necessary at the center of the doublet antenna. The twisted transmission line will inherently reject noise signals; these will flow down both wires in the same direction to the center tap on coil L_1 in Fig. 4, then flow to ground. The transmission line may be any reasonable length. A long twisted line loads the antenna and broadens its tuning, which is a desirable condition in that it tends to make the sensitivity of the antenna more uniform for all television channels. Further details regarding this subject appear in a subsequent chapter.

THE RADIO FREQUENCY AMPLIFIER: The preselector or radio frequency amplifier has two important functions. It must amplify equally well all signal components in the television channel to which it is tuned, and it must exclude image frequency signals outside of this channel. In a sight-sound television superheterodyne receiver we must consider two image interference signal frequencies, both of which lie above the desired television channel. If, for example, the preselector or antenna circuit is tuned to a 50-56 megacycle channel, one image interference frequency will be 77.25 megacycles, for an undesired signal at this frequency could beat with the 64.25 megacycle local oscillator signal to produce the correct 13 megacycle value for the video intermediate frequency channel. (Because the difference between 77.25 and 64.25 is 13 megacycles.) The other image interference frequency will be 72.75 megacycles, because this will beat with the 64.25 megacycle oscillator signal to produce the correct 8.5 megacycle value for the sound intermediate frequency channel. Such frequencies which interfere with the intermediate frequency of a heterodyne receiver are called "image frequencies."

The response of the preselector can be made essentially uniform over a band width of 6 megacycles by

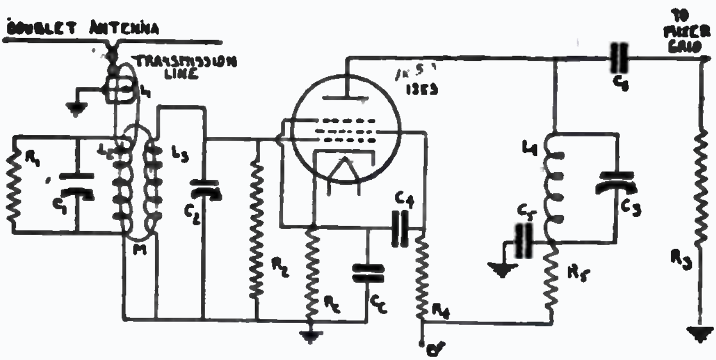


FIG. 4

L_1 = 3 turns #18 ½" dia. form
L_2, L_3, L_4 = 6 turns #18 ½" dia. form
R_1, R_2, R_3 = 2500 ohms
R_4 = 30,000 ohms
R_5 = 2,000 ohms
C_1, C_2, C_3 = 50 mmfd.
RC = 250 ohms
C_c, C_4, C_5 = .05 mfd.
C_6 = 100 mmfd.

employing three tuned circuits. Two of these are resonant to considerably different frequencies and are used in a "pass-band" circuit to give the required wide response. Two circuits alone give a deep valley between the peaks of response, so the third circuit is tuned to a mid-frequency and serves to fill in this valley.

Fig. 4 shows one way in which these three tuned circuits can be arranged. Tuned circuit L_2-C_1 is tightly coupled to the tuned circuit L_3-C_2. Resistors R_1 and R_2, having ohmic values which may be as low as 2,000 ohms each, are shunted across these first two tuned circuits to *broaden their response*. The third tuned circuit, L_4-C_3, is in the plate circuit of the first tube. This third parallel-resonant circuit is loaded through coupling condenser C_6 by resistor R_3, which also may have a value of about 2,000 ohms. With proper design, L_4-C_3 can be made to tune broadly in the mid-range of the 6-megacycle preselector pass band, thereby building up the valley in the response curve for the preselector. The values of R_1 and R_2 and the value of mutual inductance M for the first two tuned circuits play important parts in securing the required response to the wide band of frequencies.

The tube used in the preselector section is a pentode radio frequency amplifier. It is shown here with conventional cathode bias. This tube must have characteristics which make it suitable for amplification at ultra-high frequencies. Its interelectrode capacities therefore must be as low as possible, low enough so the preselector can be tuned to the highest desired television carrier frequency when the tuning condensers are set at minimum capacities.

The fact that the load in the plate circuit of the preselector tube has a low resistance, often less than 2,000 ohms, makes it extremely difficult to secure high amplification in this stage.

The mutual conductance of the type 1853 tube indicated in Fig. 4 is 5,000 micromhos;* this tube, designed especially for ultra-high-frequency work, will give an over-all gain of about 10 for the stage. Tubes with even higher mutual conductance values will undoubtedly be developed for use in television receivers in the near future; already we have the type 1852 television tube which has a mutual conductance of 9,000 micromhos.

Filter circuits R_4-C_4 and R_5-C_5, in the screen grid and plate supply circuits respectively of Fig. 4, prevent mutual couplings between stages through the power supply circuits. These filter circuits thus prevent uncontrollable degeneration or regeneration at television carrier frequencies, which is of vital importance. It is imperative we prevent such feed-backs.

The Oscillator and First Detector: This process of frequency conversion by "beating" is basically the same in television superheterodyne receivers as in conventional sound superheterodyne receivers. Because we are dealing with ultra-high frequencies, however, precautions must be taken to prevent degeneration and to prevent shifting of the oscillator frequency due to various causes.

* A micromho is the reciprocal of one millionth ohm, $= \frac{1}{0.000001}$ ohms.

Such difficulties are eliminated by the use of a separate oscillator tube, and feeding its output into the mixer-first-detector circuit by means of a connection to an injector grid. Combination triode-hexode tubes built into one envelope have been developed for this purpose. The type 6K8 tube is typical of these. The more conventional circuits may be employed in this section of a television receiver, but invariably there will be separate oscillator and mixer-first-detector tubes (not pentagrid converters) in ultra-high-frequency circuits. (Marvelously that simple little triode "audion" of 1906 has blossomed out!)

Coil L and tuning condenser C determine the frequency of oscillation in the circuit of Fig. 5. The voltage developed across the L-C oscillator tank circuit is electronically injected into the mixer (hexode) section of the 6K8 tube by means of an internal connection between the triode grid and the first grid (the injector grid) of the hexode section. This is a sample of so-called "electron coupling."

Coil L_2 is common to both intermediate frequency amplifier channels, and is broadly tuned by C_2 so that signal voltages of both beat frequencies are developed across it for transfer to the next section through coupling condenser C_3.

THE VIDEO INTERMEDIATE FREQUENCY AMPLIFIER: This process of frequency conversion produces video intermediate frequency signals ranging from 9 to 13.25

megacycles; and sound intermediate frequency signals extending for about 10 kilocycles on either side of 8.5 megacycles. The intermediate frequency amplifiers in

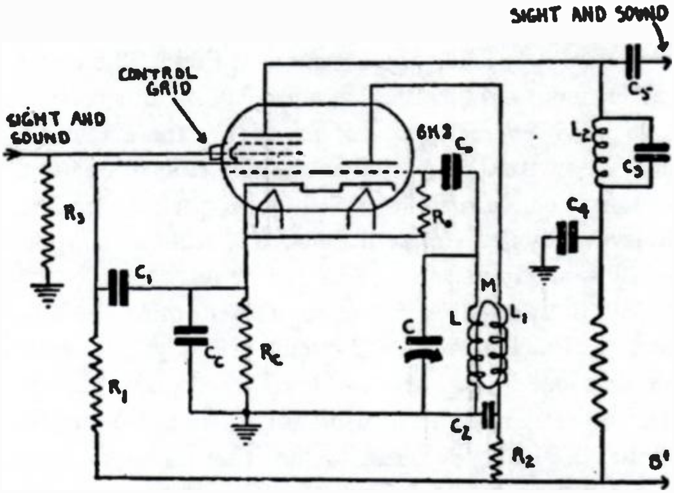


FIG. 5

R_1, R_3 = 20,000 ohms
R_2, R_4 = 2500 ohms
R_5 = 50,000 ohms
R_0 = 250 ohms
C_1 = 15 mfd.
C_2 = .05 mfd.
C_c = 50 mmfd.

L = 3 turns #18 on ½" dia. form
L_1 = 4 turns #18 on ½" dia. form
L and L_1 space wound and closely coupled
L_2 = 7 microhenries
C_3 = 100 mmfd.

a television receiver must separate and amplify these signals.

The video intermediate frequency amplifier must be reasonably flat from 13 megacycles to 9 megacycles; if peaked at all, it should be at about 9 megacycles, to compensate for attenuation of the higher-frequency signal components (near 4 megacycles). It is equally important that signals below 9 megacycles in frequency be attenuated, in order to prevent 8.5 megacycle sound intermediate frequency signals from getting through the video intermediate frequency channel.

The circuit for a typical intermediate frequency amplifier stage is shown in Fig. 7. Here again three resonant circuits (L_2-C_3, L_1-C_1 and L_3-C_6) are employed to give the required wide response characteristics shown in Fig. 6. Note that the parallel-resonant plate circuit L_2-C_3 is coupled to parallel-resonant grid circuit L_3-C_6 by coupling condenser C_5 and parallel-resonant circuit L_1-C_1. The value of C_5 is usually about 500 microfarads. This condenser serves primarily to block off the direct plate current.

Circuits L_2-C_3 and L_3-C_6 form a pass-band resonant circuit which gives a resonant response characteristic having two widely separated peaks. Resistor R_1, having a value of about 2,000 ohms, loads this pass-band circuit, broadening the response characteristic and making the peaks less sharp. By properly adjusting condensers C_3 and C_6, it is possible to make the response peak near 9 megacycles greater than the peak near 13 megacycles, as is shown in Fig. 6 (Page 150).

With L_1-C_1 out of the circuit, the sides of the response characteristic would drop more or less gradually; this would be satisfactory for the high frequencies above 13 megacycles, but would be undesirable at the low video frequencies because it would allow a portion of the 8.5 megacycle sound intermediate frequency signal to enter the video channel. It is for this reason that the resonant circuit L_1-C_1, tuned to 8.5 megacycles, is employed. This circuit rejects the 8.5 megacycle sound intermediate frequency signal and attenuates signals just

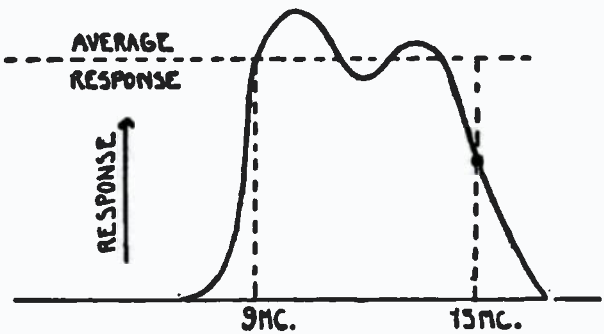


FIG. 6

below 9 megacycles, thereby giving the desired steep side for the response characteristic.

The insertion of L_1-C_1 also provides a suitable connecting point (a) from which the intermediate frequency sound signal can be fed into its proper channel. For signals at 8.5 megacycles, L_1-C_1 will act as a high resistance (any parallel-resonant circuit behaves like a high resistance at resonance), while parallel-resonant circuit L_2-C_2 will act as a low reactance at 8.5 megacycles because it is tuned to a higher frequency (13 megacycles). Practically all of the voltage of the sound intermediate frequency which exists between point "a" and ground will therefore appear across L_1-C_1 for transfer into the sound channel, and very little will be developed across L_3-C_8 for transfer to the sight channel. The sound intermediate frequency channel, being more or less conventional in design, will not be considered here.

Automatic gain control is very essential for maintaining the proper light values in a television picture.

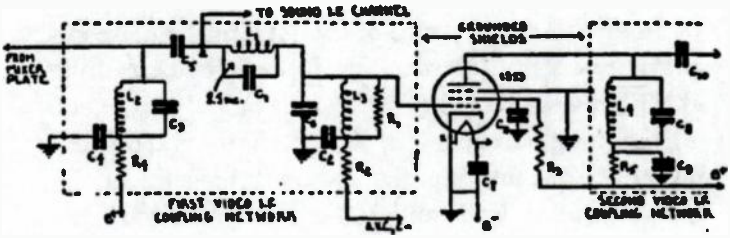


FIG. 7

C_2, C_4, C_6, C_7, C_9, C_{10} and C_{11} = .01 mfd.
C_5, C_1, C_3, C_8 = 50 mmfd.
L_1, L_2, L_3 = 7 microhenries
L_4 = 9 microhenries
R_4, R_5, R_1 = 2000 ohms
R_2 = 1 meg.
R_3 = 30,000 ohms

The voltage required for this purpose for the video amplifier stage in Fig. 7 is supplied to the control grid of the type 1853 tube through filter and time-delay circuit R_2-C_2 and through L_3. The cathode of the tube is grounded to the chassis.

It is important to note that condenser C_7 in the video intermediate frequency amplifier stage provides a path to ground for any radio frequency signals which may be in the filament circuit, thereby preventing these signals from entering other circuits. Because high-frequency currents flowing from the cathode through leads parallel to the filament, or heater, leads would cause undesirable interaction between amplifier stages if they were not shunted to ground by this .01 microfarad condenser C_7. This filament by-pass condenser may be found in any or all stages of a television receiver up to and including the video detector and audio detector stages. It is an important element of the design.

In Fig. 7 the impedance of the load in the plate circuit of this stage (the combined effects of everything within the dotted box in Fig. 7) will be less than 2,000 ohms at these frequencies in use. Each video intermediate frequency amplifier stage will have essentially this same plate load, and consequently the gain per stage will be very low. With tubes having a high transconductance, an amplification of from 10 to 15 per stage is possible. This means that at least two, and usually three amplifier tubes are required for the video intermediate frequency channel of your television receiver.

The Video Detector: The television signal at the output of the sight intermediate frequency amplifier is still of the form shown in Fig. 3A. This signal will usually be fed into a detector circuit which cuts off one-half of each cycle of the intermediate frequency current. By passing the modulated carrier through a "low-pass" filter which blocks all signals above 4 megacycles, we obtain the desired television picture element signal, having a frequency range of from about 10 cycles to about 4,000,000 cycles. This demodulated output signal of the video detector will have the form shown in Fig. 3B, as already pointed out.

Now let us consider a typical video detector circuit such as that shown in Fig. 8A. The video i.f. amplifier

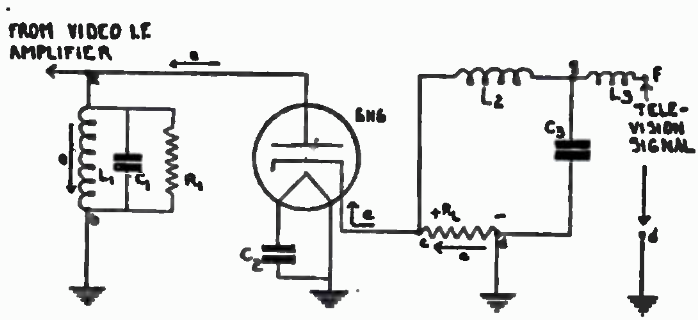


FIG. 8A

R_1 = 2,000 ohms
L_1 = 7 microhenries
L_2, L_3 = 30 microhenries

C_2 = 30 mmfd.
C_3 = .01 mfd.
C_1 = 50 mmfd.

output signal, existing across the final resonant circuit L_1-C_1 of the video i.f. amplifier, sends electrons through a load made up of the diode detector tube (one-half of a type 6H6 tube) and resistor R_L, producing across R_L a pulsating d.c. voltage. The low-pass filter network L_2-C_3-L_3 shunts to ground through C_3 all alternating current (a.c.) components above 4 megacycles, so that the video detector output voltage contains only the desired a.c. components and the d.c. component of the demodulated television signal. The pedestals for the line and frame impulses will then all line up at the same level.

The direction of electron flow through the diode load resistor R_L determines whether impulses will make

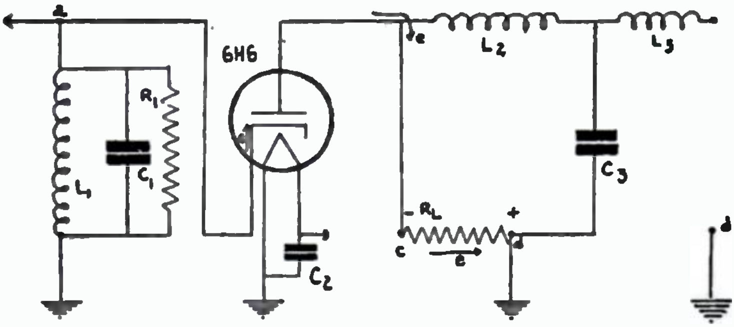


FIG. 8B
Same electrical constants as 8A.

the output terminal *f* swing in a positive direction or in a negative direction with respect to the chassis. In the circuit of Fig. 8A, electrons enter R_L at point *d*, making the end of the resistor negative with respect to point *c*. Under this condition the video detector output voltage (a modulated d.c. voltage) will vary as shown in Fig. 9A, with the impulses making point *f* swing more positive, and with bright areas in the original scene making point *f* swing in a negative direction from the pedestal level. Since this corresponds to negative modulation such as is employed at the transmitter, the modulated d.c. signal is in this case said to have a negative picture phase, as specified by RMA. The required addition of

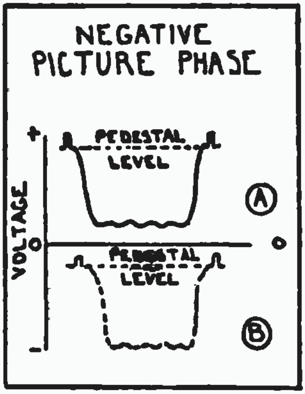


FIG. 9

a d.c. bias voltage to a video frequency television signal has no effect upon the phase of the signal.

The Video Amplifier: Unfortunately, the output of the video detector is not sufficient to drive the control grid of the cathode ray tube directly; amplification is required.

Remember the video frequency amplifier must respond more or less uniformly to signals over the entire range of from 10 cycles to 4 megacycles. This means that resistive loads must be used, and these in turn introduce the problem of phase reversal, because a resistance-capacitance-coupled video amplifier stage will reverse the picture signal phase (Fig. 9A) when fed into that stage. In other words the signal at the output of that stage will have a positive picture phase, because a resistance-capacitance-coupled amplifier stage thus reverses the phase of the applied signal.

If two stages of v.f. amplification are employed after the video detector in order to secure the required television signal voltage at the input of the cathode ray tube, the video detector circuit must be of the type shown in Fig. 8B, delivering a signal with a positive picture phase.

If either one or three stages of v.f. amplification are employed, the video detector circuit must be of the type shown in Fig. 8A, delivering a signal with a negative picture phase.

In high-definition reproduction of television signals it is absolutely essential that the pedestals shall all line up at the same constant level at the input of the cathode ray tube. When this condition is met, it is possible to adjust the bias on the cathode ray tube so that the synchronizing, or sweep impulses will always drive the spot into the "blacker-than-black" region, while video signals will always make the spot more or less bright. It is a fundamental fact that the demodulated or detected television signal (including the impulses and equalizing pulses along with the video signal) will retain its alignment of pedestals only as long as it has its d.c. component.

The only way in which we can amplify the d.c. component along with the television signal, thereby retaining the alignment of pedestals, is by using d.c. amplifier stages in the video amplifier. Unfortunately, however, the use of the d.c. amplifiers introduces serious practical problems. These amplifiers require higher plate supply voltages, draw more power from the power supply, are unstable in operation, and cause an undesirable direct connection between low and high-voltage supply circuits.

With only one stage of video frequency amplification, it is possible to connect the load of this stage directly to the cathode and grid of the cathode ray tube, giving true d.c. amplification. With two or more stages in the video amplifier, a practical solution involves the use of resistance-capacitance coupling; this allows each tube to be supplied with plate voltage from a common B+ terminal, but the coupling condenser removes the d.c. component from the television signal.

It is important to visualize what happens to a demodulated television signal when it is passed through a condenser. Signal I in Fig. 10 corresponds to a line having maximum and uniform brightness, while signal II corresponds to a solid black horizontal line on the scene being televised. These two signals are shown as they would appear across the detector load resistor, so the pedestals all line up at a constant level with respect to the zero-voltage line. Each signal is made up of an a.c. component (having equal areas on each side of the average-value line for each cycle) and a d.c. component, with the average values of the a.c. components considerably out of line, and with the d.c. component for the black line considerably larger than for the bright line. When these television signals are passed through a condenser, the d.c. components are blocked out,

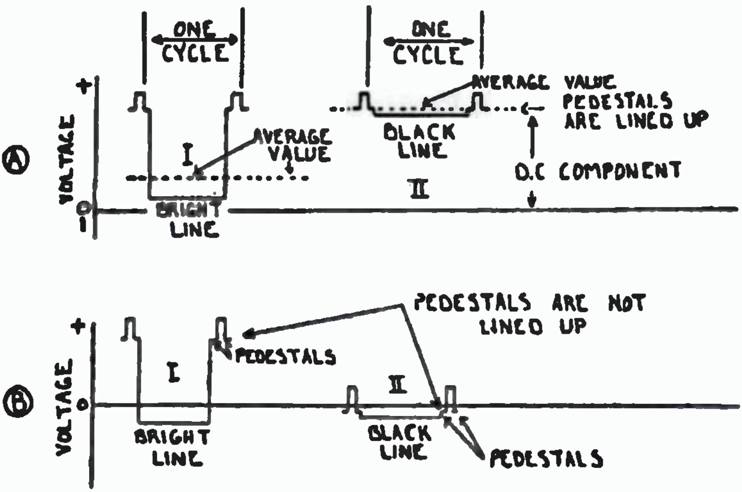


FIG. 10

bringing the average-value lines down to the zero-line. As a result, the average values of the a.c. components line up at zero (as in Fig. 10B) after the signal has passed through the condenser. Obviously the pedestals are no longer lined up.

The addition of a fixed d.c. bias voltage to the a.c. signals shown in Fig. 10B (placing the signal either entirely above or entirely below the zero-voltage line).

would convert them into pulsating d.c. signals, but would not get the pedestals in line again. We must add a different d.c. bias voltage value for each line if we are to make the pedestals all line up again after a television signal has passed through one or more condensers.

With the pedestals in an a.c. television signal all at different levels, it is impossible to line up all the pedestals with the cut-off point or level of the cathode-beam tube. Remember, however, that we chose two extreme line conditions in Fig. 10. When the average brightness of a line is about the same for all portions of the televised scene, the difference between the pedestal levels will not be anywhere near as great as that shown in Fig. 10. Under this condition it is possible to secure fairly satisfactory image reproduction by adjusting the bias on the "grid" electrode of the cathode-beam tube to correspond to the average brightness level (average pedestal level in the a.c. signal).

For high-fidelity reproduction a d.c. restorer is essential, but on small low-priced television receivers it is sometimes omitted.

A Typical Video Frequency Amplifier Stage: Assuming that we have a television receiver which requires three video frequency amplifier stages between the video detector circuit shown in Fig. 8A and the cathode-beam tube, we can consider the type 1851 tube circuit shown in Fig. 11 as being typical of that employed in the first video frequency amplifier stage. From the detector load resistor R_L, the television signal passes through a filter which removes the intermediate fre-

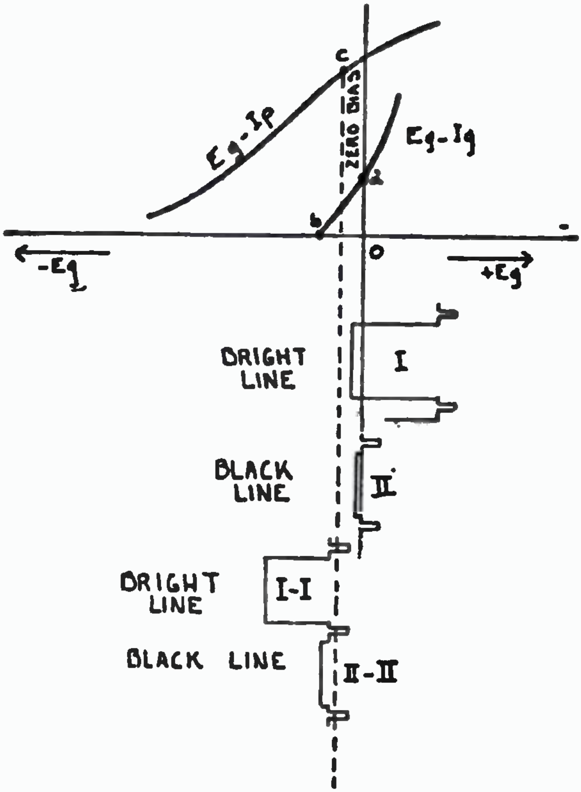


FIG. 11

quency components, then passes through coupling condenser C_1, which strips off the d.c. component. Only the a.c. component of the television signal is thus applied to the control grid of the type 1851 tube. This first video frequency amplifier tube employs self-bias, the amount of which is controlled by the value of the cathode resistor R_2 and is applied to the control grid through resistor R_1.

The remainder of this video frequency amplifier circuit is more or less conventional except for the presence of the choke L in the plate load of the tube, but very careful circuit design is necessary in order that the required wide range of frequencies be passed with negligible frequency attenuation and negligible phase distortion. In this introduction to the study of television circuits, it is only possible to indicate a few of the design features which must be given consideration when building television receivers. But sufficient information is here given to enable a careful amateur to design and construct an excellent practical television receiver for his own use.

One fundamental consideration in building a video frequency amplifier stage like that in Fig. 11 is the value of the hypothetical capacity C. This capacity is shown dotted in the diagram, since it is a combination of the output capacity of the first stage, the input capacity of the second stage and stray lead capacities coupled together by C_x. The reactance of this capacity to ground becomes low enough, at the higher video frequencies being amplified, to provide a serious shunting effect. The presence of this unavoidable capacity can be neutralized to a certain extent, however, by keeping the plate load resistor R low in ohmic value, somewhere around 2,000 ohms. With such a low plate load value, tubes with a high transconductance are needed to provide the required amount of amplification.

Even more important than the attenuation of high-frequency components in the video signal is the phase distortion which is produced by Capacity C. The coil L is introduced in the circuit for two reasons:

1. Its inductive reactance partially or totally balances out the capacitive—reactance of C, thereby eliminating or at least reducing the amount of phase distortion;

2. If the value of coil L is properly chosen, L and C can be made to resonate at the higher video frequencies, thereby giving a broad parallel-resonant circuit which boosts the gain at the higher frequencies and thus counteracts the shunting effect of capacity C. The value of coil L thus depends upon the capacity of C, upon the ohmic value of the load resistance, and upon the amount of phase correction which is desired.

Remember that a video amplifier must handle frequencies down to as low as 10 cycles. At frequencies below about 60 cycles, coupling condenser C_x will not allow square-top impulses or flat (constant-level) video signals to pass without causing a gradual drop in the flat top; this means that more than normal amplification is required at these low frequencies. It is necessary that the by-pass condenser C_4 have a high capacity in order to prevent low signal frequencies from passing through the power supply and causing either regeneration or degeneration.

In addition to its other functions, filter circuit R_2-C_2-C_4 prevents video frequency signals from entering the power supply. To be effective at low frequencies (below 60 cycles), the condensers in these filters must

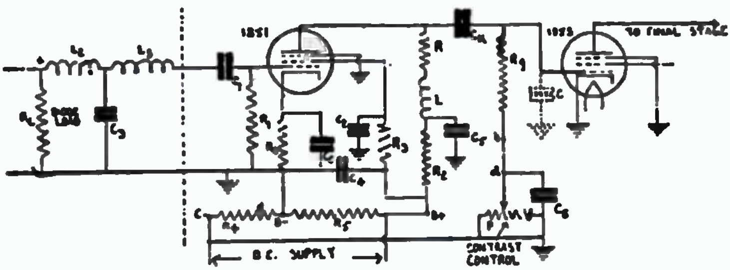


FIG. 12

R_L = 5,000 ohms	C_3 = 8 mfd.
C_0 = 30 mmfd.	C_5 = 2.5 mfd.
L_a, L_b = 30 microhenries	R_3 = 2500 ohms
C_1 = .15 mfd.	L = 75 microhenries
R_1 = .25 meg.	R = 2000 ohms
R_2 = 300 ohms	C_K = .15 mfd.
C_2 = 25 mfd.	R_g = .5 meg.
C_4 = 20 mfd.	

have high capacity, oftentimes as much as 80 microfarads. Electrolytic condensers are a logical choice for these high capacities, but it is important to know that at high frequencies their by-pass action is considerable due to the inductive reactance of the spirally-wound foil strips in the condenser, a fact not generally appreciated. It is for this reason that electrolytic condensers in television circuits are generally shunted with noninductive mica or paper condensers of about .05 microfarads. Condenser C_8 in Fig. 12 will have less capacity than C_6, C_2, or C_4, for C_8 must not by-pass the very low signal frequencies.

With a d.c. video amplifier, self-bias should not be used.

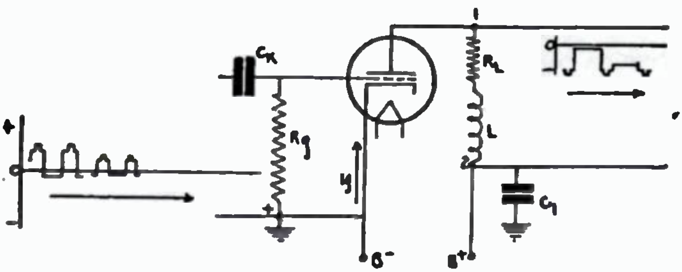


FIG. 13

The variable C bias arrangement for the type 1853 tube in Fig. 12 provides a manual picture contrast control. The contrast control potentiometer P is connected in parallel with voltage divider section R_4, and consequently the C bias voltage can be varied from zero to the potential of the C—terminal of the power supply.

The D. C. Restorer: The d.c. component of a television signal can be restored in the output stage of a resistance-capacitance-coupled video amplified in such a way that the pedestals will all line up at the same potential, simply by eliminating the fixed C bias in this last stage and allowing the impulses which are applied to the grid of this tube to develop their own C bias by means of the rectified grid current flow through a grid resistor of high ohmic value.

A typical video output circuit which reverses the phase of the a.c. signal and at the same time restores the d.c. component in the correct manner to make the pedestals line up is shown in Fig. 13. Component L in this circuit is designed to give gain equalization, while R_L and C_1 serve their usual functions as plate load and plate by-pass condenser respectively. When an a.c. television signal of the form shown at the left in Fig. 13 (having a negative picture phase) is applied to this circuit, the output signal will be of the form shown at the right, with pedestals all lined up to give proper restoration of the d.c. component and with the positive picture phase required by the cathode beam tube.

Grid resistor R_g plays an important part in the d.c. restoration process. This resistor has a high ohmic value, generally between .5 and 1 megohm.

We are thus applying, in series with the television signal, a d.c. voltage whose value is proportional to line brightness. If the ohmic value of R_g is made sufficiently high, the impulses alone will be sufficient to produce the grid current required for this form of automatic C bias and d.c. restoring action, but use of part or all of the video signal for this purpose would result in undesirable amplitude distortion.

The "time constant" (product of capacity and resistance) of parts C_2 and R_g in Fig. 13 must be so chosen that it is at least equal to the time period for one line, in order to make the instantaneous grid bias dependent upon the average brightness of a line. Since average brightness ordinarily does not change rapidly from line to line, the time constant can be increased considerably; in fact, a time constant equal to the time of about ten lines appears to be quite satisfactory.

THE CATHODE-BEAM TUBE: The C bias voltage for the control "grid" or control electrode of the television cathode tube must be a value which will make the pedestals in the television signal line up with the cut-off point on the grid voltage-brightness characteristic curve for the television cathode ray beam.

A video output circuit which is satisfactory under all conditions is shown in Fig. 14. When a set having this circuit is turned on, the power pack tube may heat up first, making point 4 on the voltage divider negative with respect to point 5. Since the cathode of the "duo-diode-triode" output tube has not yet become heated, no current flows through the diodes to potentiometer P and plate load R_L. The control grid of the television cathode ray tube is thus driven negative the instant the set is turned on, for the negative potential of point 4 (with respect to point 5 and cathode K of the television cathode tube) is applied to the control electrode G_1.

As soon as the video output tube heats up, plate current will flow through R_L, and the drop across it will drive the grid of the cathode tube even more negative with respect to its cathode. At the same time the diode becomes conductive, so a part of this increased negative voltage is offset by the positive voltage between the movable arm of P and point 5. With a proper

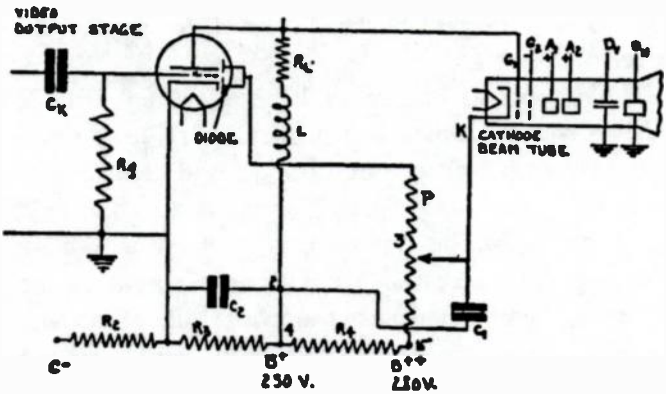


FIG. 14

C_K = .15 mfd.	R_2 = 1,000 ohms
R_g = .5 meg.	R_3 = 7,000 ohms
R_L = 2,000	R_4 = 1,500 ohms
L = 75 microhenries	C_1 = 8 mfd.
L_4 = 5,000 ohms	C_2 = 16 mfd.
P = 100,000 ohms	

choice of values for P and R_1, and proper adjustment of the movable arm on P, sufficient positive voltage can be applied to the cathode tube in series with the negative voltage drop across R_L and L to make the pedestals line up with the cut-off point of the "grid" electrode. Since adjustment of P varies the brilliancy of the scene, this potentiometer is commonly called the "brilliancy control."

When no television signal is present, the C bias on the triode in Fig. 14 becomes zero, maximum plate current flows through R_L and L, and the control grid of the cathode tube consequently gets a bias corresponding to a point beyond cut-off, darkening the spot on the screen.

The important electrodes in a television cathode tube are shown in schematic form in Fig. 14. In addition to the electron emitter (the cathode) and control electrode G_1 (the control "grid"), there is a second grid G_2 (often called the "screen grid") which is positive with respect to the cathode and serves to accelerate the electrons, thereby increasing the spot brilliancy. Anodes A_1 and A_2, which are positive with respect to the cathode, provide further acceleration of the electrons. Anode A_2 is higher in potential than A_1, and the difference in potential between these two anodes serves to produce an electric field which makes the electrons focus to a small point on the screen. Finally, there are electrostatic deflecting plates Dv and DH (or deflecting coils) which serve to sweep the beam horizontally and vertically across the screen. We have already considered the sweep circuits for tubes employing electrostatic deflecting plates, but a brief review here may help you.

THE SWEEP CIRCUITS: First consider the case where one of each pair of deflecting plates in a television cathode tube is grounded. The other must therefore be charged first negatively and then positively in order to sweep the beam from side to side or from top to bottom across the screen. The voltage applied to either pair of deflecting plates must have a saw-tooth wave form, as we have previously shown.

The simple circuit shown in Fig. 15 will produce a saw-tooth pulsating a.c. voltage if its grid is controlled

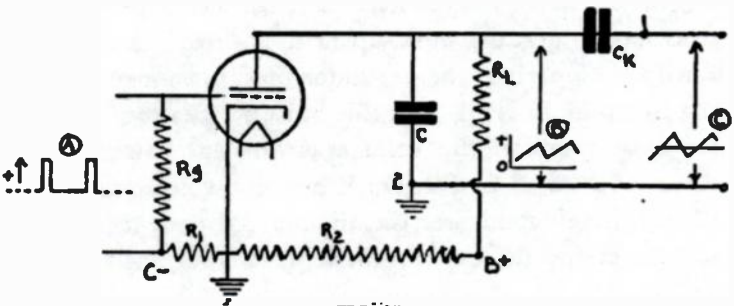


FIG. 15

by impulses, and consequently this circuit is satisfactory for a television receiver. The circuit employs an ordinary high-vacuum triode tube, with plate voltage being applied through resistor R_L. A "C bias" voltage applied through grid resistor R_g makes the grid sufficiently negative to produce a cut-off of the plate current. Under this condition there is no plate current, and condenser C becomes charged to the full plate-cathode voltage of the tube.

Each time a positive synchronizing impulse (A) reaches the grid of this tube, the impulse overcomes the negative grid-bias and makes the tube conductive for the duration of the pulse. Condenser C then discharges through this tube, which has a definite resistance when conductive. At the end of an impulse, the plate current flow stops and the condenser C charges up again through the resistor R_L. Since the tube when conductive has a considerably lower ohmic value than R_L, the discharge is far more rapid than the charge. We thus have a gradual build-up in the voltage across C until a pulse arrives, then a sudden drop in voltage during the pulse interval, with this process repeating itself for each impulse, the voltage having the saw-tooth wave shown at B in Fig. 15. When this voltage is applied through condenser C_K, the d.c. component is removed, giving the a.c. saw-tooth wave shown at C in Fig. 15.

The chief drawback to the use of the saw-tooth generator circuit in Fig. 15 by itself is the fact that the shape of its saw-tooth output wave depends upon both the amplitude and the duration of the synchronizing impulses fed into it. It is absolutely essential to maintain a constant and correct saw-tooth sweep voltage at all times, yet the synchronizing impulses are never sufficiently constant nor free from interference under practical receiving conditions to provide this voltage. For this reason, according to present RMA standards, we need, ahead of each saw-tooth generator circuit, an oscillator circuit which will produce impulses of constant amplitude and the correct duration to make the saw-tooth generator circuit produce the required sweep voltage. Each oscillator circuit must produce positive pulses at a rate slightly lower than the correct frequency for that generator, and must be so designed that its frequency will be increased to the correct value automatically when fed with the synchronizing impulses associated with the television signal.

An oscillator circuit which meets these requirements is shown in Fig. 16; it is known as a "self-blocking oscillator." Transformer T in this circuit provides feed-back from the plate circuit to the grid circuit.* Transformer connections are such that when the circuit is in operation, the feed-back voltage drives the grid positive, just as in a conventional oscillator. The secondary half cycle drives the grid highly negative and at the same time charges condenser C. This charging action lasts only for a very brief interval, equal to the time required for the negative grid to stop all electron flow in the entire circuit. Condenser C then begins discharging through resistor R at a rate determined by the values of C and R (both R_1 and the grid winding of transformer T have a low resistance, and consequently one terminal of T can be considered as connected to ground during this discharging process). When enough of the charge on C has leaked off to lower the negative C bias on the grid sufficiently to allow plate current to flow again, feed-back re-occurs, driving the grid positive and causing a repetition of the entire cycle.

* The writer discovered this type of feed-back circuit in the Palo Alto Laboratory in 1912 while designing a cascade amplifier to be used as the first electronic telephone relay.

The frequency of the self-blocking oscillator circuit in Fig. 16 is controlled by the ohmic value of variable resistor R, for this controls the time constant of C and R. The natural frequency of blocking should always be lower than the frequency of the impulse fed into the circuit. Under this condition, impulses will arrive just before C has discharged to the point where the tube begins conducting. An impulse will swing the grid

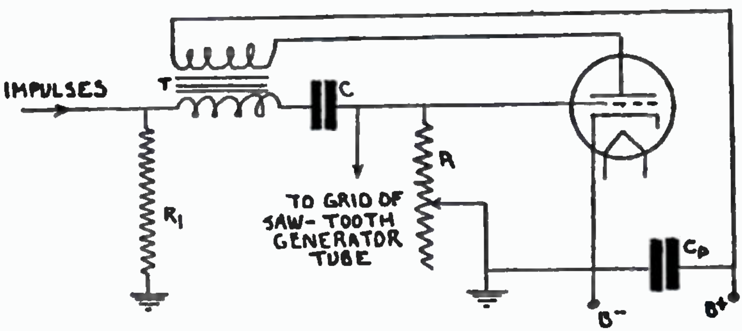


FIG. 16

positive almost instantly, starting a new cycle a short time before it would normally occur. The same form of impulse is produced by this self-blocking oscillator regardless of the amplitude and duration of the synchronizing impulses (provided the amplitude is sufficient to swing the grid positive). Synchronizing impulses thus control the exact frequency of the new impulses which are fed into the saw-tooth generator, and these new impulses always have the correct amplitude and duration to produce the desired sweep voltage.

In an actual television receiver, resistor R is of the semi-adjustable type and is adjusted at the factory (or by a "Teletrician," as the television servicing engineer may be styled) to a compromise setting which gives maximum sensitivity to weak impulses and at the same time insures that the impulses will control the frequency of blocking under all normal receiver conditions.

The grid of the self-blocking oscillator circuit in Fig. 16 being highly negative with respect to the chassis except for the duration of each impulse, may be connected directly to the grid of the saw-tooth generator circuit in Fig. 15. With this connection, no separate negative bias is needed for the saw-tooth generator grid, and parts R_2 and R_1 in Fig. 15 may therefore be omitted. Usually these two triodes are in a single envelope, with a double-triode tube, such as the type 6N7 tube, serving both circuits. One double-triode with its self-blocking oscillator and saw-tooth generator circuit must be provided for the horizontal sweep, and another similar system for the vertical sweep, with each circuit being adjusted to give the proper sweep frequency.

SPOT-CENTERING CONTROL: The required sweep voltage now exists between points 1 and 2 in the saw-tooth generator circuit in Fig. 17; this voltage must therefore be applied to the deflecting plates of the cathode-ray tube. One way in which this can be done is shown in Fig. 17. One deflecting plate of a pair is grounded, and the other is connected to point 1. The chassis provides the connecting path between the grounded deflecting plate and point 2 in the saw-tooth generator circuit of Fig. 15.

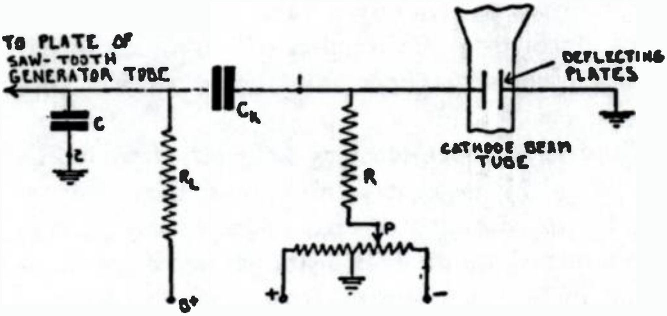


FIG. 17

C = .1 mfd. (frame)
C = .0005 mfd. (line)
R_L = 250,000 ohms
C_K = .15 mfd.
R = .5 meg.
P = 250,000 ohms

It is not economically practical to build a cathode ray tube which will produce a spot in the exact center of the screen when there are no voltages on the deflecting plates. For this reason, we need a biasing voltage which will move the spot to the exact center and thereby center the reproduced image on the screen. A center-tapped potentiometer P in Fig. 17 connected between power supply terminals which are respectively positive and negative with respect to the grounded center tap, will provide the required positive or negative voltage to bias the deflecting plates and center the spot. Resistor R, having an ohmic value of about 1 megohm, must be connected into this bias voltage circuit to prevent shorting of the saw-tooth generator circuit.

Impulse-Separating Circuit: Before the synchronizing impulses which accompany the video signal can be made to control the horizontal and vertical sweep circuits, the impulses first must be separated from the video signal, and then the horizontal impulses must be separated from the vertical impulses.

Either a triode tube which is negatively biased to plate current cut-off, or a diode tube, will separate the impulses from the video signal, provided that only the impulses cause plate current to flow. The television signal which is fed into the amplitude separator circuit can have either a positive or negative picture phase, but in either case the pedestals must be lined up. The latter requirement (alignment of pedestals) makes the use of a negative picture phase more desirable. If the amplitude separator is to be connected to a point in the video amplifier where pedestals are not lined up (where only the a.c. component of the television signal is present) the pedestals as stated before, must be lined up by properly restoring the d.c. component before the signal can be fed into the amplitude-separator tube.

The amplitude separator will have a loading effect upon any stage to which it is connected, even though the separator tube is negatively biased, for the amplitude separator circuit has an input capacity which can affect the high-frequency response of the video amplifier. There is, however, one point in a television receiver to which this input capacity can be connected *without* affecting high-frequency response. Refer back to Fig. 7. There you will note that condenser C_3 in the low-pass filter network is connected across the video detector output. Therefore by connecting the input of the amplitude separator to points d and g in this circuit (across C_3), and lowering the value of C_3 by an amount equal to the correct capacity across the video detector, we will secure the desired connection to the amplitude separator.

One type of amplitude-separator circuit is shown in Fig. 18. This is typical of the circuits which connect to the video detector and provide amplification of the impulses. Tubes VT_1 and VT_2 serve as an a.c. amplifier; two stages are required since we are assuming a negative picture phase at the video detector, and we require this same phase for the d.c. restorer. The gain of this amplifier should be equalized up to at least 250,000 cycles per second, for equalizing impulses occur at the rate of 26,460 per second, and harmonics of this frequency up to about one tenth harmonic should be passed in order to maintain the steep fronts of these impulses, which it is obviously important to do. Coil L is inserted in the plate circuit of tube VT_1 to provide this required equalization when high gain is required at each stage.

Tube VT_3 in Fig. 18 acts both as a d.c. restorer and an amplitude separator. Resistor R_3 has a high ohmic value, somewhere between 3 and 5 megohms. Consequently a very high negative voltage is produced across it. This high negative voltage drives the grid of this tube beyond plate current cut-off for the video com-

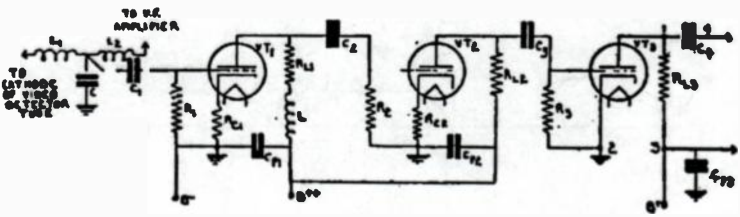


FIG. 18

L_1-L_2 = 30 microhenries
C = 30 mmfd.
C_1, C_2, C_3, C_4 = .15 mfd.
R_1, R_2, R_3 = 250,000 ohms
RC_1, RC_2 = 2,200 ohms
RL_1 = 5,000 ohms
RL_2, RL_3 = 10,000 ohms
L = 75 microhenries
C_{p3} = 2-mfd.
C_{p1}-C_{p2} = 8 mfd. each
VT_1-VT_2-VT_3 = 6J5G

ponents of the television signal. The tube also lines up the pedestals, in the same manner as did the circuit in Fig. 13.

As a result, only the synchronizing impulses or pulses cause plate current flow in VT_3. This plate current, flowing through resistor R_{L3} develops across it (between points 1 and 3) impulse signals of the form shown in Fig. 19A. Now condenser C_4 in the output circuit of VT_3 strips off the d.c. component from the impulse signals, and consequently the signal at point 4 after passage through the condenser is of the form shown in

Fig. 19B. It is this signal which is fed into the impulse separator circuit in Fig. 20. This circuit separates the horizontal impulses from the vertical impulses.

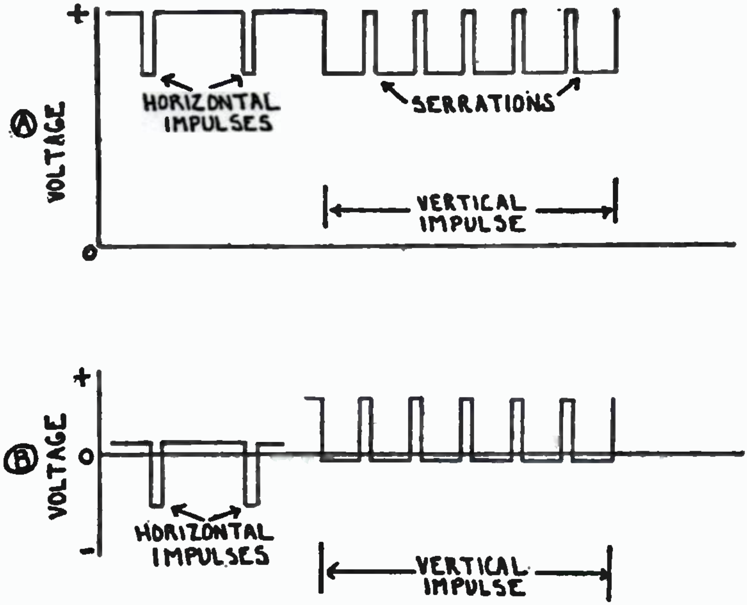


FIG. 19

Signals arriving at point 1 in Fig. 20 have two different paths to ground. The upper path has a short "time constant," while the lower path is associated with a circuit having a long "time constant."

The beginning of a horizontal line swing impulse changes the condenser voltage suddenly, causing current to flow in one direction for an instant through the resistor-condenser circuit; the end of a horizontal impulse returns the condenser voltage suddenly to its between-impulse value, causing current to flow in the reverse direction. The change in condenser charge occurs almost instantly, due to the short "time constant" of this path.

Vertical swing impulses will also take this upper path to ground. The beginning of each vertical impulse and the beginning of each serration will also swing the grid of the tube VT_H momentarily negative, thereby increasing momentarily the plate voltage. As a result, horizontal impulses are passed on to the horizontal blocking oscillator during both horizontal and vertical synchronizing periods, as is required. This results in extinction of the cathode beam during its swing back.

Now consider how the lower path in Fig. 20 reacts only to vertical impulses. The 1,000 mmfd. condenser C_2 and .1-megohm resistor R_2 in shunt with part of this path have a long "time constant." Horizontal impulses taking this path to ground feed just as much energy to this condenser in one direction as in the other, and are of such short duration that they really have no effect on the condenser voltage. The grid and cathode of VT_V are connected directly across this condenser, and hence the plate current through R_3 in between vertical impulses corresponds to zero-bias conditions.

Vertical impulses taking the lower path to ground exist for the duration of three complete picture lines (considerably longer than the time constant of R_2 and C_2), and hence make point x and the grid of VTv negative with respect to ground. This negative bias reduces the plate current through R_5, thereby increasing the

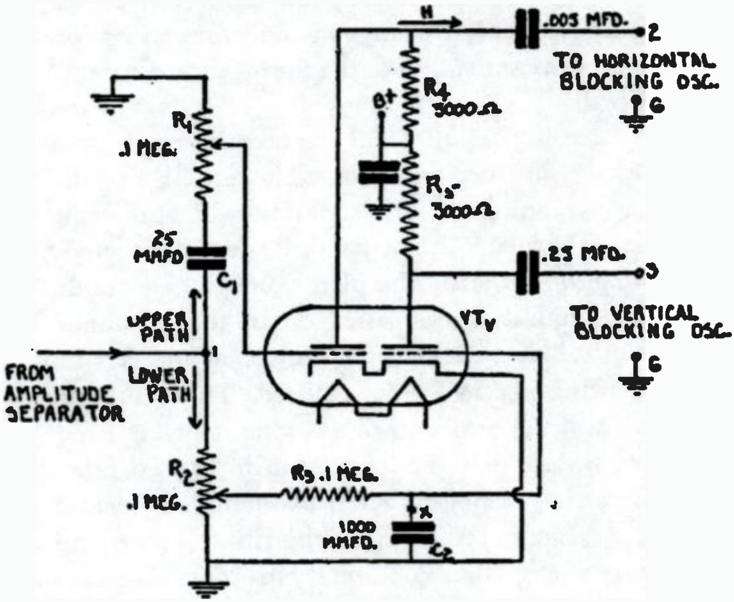


FIG. 20

plate-to-cathode voltage for the duration of each vertical impulse.

We thus see that tube section VTH responds to the beginnings of all horizontal impulses, vertical impulses and serrations, while tube section VTv responds only to the long vertical impulses. The impulse voltages developed across R_4 and R_8 in Fig. 20 are applied to the horizontal and vertical blocking oscillators (to the terminals of resistor R_1 in Fig. 16 through d.c. blocking condensers which prevent the d.c. plate voltage of the impulse separator section from affecting the blocking oscillator sections).

AUTOMATIC GAIN CONTROL: The final television receiver section to be considered is that which provides the automatic gain control voltage. In this section, again, it is best to use the television signal in its d.c. form with pedestals lined up. The voltage for the automatic gain control circuit should be obtained across a load resistor which is shunted by a large condenser, in order to give a time constant so long that the voltage will follow the impulse peaks. Doing this insures that the automatic gain control voltage will depend upon carrier level (or its equivalent, the level of the impulse peaks), rather than upon line brightness.

A satisfactory arrangement is shown in Fig. 21, where one half of a type 6H6 double diode tube serves as the video demodulator (or detector) and produces, between points f and d, a television signal voltage with the pedestals lined up. Now since this voltage is a pulsating d.c. voltage, with point f always positive with respect to point d, electrons will flow from point d through resistor R and then from the cathode to the plate of the second diode section. This electron flow will produce across resistance R a voltage having the polarity shown. And condenser C will tend to maintain this voltage constant.

When the television signal contains a bright line, the voltage across R_1 in the video detector circuit will be low, and consequently the voltage acting on the automatic gain control diode will drop. Under this condition the a.v.c. diode acts as a very high resistance, preventing the voltage across R from discharging back into R_L. During impulses, the voltage across R_1 will be high, a high d.c. voltage will be applied to the diode, the diode will have a low ohmic value, and condenser C will in consequence charge up. In this way parts R and C assume a voltage which depends upon the strength of the impulses.

The voltage developed across resistor R in Fig. 21 is unfortunately too low for automatic gain control purposes. It must therefore be boosted by a d.c. amplifier, consisting of the type 6C5 tube in Fig. 21. With this type of amplifier special voltage-feed problems are encountered. You will note that the plate of the 6C5 tube is connected through plate load resistor R_{L1} to a -3 volt terminal; as a result, this fixed negative bias is applied to the grids of all tubes which are controlled by the automatic gain control circuit. In order to place the plate of the 6C5 tube at a positive potential with respect to its cathode, the cathode is connected to a -50 volt supply terminal. The grid of this tube is connected to a -56 volt terminal through resistors R and R_2; this bias keeps the grid negative with respect to the cathode when no television carrier is tuned in, and at the same time prevents the type 6C5 tube from drawing grid current during the peaks of the television carrier.

In the video demodulator circuit of Fig. 8A, point d was grounded. If this ground were present in Fig. 21,

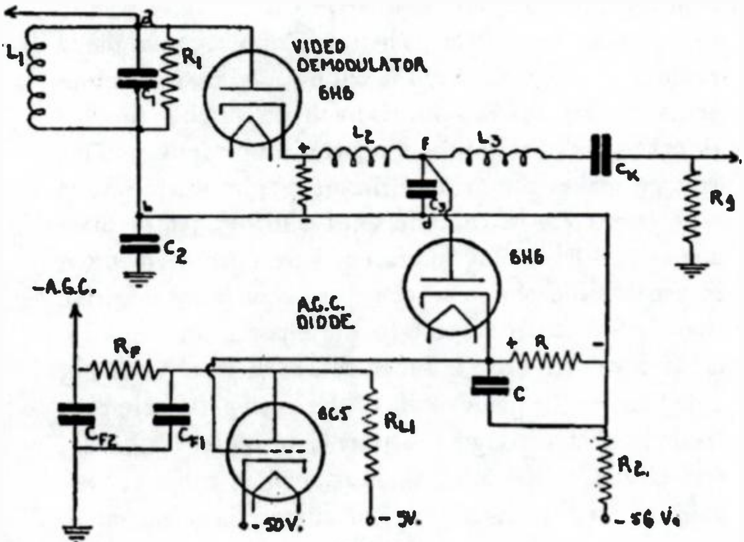


FIG. 21

the −56 volt terminal of the power supply would be grounded. To avoid this, condenser C_2 is introduced in the circuit of Fig. 21. Being quite high in capacity, this condenser provides a return path for the intermediate frequency signals without affecting the rectified television signal.

When no carrier frequency current is tuned in, the voltage across resistor R in Fig. 21 is zero, and the grid of the 6C5 tube then has a negative bias of 6 volts with respect to its cathode. The plate current is therefore near zero, and the potential of the plate with respect to the chassis is −3 volts. When a high-level modulated radio frequency television signal is tuned in, it develops across the resistor R a positive voltage which is proportional to the peaks of the synchronizing impulses. This voltage makes the grid of the 6C5 tube less negative with respect to its cathode, thus causing greater plate current to flow. But increased plate current through R_{L1} makes the plate end of this resistor more negative than before with respect to the chassis, and this increased voltage drop is added to the original fixed −3 volt bias on the grids of all of the automatic gain-controlled tubes through the time delay filters R_F, C_{F1}, and C_{F2}, thus operating these controlled tubes at low-gain conditions. In this way the automatic gain control system provides essentially constant signal output at the video frequency demodulator (detector).

In reviewing this rather involved chapter, it will greatly help if you try to visualize the frequency conversions which occur as the television signal progresses through the receiver, the frequency ranges which are handled by each stage and section. Above all, visualize the characteristics of the television signal at each stage or section. Furthermore, keep in mind that in television literature the terms "picture signal," "video signal," "image signal" and "sight signal" are used interchangeably. The terms "sound" and "audio" are likewise used interchangeably.

If you have carefully followed the foregoing description of circuits used in a modern, high-definition television receiver, you are in a position to properly appreciate the immense amount of skilled experimentation and engineering on which corps of trained minds have been employed during the past eight years to bring cathode-beam television to its present state of development. No words can be found which would overpraise the ability, the ingenuity, the indefatigability of these engineers.

It would have been easy for me to merely include here one or two complex and complete circuit drawings embodied in as many modern television receivers. But many of you amateurs would have been simply discouraged thereby from attempting to carefully trace out, or thoroughly understand the circuits. And you could not form a proper idea as to the reasons for all the various complicated details involved. I have therefore thought it better to inject a long chapter delineating, section by section, the various steps involved in such a practical, high definition receiver as you, supposedly, are interested in building—or at least in thoroughly understanding.

NOTE: *For much of the material appearing in the preceding chapter, and that dealing with Electron Optics, the writer is indebted to the National Radio Institute of Washington, D. C.*

Twelve: Studio Technique

SET UP OF CAMERAS, LIGHTING, DIRECTORS, CHANGING SCENES, SOUND EFFECTS, MAKE-UP.

A VISIT to a television broadcasting studio will give us a better idea of how pictures are originally assembled, to be sent out over the air.

We enter the studio—it is almost time for the final dress rehearsal before the broadcast, or telecast, as it will be called to distinguish it from radio. The room is not large, but literally packed with the mechanical apparatus and scenery necessary for one television production.

The studio is thoroughly sound-proofed, the walls covered with perforated material for accoustic perfection. Overhead is a network of wires and pipes, from which are suspended batteries of lights, and here and there a microphone hung on a wire, or on a long boom, near the sets but out of range of the cameras.

Around the sides of the room are three or four stage settings. In one corner is a living room scene—a chair, a lamp, and a radio. Across the end of the room is a garden with a bench. The deepest background of the scene is painted, but the bench and the closer flowers and shrubs are real. Next to the garden, in the other corner, is a restaurant table set for a meal, with chairs, and in the background a real door. Painted doors used in stage productions will not suffice in television performances, because as the television camera moves, the natural highlights in the scenery should appear to move also. Painted ones would remain stationary, and the realistic effect would be destroyed.

All background scenery and properties are painted in shades of gray because most television cameras do not yet register color, and only the contrast of light and shade is recorded. Dead white, which would reflect the lights glaringly into the camera lens, is never used. All properties and scenery are of extremely light-weight material, and portable, to make scene changing quiet and rapid. If more scenes are needed than can be set up in the studio at one time, they must be changed while the performance is in progress. When the cameras have moved away from the first set it is quietly taken down and another put in its place, for any noise would register on the sound transmitter.

Since the television audience will not want delays, the new scene must be ready for use when the cameras have finished with the last of the series, and this necessitates great speed in shifting from one to another.

On the floor of the studio in front of the stage settings stand three or four box-like cameras on rolling platforms, floor lights, and a platform supporting a fishing-rod structure called the microphone boom, with the microphone hanging at the end of the long rod. Cameras are mounted on standards so that they may swing easily and silently in all directions, and motors regulated with push-buttons elevate and lower the camera boxes to any desired height. The boom is hinged, with a crank to move it back and forth, and a swivel on which it swings in an arc from side to side.

At the opposite end of the room from the stage settings is a long window, behind which can be seen a row of receiver tubes and control boards. This is the control room, where engineers observe the final results of the broadcast on the screens in front of them and give directions by telephone to the technicians in the studio.

It is now time for the final dress rehearsal before the actual production. The actors, directors, and technicians already have rehearsed from 20 to 40 hours for this one hour of television broadcasting, as compared to four to ten hours of rehearsal for each hour of sound radio. There can be no retakes in television, as in motion pictures. Every move of actors and cameras must be perfect, and intricately mapped out beforehand. Any error in the broadcasting speeds out into space and is caught by thousands of viewers on home receivers almost before the actor or director can detect it.

First the technicians enter the studio and take their places at the equipment. One man mounts the platform of the microphone boom and adjusts the crank and swivel so that the microphone hangs over the first set. Other men take their stations at the cameras and arrange them for the first shot. All cameramen are skilled in framing the pictures and focusing the cameras, under the supervision of the production director in the control room. One camera, rolling on its own wheels, is placed at some distance from the set, for long shots. The close-up camera stands on a low, rubber-wheeled platform. The cameraman stands on the platform, while his assistant on the floor pushes the camera "dolly" wherever it is needed. Other cameras are either on wheels or platforms, and are trained on the first set.

Lighting engineers are ready at switches and floor lights. The silently rolling floor units are hinged so that their angle may be changed at will to augment the ceiling lights or spotlight certain portions of the scene. Property men, scene shifters, and special men for the title machines take their places in the studio.

In the control room the production director, the video engineer, the audio engineer, and assistants take their seats at the control boards and television receivers and don head phones. The assistant production director and actors enter the studio and the rehearsal is ready to begin.

During rehearsal the director on the studio floor gives directions through a public address system. The exact timing of the scenes is worked out and coordinated with the camera movements. Each camera man and pusher must know his exact route, at what moment he must move, and the way the camera must be pointed for each change of viewing angle. In addition to their lines, the actors must know when to move to another scene, and to their exact positions, so that no time may be lost when the program is on the air.

The time arrives for the broadcast. All sound ceases in the studio. The public address system is shut off, and from now on all directions must be given from the control room through the headphones to the assistant production director on the floor, who may communicate with the actors and technicians only by gestures. No sound must be heard other than the voices of the actors and the sound effects, which are usually produced in a different room and added electrically to the sound coming from the studio.

The television broadcast is opened with an announcement, or with a printed title describing the play or other entertainment to follow. One camera picks up the title from a board, or sometimes a "windmill" machine which can be turned to expose one title after another. Appropriate music is turned on in the sound effects room and blended into the title. A miniature stage is photographed in the effects room, curtains draw aside, and the miniature setting fades into the full-sized stage in the studio.

Although all the acting takes place in the studio, the production director in charge of the program sits in the control room and gives instructions through the telephone system by wires and headphones to the assistant production director on the floor, who relays them to the technicians and actors.

During the progress of a scene cameras are busy switching from one angle to another, on an average of once every twenty seconds. One camera is photographing the scene for actual broadcast; three more are trained for different shots, ready to be switched into the circuit as soon as a signal is given from the control room. When the first camera is finished with its particular shot the second camera is cut in. The first camera then is moved to a different angle and awaits its turn to shoot as soon as the fourth one is finished. In this way the viewing angles can be quickly and easily shifted with no delay or confusion. The three or four cameras are usually placed at various distances from the stage, for long shots, intermediate, and close-ups. The broadcasted picture then may be easily changed back and forth from close-ups to long-distance and vice versa. All switching from one camera to another in the transmitter is handled in the control room, and while more than one camera in the studio may be picking up its special scene, only one at a time will be linked to the sending station.

Next to the production director sits the video engineer, who observes the broadcast results on his receiver, or kinescope monitor, and gives instructions to the camera men on the floor. From his position he can see faults in the picture not apparent to the camera men, and can see through the window what change of camera angle or distance from the stage will correct the error. The video engineer selects all the shots, instructs the cameramen on the floor in switching and focusing, and gives cues for turning the cameras on and off the outgoing channel. In motion picture production the video engineer's counterpart is the editor and the film processing laboratory, but in television all editing must take place on the spot.

On the other side of the production director sits the audio control engineer. He is responsible for the sound effects, hears them as they come over the radio receiver, and communicates by telephone with the man on the microphone boom. The microphone follows the action, always as close as possible to the speakers without coming within the camera range. All of the sound portion of the broadcast is monitored through an individual circuit and broadcast on a radio channel, separate from that of the video signals.

The production director in the control room, through the video and audio engineers, coordinates the microphones and the camera with the lighting effects, and sees that the complete effect is satisfactory.

In the studio, the assistant production director is the only medium between the actors and the production director. Receiving instructions through his headphones, he directs by gestures the timing of the printed titles, the moving of scenery, and supervises the acting as best he can.

The acting should be perfected before the broadcast, because the actors cannot watch the director, nor can they be prompted. They must memorize their lines perfectly, since use of script is taboo in television. Because the camera apertures are large, focusing is limited, and the actors must learn to keep within this focus, limited, usually, to about six feet. It is the frequent changes of camera viewing angle which compensate for the possible monotony of this narrow range of action.

The small acting range also limits the number of persons photographed at one time. For a close-up shot, not more than three actors can be conveniently included at one time. A long-distance picture can cover nine or ten, but more than that would be crowded to the edges of the scene, and the limit of focus would tend to blur those on the outside. If a close-up is desired of some particular property on the stage during a multi-character scene, it is necessary to narrow the picture down to a portion of the characters in order to focus on the object. The background scenery must be within three feet of the actors in order to photograph properly.

At the end of the program, the curtains draw on the miniature stage, the title windmill turns to "The End" and is picked up by one of the cameras, music plays, and the announcer appears to introduce the next feature, which may be a film presentation of some kind —a newsreel, or perhaps an illustrated travel lecture.

Acting in television will assume a completely new method, different from that of the stage or radio. With the intimate relation of speaker to listener achieved by the television system, orators will no longer need the exaggerated gestures and booming voices now used to sway a distant crowd or an invisible audience. A pleasant smile, a well-modulated voice, and physical poise will be the greatest assets in televised political speeches, as they have always been in man-to-man conversations. A candidate or announcer will speak to the television camera as to another person, and much of the effective vocal inflection now used over the radio will be supplanted by convincing facial expressions.

The dramatic action on the television stage will be toned down to a quieter key. Since all of the audience is literally in the front row, there will be no necessity for throwing voices and emotions to the back of the theater, and the acting can become natural and unexaggerated. The chronological sequence of scenes and acts will provide for the actors an emotional continuity of action impossible in motion pictures, where scenes are filmed entirely out of their natural order.

In addition to the "live talent" studio, where actors' images are broadcast instantaneously, with no intervening medium, a typical television station has two other essential studios, one for motion-picture television, and one for special effects. Three other units are necessary in preparation for the broadcasts: a technical laboratory, machine and carpenter shops, and a scenic paint shop, including modeling in clay and plaster.

The motion pictures provide comparatively inexpensive filler between live-talent programs, and often are necessary where daylight rules out the television receiver, and as in a travel talk, where the scene must jump from one territory to another, an impractical feat for spot television transmission. In the middle of a live-talent broadcast, when the scene must shift to an outdoor scene impossible to reproduce in the studio, previously prepared motion-picture film is used to effect the change. Continually more film will be used.

In the special effects room are arranged all the properties from which close-ups are to be made during the performance. It is not possible for the camera to come near enough on the stage without interfering with the longer distance shots, or causing delay while the camera is moved out of sight. If a player on the stage tips over a glass of water, the picture is switched to the effects room, where an identical glass of water, close to the camera, is tipped over, and the water is shown running over the table. Close-ups of hand movements are also executed in this room. If a character lights a lamp, the effects camera is turned on and hands are shown striking the match and lighting the wick. Hands playing a piano or other musical instruments also are shown in this way. Special sound effects are here executed and added to the sound broadcast from the studio.

For extremely long-range shots of outdoor scenes, miniature sets are built. A distance view of a town or a building actually looks like a small model, and televized, cannot be distinguished from the full-sized subject. An airplane crash is a model plane operated in the effects room. If a character enters the scene in a boat, a miniature ship is photographed on a miniature sea, and a tiny model of the character stands at the rail. This scene in the effects room fades into a close-up in the broadcasting studio, where only the actor and the rail are visible.

To make an indoor scene with an outdoor view, such as a window of a room overlooking a courtyard or a mountain scene, realism is obtained by the use of an image focused on the screen from behind by a still projection machine. The light values and perspectives thus become as natural as a real scene. Moving backgrounds, as horses, cattle, or people, can be projected in the same way from the rear with a motion picture projector. Even the sets themselves sometimes may be background projected, if desirable—chairs, doors, or other furniture not in use in the scene, if at a sufficient distance from the actors. An ingenious but more complicated method of producing an elaborate or impossible background is to place the actor in front of a black curtain and add the background electrically in the control room.

Electrical manipulation of sound and light in the control room permits effects which would be difficult to produce in the studio. When a long shot is changed to a close-up, the volume of the voices must naturally become greater as the camera approaches the subject. If the microphone cannot be conveniently moved closer without coming within range of one of the cameras, the sound perspective is changed in the control room by electrical adjustment of the audio circuit.

Between scenes, and from scene to title and return, there must be some kind of a gradual light transition. The director has a choice of three methods now in use. One is an "out-of-focus" fade, in which the cameraman simply turns the camera lens until the scene becomes a blur. The following scene or title then comes in as an out-of-focus blur in the next camera, and is brought into focus by turning the lens. In this way the picture subject is completely changed without an abrupt shift, which would spoil the continuity. The second method of fading is a dimming of the lights to total darkness, and gradually relighting when the change of scene has been completed. The change can be accomplished independently of studio operations by electrically fading from one to another in the control room.

Illusions of size and distance can be achieved by special scenery arrangements and camera positions. When Dallas Bower produced "Emperor Jones" for television, the forest scene was arranged in a semicircle around three sides of the studio. Robert Adams, as Jones, followed this semicircle, plunging through the forest, and the camera followed him. In the televised picture he appeared to be going always straight ahead, for a distance impossible to represent as a straight line within the limits of the studio.

The lighting of scenes for television broadcasting should be "hard" or bright on the background, to bring out features which are somewhat out of focus. For general lighting, the reflectors should have a dull finish, and the light on the faces of the actors should be diffused with diffusing screens. An excess of light on the face sends into the iconoscope tube more light than it can stand, and the sharpness of the features is lost. A portable switching panel controls the individual groups of lights.

Colors photograph in television as shades of gray or black, and these shades vary for different types of photocells. The potassium hydride cell is most sensitive at the blue end of the spectrum, and red through this cell appears black. Lipstick must accordingly be blue in order to have a natural tone on the screen. In the red-sensitive cell, blue appears as black, and red lipstick can be used.

Makeup in general must be correlated with the lighting and the camera aperture. It is most important in long shots. For short ones, however, street make-up usually is sufficient. A popular combination, with a red-sensitive camera, is No. 26 or 29 panchromatic base paint, black or brown liner for the eyebrows, eye-shadow, artificial eyelashes, and brownish-violet lipstick. Another combination used is Indian red-brown lipstick, the complexion from burnt orange to peach tan, and the eyes outlined in brown.

Thirteen: The Television Transmitter and Studio Pickup

ICONOSCOPE, DISSECTOR, AND ORTHOCRON TUBES; THE MULTIPLIER AND MULTI-VIBRATOR.

THE economics involved in television programs have been considered in a previous chaper. There it is shown that motion-picture film, whether 16 mm. or 35 mm., is destined to play a very large or even preponderant role in making commercially possible a nation-wide television service. But, regardless of whether the subject to be televised be from films or live scenes, the apparatus required for the studio program pickup remains essentially the same.

A camera tube is required in order to break up the scene into a series of picture elements, which can be converted into electrical signals for radiation through space, and reassembled at the receiver into a picture.

The RCA camera tube is known as the iconoscope, and in its most improved form, the Orthocron. The Farnsworth camera tube is known as a Dissector tube; the British version of camera tube is known as the Emitron. Although these tubes differ considerably in construction and design the results they produce basically are the same.

In the Farnsworth dissector tube, all of the electrons emitted by the photo-sensitive surface are drawn out simultaneously into a broad stream. This entire electron stream is moved, horizontally and vertically, past a single collector point, preferably by electromagnetic means. This collector point thus delivers an electrical signal which, at any instant, is proportional to the brightness of an elemental picture area.

In the iconoscope tube an electron gun, with associated horizontal and vertical deflecting systems, is used to produce an electron beam which sweeps across the photosensitive plate horizontally, line after line. This produces an electrical signal proportional, at any one instant, to the brightness of the picture element which the electron beam strikes at that instant. A control grid cuts off the electron beam during each retrace interval.

Synchronizations: Interlocked master signal generators at the television transmitter produce the 60-cycle vertical synchronizing impulses and the 13,230-cycle horizontal synchronizing impulses, and these impulses control the saw-tooth sweep generators which feed into the deflecting circuits of the camera tube. These synchronizing impulses are added to the signal which is to be radiated.

The picture signal generated by the camera tube is now amplified by carefully designed amplifiers which have the required wide frequency response. The resulting television signal, including "pedestals," is then forwarded from the studio to the transmitter either by a coaxial cable or an ultra-high-frequency radio link, in which the television signal is placed upon an ultra-high-frequency carrier and radiated through space.

An ultra-high-frequency transmitter capable of radiating at least 1,000 watts of carrier power is required. The higher the transmitting antenna, of course, the greater will be its area of coverage. The Chrysler building (Columbia Broadcasting System transmitter) and Empire State Building (National Broadcasting Company) in New York City are excellent examples. The transmitters should be located preferably at or near the antenna to eliminate long, power-wasting interconnecting coaxial cables.

The ultra-high-frequency carrier is generated by a master oscillator, and boosted in level by buffer stages, intermediate power amplifiers, a modulated amplifier, and by power output amplifiers which partially suppress one side band of frequencies. The resulting modulated r.f. carrier signal is then fed to the antenna through the coaxial cable, and radiated (preferably?) as horizontally polarized waves in accordance with RMA standards. In Europe the dipole antennas usually are vertical. A conventional sound broadcast transmitter entirely separate from the picture transmitter, except that its carrier frequency is exactly 4.5 megacycles above the video carrier frequency, and its frequency band relatively very narrow, is employed for the sound portion of the television program.

Classification of Camera Tubes: Camera tubes can be divided into two groups, storage and non-storage type tubes. The latter produces a picture signal proportional at any instant to the intensity of the illumination on the corresponding elemental area of the scene at that instant.

RCA Iconoscope: The essential details of a standard RCA iconoscope are shown in Fig. 1. This iconoscope

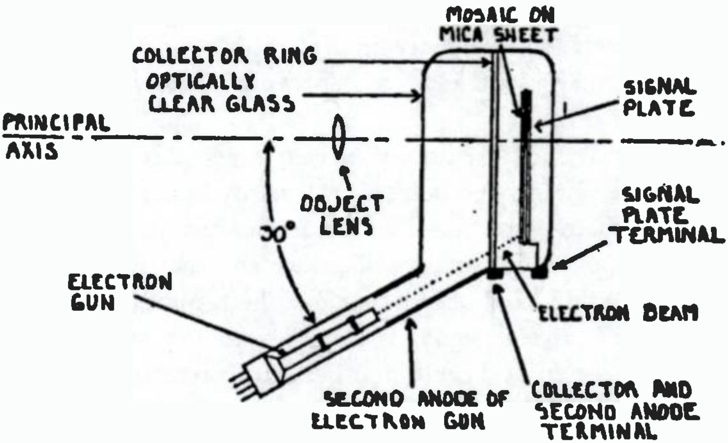


FIG. 1

Essential details of a standard RCA iconoscope, which is a storage-type television camera tube.

consists essentially of a conventional electron gun mounted in the narrow neck of the tube and aimed at a light-sensitive surface inside the large cylindrical glass envelope of the tube. That end of the envelope nearest the electron gun is of optically clear glass; light from the scene being televised is focused upon the light-sensitive surface through this glass by a conventional object lens.

THE MOSAIC: The light-sensitive surface is a mosaic consisting of millions of tiny silver globules insulated from each other but attached to a rectangular sheet of very thin mica. Other chemicals are added to make the color response of the mosaic more natural, permitting ordinary make-up for actors in television studios, and giving accurate black-and-white reproduction of all tones in outdoor television scenes.

The televised scene is projected on the mosaic by the optical lens and each light-sensitive globule emits electrons in proportion to the intensity of the illumination on that globule.

On the back of the mica sheet supporting the mosaic is a metal plate. An electric capacity exists between this signal plate and each globule of the mosaic, the mica sheet serving as the dielectric. As each globule loses electrons, the effect is relayed electrically to the common signal plate through the mica dielectric.

THE COLLECTOR: On the inner surface of the large cylindrical envelope, about midway between the mosaic and the glass window end of the envelope, is a conductive coating or ring, preferably of vaporized copper, a small fraction of an inch wide, which collects the electrons which leave the mosaic. The collector is connected internally to the second anode of the electron gun.

The electron beam produced in this tube is generated and controlled by the electron gun, the same as in a kinescope, or cathode-beam receiving tube. It is focused on the mosaic and is deflected horizontally and vertically across the mosaic by an electromagnetic deflecting system. The mosaic is thus scanned by the electron beam.

When an illuminated globule on the mosaic is hit by the electron beam, this globule emits secondary electrons, because the chemical which makes a globule photo-sensitive also enables it to emit secondary electrons. Some of these secondary electrons return almost immediately to the globule. The other secondary electrons escape, either to other parts of the mosaic or to the collector ring. Since globules are insulated from each other, the potential of a globule will increase in a positive direction when it loses electrons (when more electrons leave than arrive). As the potential of a globule becomes more positive, an increasingly larger number of the secondary electrons are attracted back to the globule, and these offset any tendency of the globule to become more positive.

The number of secondary electrons escaping finally becomes equal to the number of beam electrons arriving. Therefore the globule remains at a definite positive potential, until the next scan.

The iconoscope mosaic is illuminated by focusing a scene on it, or projecting thereon a movie scene. Each globule then emits electrons in proportion to the intensity of the illumination. This emission of electrons makes the globules slightly more positive, as stated above.

As the electron beam sweeps across the mosaic and strikes the globules the charge on each one in turn is built up to the saturation value of +3 volts. Those globules which are brightly illuminated change the least in potential when hit by the electron beam; globules which are least illuminated change the most in potential when struck by the electron beam. It is this *change* in the charge of a globule, at the instant when it is hit by an electron beam, which produces the picture signal. A dark element on the mosaic thus gives the greatest change in the output signal of a standard iconoscope.

Those who have carefully followed the foregoing description of the iconoscope and the operation of the mosaic when scanned by the cathode beam have, I am sure, been struck by the basic beauty of this idea. I consider the cathode-beam television camera one of the most exquisite inventions and developments in the history of electronics. All praise then to Campbell Swinton for the brilliant original invention, and to Dr. Zworykin and his eager assistants who have developed the idea to its present marvelous degree of refinement—a development which still is being continued.

It has been explained that whenever a globule of the mosaic is hit by the electron beam, some of the secondary electrons knocked out of the globule travel to the collector ring. This makes the globule (and therefore the mosaic) more positive, destroying the equilib-

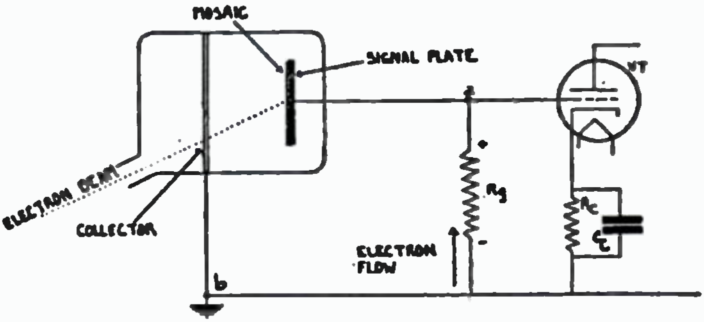


FIG. 2

rium in the condenser formed by the mosaic, the signal plate and the mica. To restore this equilibrium, the secondary electrons which leave the mosaic eventually must get back to the signal plate through an external conductor circuit. In the circuit shown in Fig. 2, for a standard RCA iconoscope, the path taken by these secondary electrons is from the mosaic to the collector and point *b* which is grounded, then through grid resistor R_g (for the first amplifier stage) to point *a* and the signal plate. But this signal plate also is connected directly to the grid of the first amplifier tube. The voltage thus impressed on this grid has a steady component which depends upon the total illumination on the mosaic and upon the electron beam current, and also a rapidly varying component which depends upon the intensity

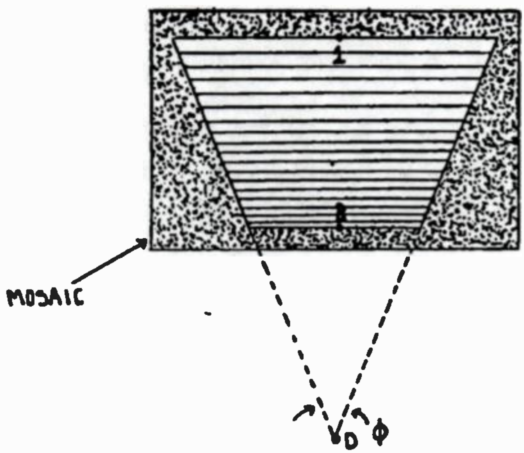


FIG. 3

of the illumination on that particular globule. This voltage component is our desired picture signal.

In a standard iconoscope the object lens, the mosaic, and the scene being televised are all on the principal axis of the tube. This arrangement gives a true image of the scene on the mosaic. The electron beam, however, is directed toward the mosaic at an angle of approximately 30° with the principal axis. The result is a keystone-shaped scanning pattern in which the bottom lines are the shortest and closest together, Fig. 3.

Correcting signals therefore must be introduced into the horizontal and vertical sweep circuits of a standard iconoscope to correct for this keystoning, and also for the unequal line separation that results.

Thus we see many additional and intricate problems faced the electron engineers before today's degree of perfection in the television camera was attained.

Farnsworth Dissector Tube: As I have pointed out, this tube is fundamentally different from the iconoscope, based on the Campbell Swinton idea, although both devices employ a photo-electric surface on which is projected the scene to be televised, and over which electron streams play to interpret the picture in electrical units.

A simplified diagram of a non-storage type of camera tube, as originally developed by Philo T. Farnsworth, is shown in Fig. 4. The three important internal elements in this tube are the photo-sensitive cathode on which the scene is focused, the accelerating anode, and the target.

The photo-sensitive cathode is one continuous surface of light-sensitive material such as caesium and caesium oxide on silver, just as in ordinary photo-electric cell. When a scene is optically projected upon the cathode through the clear glass window by the lens, electrons are emitted from various portions of the cathode in proportion to the illumination on each part. These emitted electrons are drawn away from the cathode by the large cylindrical accelerating anode, which is in the form of a solid layer of nickel or other conducting material deposited on the inside of the cylindrical glass envelope. It is at a fairly high positive potential (about 600 volts).

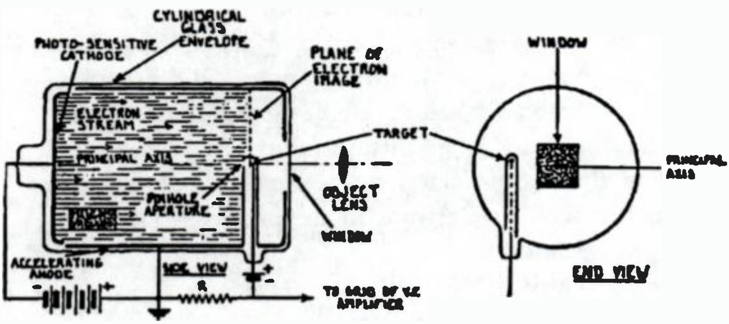


FIG. 4

The essential details of a non-storage type Farnsworth dissector tube are shown in these simplified side and end views. The cylindrical glass envelope is about 10 inches long and 4½ inches in diameter.

The rectangular-shaped mass or aggregation of electron beam emitted from the photo-electric surface is retained in that form by virtue of the long (electron focusing) solenoid, or magnet winding* surrounding the cylindrical glass envelope; so that all these minute and parallel electron beams strike the rear flat surface of the tube; that is, until the bundle of electron rays is caused to sweep up and down and from right to left. This is done by means of two pairs of deflecting coils

* This coil contains about 17,000 turns of No. 35 enamelled copper wire, and carries a focusing current of approximately 20 milli-amperes of direct current.

placed oppositely on the four sides of the rectangular, or cylindrical, glass envelope.

As this rectangular bundle of rays is swept from right to left and from down to up, only a very small part of the electron stream is allowed to enter a pin-hole aperture to strike a tiny target. Through a small battery this target is connected to the grid of the pre-amplifier tube, or to an electron-multiplier tube. All other electrons are grounded as they strike an extension of the accelerating anode. In this way only one elemental area of the photo-electric surface, or cathode, is permitted to send its electrons to the protected target at any one instant.

Being positively charged with respect to the accelerating anode the target attracts these electrons and sends them through resistor R, so that a picture signal voltage is developed across this circuit. The voltage developed across R is the desired picture signal. It will have a *positive picture* phase, because increases in brightness on an elemental area of the cathode increase the electron emission from that area, thereby increasing the target current when that area is scanned.

The end view of the Farnsworth dissector tube in Fig. 5 shows that the target and its housing are placed at one side of the principal axis of the tube; this is done so the target will not interfere with optical projection of the scene upon the cathode.

Focusing the Electron Stream: To insure correct distribution of electrons in the stream as it passes the target, the electrons emitted from the cathode are focused onto an imaginary plane (imaginary flat surface) which passes through the target, as shown by the dotted line in Fig. 4. Varying the d.c. focusing current makes these electrons take a particular desired spiral path to the plane of the target, where they form a true so-called electron image of the original scene. But only a small part of this electron image hits the target at one time.

The original Farnsworth dissector tube is of the non-storage type, for electrons are emitted continually from all points on the cathode surface under the influence of light. Electrons which do not strike the target are captured by the accelerating anode surrounding the entire cylindrical envelope and the end area except the rectangular window.

Due to this non-storage action, the original dissector tube was extremely insensitive. Considerable amplification was required to build up its signal intensity, and this in turn increased circuit noise due to the so-called "shot" effect and thermal agitation, which occurs when an extremely low input voltage is fed into a high-gain amplifier. This difficulty has been overcome in an improved version of dissector tube utilizing the Farnsworth electron-multiplier type of target tube.

Such a multiplier tube is shown in simplified form in Fig. 5. Electrons enter through the same pin-hole aperture as in the older tube but encounter a curved electrode 1 at the original target position. Electrons hitting electrode 1 are reflected downward as indicated by the dotted lines in Fig. 5. The inner surface of electrode 1 is coated with some alkaline oxide such as barium or strontium oxide, which releases two or more

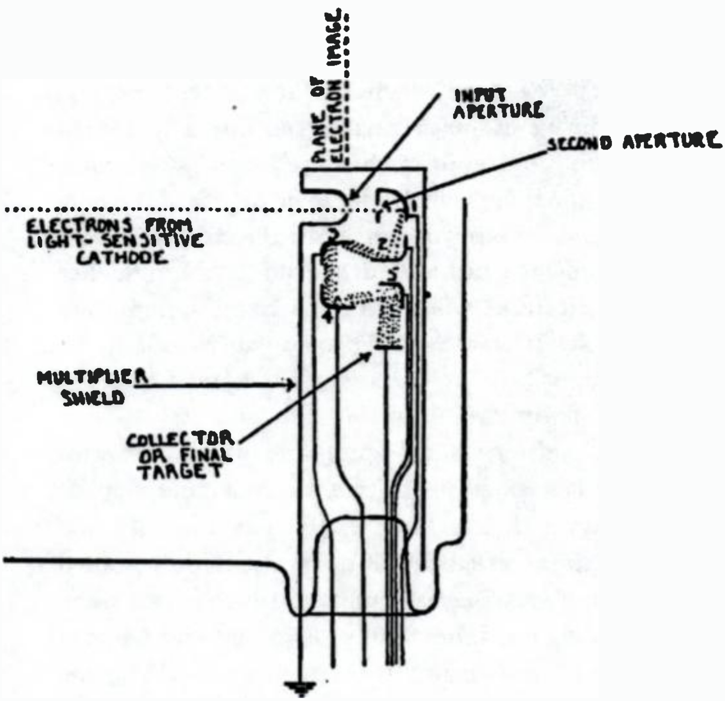


FIG. 5
Electrodes 1, 2, 3, 4, and 5 are secondary emission electrodes.

secondary electrons for each electron hitting it. The secondary electrons leaving electrode 1 travel to other similarly curved electrodes, and in turn are reflected from each and increased in number by secondary emission from each reflecting surface. Electrode 1 is about 100 volts positive with respect to the original aperture, and each succeeding secondary-emission electrode is about 100 volts more positive than the preceding electrode. In other words, a potential of 100 volts is attracting secondary electrons from each emitting surface.

The ratio of secondary to primary electrons is about 2.6 for a typical tube; this means that 2.6 times as many electrons leave an electrode as arrive at it. In one tube, eleven secondary-emission surfaces are employed; with this arrangement the initial electron current may be increased about 37,000 times by the action of the multiplier. Even with this tremendous increase, the final output of an improved Farnsworth dissector is only about 50 microamperes for scenes of normal brightness. This indicates how small the intensity of an electron current may be at the input aperture under normal conditions.

With such an electron-multiplier target built into a non-storage type dissector tube to boost its output voltage the resulting signal-to-noise ratio is entirely satisfactory for high-definition television pictures.

The improved Farnsworth dissector with electron multiplier possesses a number of important advantages over the iconoscope. First of all, scanning circuits are considerably simpler, for the plane of the electron image at the target is parallel to the plane of the optical image on the cathode, eliminating keystone effects and crowding of picture lines. Furthermore, since all of the electrons emitted from the cathode but not received by the target find easy access to the anode, no appreciable space clouds form; this means that there are no dark spot defects in the picture, and no need for complicated shading controls.

Theoretically, the standard iconoscope is more than 250,000 times more sensitive than a dissector tube used

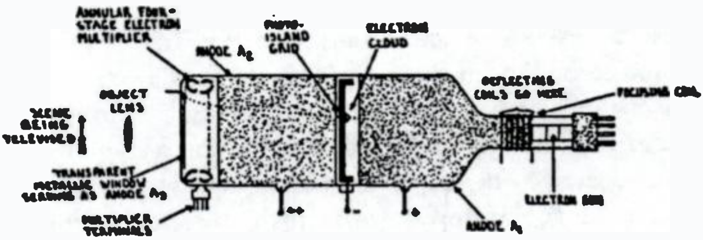


FIG. 6

Simplified diagram of the new storage-type Farnsworth dissector tube, which has exceptionally high sensitivity. Anodes A_1 and A_2 are metallic layers deposited on the inside of the cylindrical glass envelope.

without a multiplier (the actual ratio of sensitivities is equal to the number of elemental areas in one frame, for each elemental area in an iconoscope charges up energy for the duration of one frame before releasing it). Actually, however, space clouds, together with electron leakage between globules on the mosaic, reduce the sensitivity of a standard iconoscope to about 10 per cent. of the maximum possible value. Furthermore, the sensitivity of a non-storage type dissector tube is increased considerably by the use of an electron multiplier. The dissector tube shown in Fig. 4, when used with a suitable electron multiplier, gives adequate sensitivity for film pickup or "telecine" programs, but not quite enough sensitivity for studio and outdoor scenes.

In order to provide a camera tube with sufficient sensitivity for use on studio stages having a reasonable amount of illumination, as well as for outdoor pick-ups on cloudy days, Farnsworth has developed the improved dissector tube shown in Fig. 6. This tube is claimed to be even more sensitive than the standard iconoscope.

Improved Storage Dissector Tube: Its design and operation will give you a further and clearer understanding of the interesting and docile manner in which these tiny electrons, material of which our universe is largely built, can be made to travel about and perform neat tricks inside the cathode beam tube, all for mankind's amusement—and education.

This tube, of the storage type, is entirely free from dark spot and keystone defects. The scene being televised is optically focused through a transparent window made of metal thinly sprayed on glass, upon a specially constructed photo-sensitive plate called the "photo-island grid." As the detailed sketches in Fig. 7 show, this photo-island grid is constructed from thin sheet nickel having many very fine perforations, about 400 perforations or holes per linear inch, each hole being one-thousandth of an inch square.

The side of the photo-island grid which faces the transparent metal window is first covered with an insulating material, then with globules of a photo-sensitive material such as caesium oxide on silver. Each elemental picture area on the photo-island grid there-

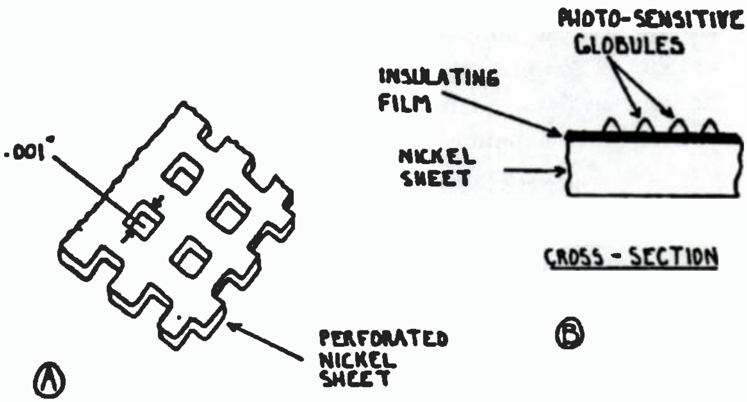


FIG. 7
Details of the "photo-island" grid used in the storage-type Farnsworth dissector.

fore emits electrons in proportion to the brightness of the optical image focused on the surface, and the charge on each globule of the grid is proportional to the illumination on the globule.

The electrons which leave the photo-sensitive surface due to the action of light are speeded up by the cylindrical anode A_2, and travel through it to transparent metallized glass plate anode A_1 and the ring-shaped electron multiplier which surrounds that end of the tube. These electrons therefore produce a multiplied output current, the amount of which is dependent upon the total amount of light in the optical image. The total illumination on a scene usually changes very gradually, hence this total electron flow remains essentially constant and has no appreciable effect upon the individual picture signal output.

Since all of the insulated photo-sensitive globules will lose electrons in varying amounts when an image is optically projected upon the photo-sensitive surface, the globules will acquire varying positive charges with respect to the sheet nickel grid. At the right-hand end of the improved dissector tube in Fig. 6 is a conventional electron gun with its horizontal and vertical deflecting coils. This produces an electron beam which sweeps horizontally and vertically across the back of the photo-island grid at the correct rate for a standard RMA 441 (or higher) line picture.

The electron beam, focused on an elemental area of the nickel surface, knocks out large numbers of secondary electrons from the electron-emissive material coating; these instantly form an electron cloud in space near the point of impact. The positively charged globules on the other side of the nickel photo-island grid then acts upon this electron cloud through the perforations in the nickel, drawing electrons through these holes in proportion to the values of the positive charges on that elemental area.

The electron cloud thus serves as a "virtual" cathode, with the positively charged photo-sensitive surface operating much like the grid of a conventional triode vacuum tube, with cylindrical anode A_2 acting as its plate. As soon as electrons from the space cloud get through the holes in the photo-island grid they come under the influence of anode A_2, and are instantly pulled through A_2 toward A_3 and the electron multiplier.

It is this electron flow, originating in the electron cloud created by the electron beam, which constitutes the picture signal of the improved Farnsworth dissector. This picture signal therefore is *proportional to the charge stored in the globules,* rather than to instantaneous action of light on the globules, hence we may call this a storage-type tube. Those electrons in the space cloud which are not drawn through the holes in the nickel sheet are pulled back away from the nickel surface by the positive charge on anode A_1, thereby clearing the nickel surface of electrons in readiness for the next sweep of the electron beam. Isn't this a really beautiful procedure of Nature's forces harnessed by man?

The electron flow from the photo-island grid to the electron multiplier input now has two components: one fixed, and proportional to total illumination on the photo-sensitive surface; the other a rapidly varying picture signal component proportional to the illumination on the elemental picture areas being scanned. No attempt is made to focus these diffused electrons as they travel through anode A_2 on their way to the electron multiplier, for one is interested only in capturing the entire electron flow and converting its varying component into the desired picture signal. Anode A_3 is made slightly negative, so that it will turn away some of the electrons which approach it, forcing these electrons directly into the electron multiplier.

The electrons which do hit anode A_3 will cause secondary emission therefrom and these knocked-off electrons will flow radially outward to the circular electron multiplier electrodes, so curved that they will accept and reflect electrons approaching from any radial direction. Electrons leaving the final multiplier electrode travel through the output lead to form a signal voltage which varies from instant to instant in proportion to the illumination on the elemental area being scanned at this instant.

The sensitivity of the camera tube is a most important practical consideration in connection with a television transmitter. If the camera tube has low sensitivity, an intense artificial light must be provided in the television studio, and outdoor pick-ups may be unsatisfactory or even impossible on cloudy days. High image definition and high sensitivity are therefore the two requirements definitely desired in a television camera tube.

Recognizing that a surface sensitive to electron impact will emit more electrons than a photo-sensitive surface, RCA engineers developed the improved iconoscope shown in diagram form in Fig. 8. In this improved form called the "Orthocron," the scene as represented by the vertical arrow in the figure is focused upon a semi-transparent photo-sensitive, thinly metal-

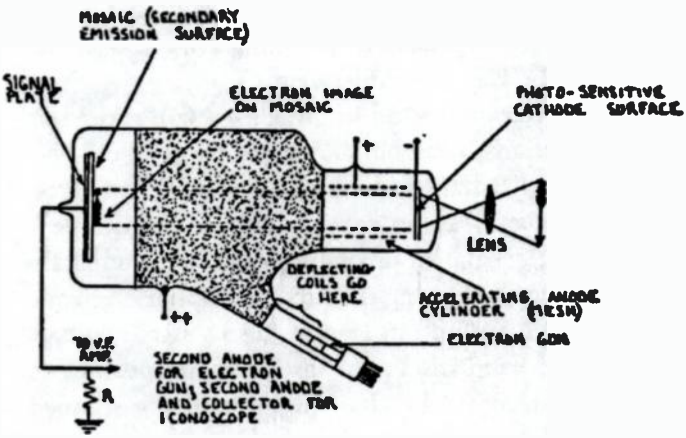


FIG. 8
Improved RCA iconoscope, employing an electron image produced by a photo-sensitive cathode surface and focused by an electron lens (the accelerating anode acting with the second anode) upon an electron-sensitive mosaic.

lized glass plate. Although the photo-sensitive surface of this plate faces away from the lens and scene, enough light passes through the semi-transparent plate to activate the photo-sensitive material and produce photoelectron emission.

The cylindrical accelerating anode, being at a positive voltage with respect to the cathode photo-sensitive surface, attracts these emitted electrons and speeds them toward the mosaic plate at the far end of the large glass envelope. Upon emerging from the accelerating anode, these electrons pass through the second anode, which consists of a metal coating on the inside of the glass envelope, at an even higher potential than the accelerating anode. These two anodes together form an "electrostatic lens" which focuses an electron image on the mosaic, corresponding in every detail with the optical image focused on the photo-sensitive surface.

In this improved iconoscope, the mosaic consists of chemicals which are extremely sensitive to electron bombardments instead of to light rays, and hence the mosaic releases many secondary electrons whenever it is hit by an electron. In this manner, the globules on the mosaic are driven positive by an amount proportional to the illumination of the corresponding elemental area in the original scene.

Although this new arrangement gives far greater sensitivity than the standard iconoscope, shading controls are still required to correct for dark spots due to electron clouds in space.

THE STANDARD ICONOSCOPE: It requires more of these signal voltages and control devices than the other tubes just considered, therefore let us take up its more involved case. To scan a rectangular area approximately 4 inches wide and 3 inches high on the surface of the mosaic in an iconoscope, we need a horizontal-deflecting system producing a 13,230-cycle saw-tooth sweep voltage; a vertical deflecting system producing a 60-cycle saw-tooth sweep voltage; and a horizontal keystone-correcting system.

The important requirement for accurate interlaced scanning* is that for every 60 vertical sweeps there shall be exactly 13,230 horizontal sweeps. To maintain the charge-discharge tube circuits of the deflecting systems at the correct frequencies for the 60-to-13,230 ratio, synchronizing impulse sources are required, and these must be interlocked so that any frequency drift will affect both sweeps proportionately and maintain their ratio constant.

The synchronizing impulse signals which control the saw-tooth discharge scanning circuits are also utilized in a camera tube to extinguish the electron beam during the interval between the end of one vertical scan and the beginning of the next. The time duration of each synchronizing impulse is therefore highly important.

Synchronizing impulses must of course be radiated from the transmitter along with the picture signals. The same impulses can be added to the picture signal output of the camera tube to give the standard RMA

* By interlaced scanning is meant the method of first scanning a picture horizontally over only the *odd* number of lines of the picture-from 1, 3, 5, 7 etc. to 441—(all this in 1/60 of a second) and then scanning it again, beginning at line 2, and traversing only the *even* lines, like 2, 4, 6, 8, etc., down to line 440, again in 1/60 of a second; or a complete scanning of 441 lines in 1/30 of a second. Such interlacing at the receiver very greatly reduces, or eliminates, any flicker noticed otherwise by the eye, and corrects any tendency of the eye to follow the course of the scanning beam as it travels from the top to the bottom of the picture. Likewise for 525 lines.

television signal, ready to modulate the radio-frequency oscillator or transmitter.

The camera tube itself must be directed toward the scene to be televised; and it must follow this scene if the action is moving. Proper lenses must be available to take care of close-ups as well as distant shots. The illumination of the scene must be ample to give sufficient picture signal output to override tube and circuit noises.

The electrical controls for a standard iconoscope must include an electron-beam focusing control, beam-centering controls, vertical and horizontal-sweep beam magnitude controls, and controls for correcting various inherent defects of the iconoscope.

It has proven good practice to have the monitor engineer handle the electrical controls for the camera tube, allowing the camera man to devote his entire attention to camera technique and showmanship. With a monitoring image-reproducing tube in front of him, the monitor engineer can judge the effects of the various adjustments he makes on the electrical controls. The adjusting signals are sent to the camera over a multi-lead cable, along with the various voltages required for operation of the camera tube. The video output signal of the camera tube goes to the studio control room over this same cable, where it undergoes further corrections, changes and additions before it is made to modulate the radio-frequency carrier signal of the transmitter.

The camera man and the studio engineer or monitor man can converse with each other at any time by means of a two-way telephone line between their locations. The monitor can thus advise the camera man of image defects which can be corrected only at the camera.

The studio monitor engineer, by means of shading controls must remove any "dark spots" due to electron clouds thrown off from the mosaic surface of the iconoscope. Although the black level for the picture signal at the output of the camera tube is determined by the signal voltage applied to cut off the electron beam during each re-trace of the beam, it is sometimes desirable to change this black level during a transmission to a more suitable value.

Across the plate load of one of the amplifier stages of the transmitter the "blanking signal" (having the correct phase and correct time duration for each re-trace) is injected into the picture signal circuit. Then the operator, by varying the amplitude of the blanking signal, varies the black level of a television signal, and this in turn varies the brilliancy of the scene as this is reproduced at the receiver.

A photocell facing the televised scene might be arranged automatically to control the amplitude of this blanking signal, thus relieving the monitor of at least one of his manifold, lightning-like movements and responsibilities.

When the resulting picture signal with its correct black level has been further amplified, the horizontal, vertical, and equalizing impulses can be inserted in much the same manner, by applying these pulse voltages across a resistor which is common to both the picture signal circuit and the amplifier which generates the pulses. All of these synchronizing impulses can be inserted while the picture signal is passing through the video amplifier.

The accuracy of interlaced scanning depends to a great extent upon the frequency sources which control the 60-cycle and 13,230-cycle saw-tooth horizontal sweep generators.

Since the power-line frequency throughout the United States is accurately maintained at 60 cycles, it could be used as a standard frequency source for a local television system. But the frequency-multiplying process required to make a 60-cycle voltage control a 13,230-cycle frequency course is entirely too cumbersome and difficult to maintain for a practical installation. A much better method involves starting with a high frequency such as 26,460 cycles, or some multiple of this value, then changing to 60 cycles per second by means of frequency division.

With this method, any variation in the original high-frequency source will be almost negligible when finally reduced to 60 cycles. The reason is this: A frequency of 26,460 cycles is 441 times 60 cycles, and a variation even of 441 cycles in the higher-frequency source would mean a change of only one cycle per second in the 60-cycle source which it controls. Or, by beginning with a signal having 4 times 26,460 cycles, or 105.84 kilocycles, the frequency drift in the original source will have even less effect upon the low-frequency source. The basic oscillator can be either a crystal-controlled oscillator or a highly stable temperature-compensated I-C (Induc-

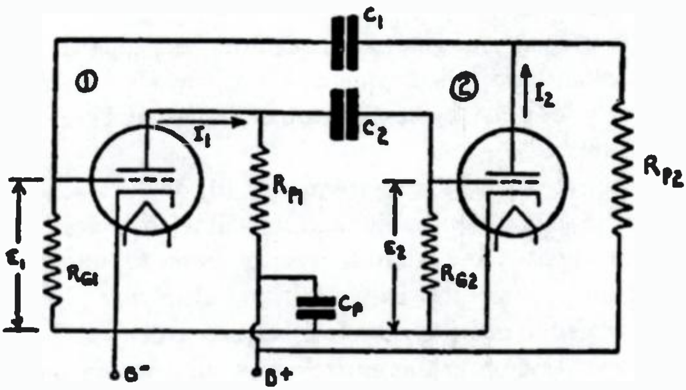


FIG. 9
Basic multi-vibrator circuit.

tance-Capacity) oscillator. As a matter of fact, when a power supply with good voltage regulation is employed to provide a constant direct-current voltage for each tube, crystal oscillators are not required.

The division of a high-frequency source into sub-multiples to secure much lower frequencies is achieved by the use of so-called "multivibrator" circuits. A typical multi-vibrator circuit is shown in Fig. 9. Each multi-vibrator stage is essentially a resistance-capacitance coupled amplifier employing two triode tubes, with the output of one tube being fed into the input of the other tube. Self-oscillation takes place, and both square-top and saw-tooth signal voltages are generated. A multivibrator circuit can be controlled by an external standard-frequency source in such a way that this external source determines the multivibrator output frequency. For example, when a multivibrator circuit oscillates normally at slightly less than 540 cycles, a signal having 7 times this frequency (3,780 cycles) can be injected into the multivibrator circuit in such a way that every seventh pulse of the higher-frequency source will correct the oscillation of the multivibrator. Then if the 3,780-cycle-per-second frequency source is accurate and constant, the resulting 540-cycle multivibrator output signal will likewise be accurate and constant.

Note that this multivibrator circuit simply is a conventional push-pull oscillator, a feed-back circuit between two triodes, except that in place of inductances with condensers in shunt thereto, simple resistances are used.

An impulse impressed across the resistance R_{G_1} is amplified by tube (1) and passed on in reversed phase to the grid of tube (2), from whose plate it is delivered back to the grid of the first tube in phase, to cause there a reversal of the original section upon that tube. Thus the action becomes reciprocal and builds up to quite powerful swings, or oscillations of current across the load resistor R_{P_2}.

The positive pulse injected into the multivibrator circuit can be a signal having some multiple of the natural frequency of the multivibrator (the injected voltage may thus be 2, 3, 4, 7, or 10 times the multivibrator frequency). Signals up to 10 times greater in frequency will give satisfactory control over a conventional multivibrator circuit.

But the natural frequency of a multivibrator must be slightly lower than the frequency of the impulses which are to control it. Furthermore, the d.c. supply voltage for the multivibrator must be very constant, so that changes in supply voltage will not initiate feedback. The natural frequency of the basic multivibrator circuit in Fig. 9 is governed essentially by the values of C_1 and C_2 and the ohmic values of their respective discharge paths. The resistances and capacities for the two parts of the circuit should be alike.

The actual multivibrator circuit is not quite so simple as here shown, but the essentials remain the same.

Since the natural frequency of the multivibrator circuit can be changed by using different capacity values for C_1 and C_2, it is common practice to use the same circuit for all multivibrator stages in the transmitter chain, changing only the values of C_1 and C_2 to give the correct frequency in each case.

Interlocking between the 60-cycle current obtained from the multivibrator and the alternating-current power line makes the vertical sweep frequency of the picture exactly 60 cycles, so that these undesirable effects are stationary and therefore considerably less objectionable. This interlocking can be attained by feeding both alternating-current voltages into a common frequency circuit, and by means of the output controlling the frequency of the master high-frequency oscillator.

The change in output voltage from this discriminator circuit, after rectification, increases or decreases the positive bias upon the driver tube in the 26,460-cycle multivibrator, making this multivibrator increase or decrease in frequency, as the case may be, in order to hold the 60-cycle multivibrator in synchronism with the power-line frequency.

Once the master 26,460-cycle multivibrator is adjusted for stable operation, the control circuit will hold this multivibrator at 26,460 cycles, and hold the field frequency multivibrator at 60 cycles. Here is another beautiful example of how benignly Nature operates to meet man's requirements. But only when man's ingenious mind diligently finds out her ways and means.

Now the output voltages of the three multivibrator stages are of the correct frequency for their respective synchronizing impulses, but the *phase* of each voltage may be incorrect, the time duration of each half-cycle pulse is too long, and the wave form does not have the required square shape. So these output voltages must first be sent through phase-shifting networks, then through pulse-squeezing sections which reduce the time duration of the positive half-cycle pulses to the correct values. The impulses are finally ready for injection into the picture signal, where they are superimposed upon previously injected pedestals. The tops of the impulses can then be clipped off at the correct amplitude to give automatically the desired square-top wave forms.

The horizontal and vertical synchronizing impulses at the output of the amplifier are, in addition to being fed into the television transmitter radiating system, also fed into the horizontal and vertical saw-tooth sweep generators for the camera tube.

Thus at last we complete our television signal. After amplification in the final video frequency stage, it is fed into the grid circuit of the class B grid-modulated radio frequency power amplifier stage. The modulated radio frequency carrier output is then fed to the television sight antenna for radiation through space.

The block diagram in Fig. 10 presents in convenient reference form the complete synchronizing system which has just been described.

It has been previously pointed out that in a standard iconoscope the scanning line length is inherently quite short at the bottom, and increases uniformly as scanning proceeds to the top. To correct for this keystoning effect, the charging voltage applied to the horizontal sweep circuit condenser should be higher than the normal value for the bottom line on the mosaic, and should reduce gradually to the normal value as scanning proceeds to the top of the mosaic.

Since the horizontal line length and re-trace time

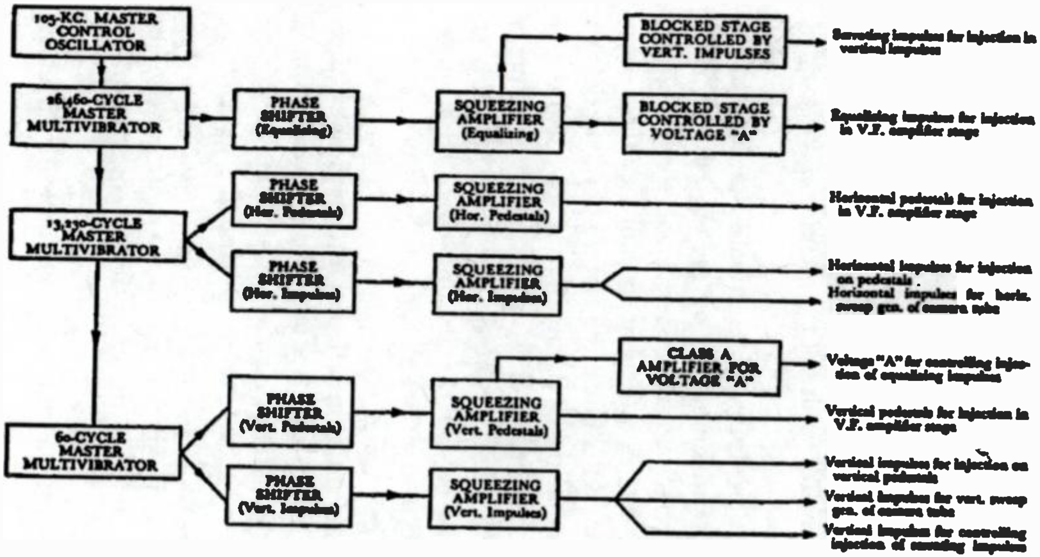


FIG. 10

Block diagram illustrating one possible arrangement for the synchronizing system of a television transmitter. Only the major sections are shown; in an actual transmitter these sections will be separated by amplifying, phase-reversing and clipping stages.

must vary uniformly in step with the vertical sweep frequency in order to provide the proper correction, the vertical saw-tooth sweep voltage is used for this purpose to control the correcting circuit. This serves to extend the horizontal sweep at the bottom of the mosaic, reducing it gradually towards the top so that all of the lines scanned are the same length. By adjusting width control R_9, the full width of the mosaic can be scanned.

SHADING CONTROLS: To eliminate the dark bands, areas or spots which appear on the reproduced image due to electron clouds in an iconoscope, shading signals must be injected into the first stage of video frequency amplification. Since these dark areas have no definite shape, the monitoring engineer must have access to a variety of different shading signals. While watching a television cathode-ray tube on which the image is reproduced, he adjusts the shading controls whenever necessary, so as to give at all times a clear image having the correct brightness.

In one transmitter installation, the monitor engineer is provided with a compact unit which gives any or all of the six basic signals which he will need for correction. These shading signals serve to raise the gain of the video frequency amplifier for the duration of each dark area. Shading signals can be made to control the screen grid voltage, for this will affect the gain of an amplifier stage.

By employing a phase-shifting network like that shown in Fig. 11, it is possible to shift the effect of the vertical (60-cycle) sine wave shading signal up or down on the mosaic; another phase-shifting network can be used to shift the horizontal sine wave shading signal to the right or left on the mosaic, as required for elimination of a dark area which may wander about slowly on the screen. All of these shading signals have a fixed effect upon the final image, for all shading sources are

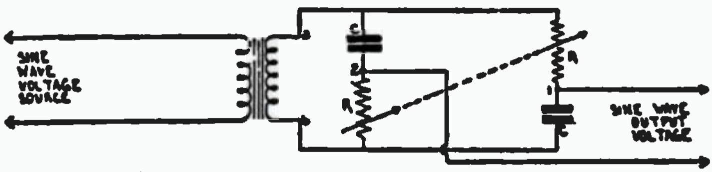


FIG. 11
Phase-shifting network for sine wave shading signals.

either common to or interlocked with the synchronizing signal sources.

A typical phase-shifting network well worth studying is that shown in Fig. 11. This will deliver a sine wave shading signal if it is fed with a sine wave signal. For a given sine wave input voltage, the output voltage will remain essentially constant for all settings of the phase-shifting control. The phase-shifting action of this circuit can be explained most easily by considering the two extreme conditions, corresponding to the extreme settings of the control.

The two variable resistors R are identical, and are operated by a single control. The condensers C are likewise equal in capacity. When the resistors R are set at zero, point 2 will be connected directly to point *b*, and point 1 will be connected directly to point *a*. Under this condition, it is obvious that the output or load will be connected directly across the secondary terminals *a* and *b*, with the two condensers connected in parallel with the output. Under this condition, the sine wave output voltage is in phase with the sine wave input voltage of the transformer secondary.

What happens when resistors R are increased to their maximum ohmic values? Under this condition, the resistance of R is very much higher than the reactance of the condenser C, so that the reactance of each condenser is negligible in comparison to the resistance of its associated variable resistor R. This means that point 2 will now be at practically the same potential as point *a*, and point 1 at practically the same potential as point *b*. We have thus reversed the output connections to the secondary of the transformer, giving an almost complete 180° phase shift between the input and output sine wave voltages. Since the values of resistors R can be increased gradually from zero to their maximum ohmic values, the amount of phase shift can likewise be increased gradually from 0° to almost 180°. This phase-shifting circuit is of great practical value, not only in television, but for numerous other applications.

We have thus seen how sine waves can be shifted for shading purposes. If only a half sine wave is desired, the complete sine wave signal can be passed through a rectifier stage after being shifted the desired amount. Means are provided for adjusting the amplitude of each shading signal, so the amount of shading can be controlled along with its position on the screen.

The details I have given regarding a television monitor's multifarious and exacting duties constitute by no means the whole story. A complete exposition would far exceed the scope of this volume. Enough has been explained to give you a fair idea of the skill of judgment, and the precision and speed of manipulation which the successful television studio operator must attain before one can expect the best possible picture transmission.

The foregoing details will also give you some conception as to the infinite amount of painstaking, ingenious research which has been necessary over the past five years before the present beautifully functioning circuits and devices were finally evolved. One can thus form some idea as to why was necessary the generous outpouring of millions of dollars in television research on the part of RCA and Farnsworth in this country, and by Baird and EMI in England; and some ideas as to what has been actually accomplished thereby.

If you have read, even casually, the foregoing long exposition of complications, compensations, and adjustments which are required in a modern television studio, you will be ready, I believe, to admit that an immense amount of simplification and insurety of results may be enjoyed when the scene, instead of being rushed together, rehearsed, and "shot on the spot," is previously properly reduced to a motion picture film.

Of an importance here almost equal to the advantages from actors', directors', and *mise en scene* standpoints is the fact that with film projection and pickup we have, first of all, a superabundance of accurately controlled illumination on the camera tube. If the film, whether a studio or an external shot, has been taken by a skilled camera man, the illumination facing the iconoscope will be adequate, uniform, or properly shaded. This means not only greatly lessened responsibilities upon the judgment and skill of the television camera man and monitors, but is an almost positive assurance that the output picture signals will be of the finest quality possible for that scene.

Such technical considerations, as well as economic factors, will weigh preponderantly in favor of using the telecine picture wherever this is possible, as the new art develops commercially.

Fourteen: Film Projectors for Television Pickup

INTERMITTENT AND CONTINUOUS SYSTEMS; TRANSMITTING CIRCUITS, ETC.; METALLIC QUARTER WAVE INSULATORS.

THE televising of motion picture film involves special problems. In the first place the standard motion picture sound on film was taken at the rate of 24 pictures or frames per second, or at a film speed of 90 feet per minute, whereas, by RMA television standards the scene must be scanned horizontally 60 times per second, with interlace, giving 30 complete pictures per second.

In an ordinary 16 mm movie projector, a ratchet-and-pawl mechanism is employed to snap each frame suddenly into position for projection on the screen by a suitable lens system. A rotary shutter in front of the projection lens serves to block all light coming through the lens while a new frame is being moved into position for projection. Thus we have an intermittent film movement in the standard projectors used in theaters. We cannot, as might first be supposed, use this standard intermittent movement and simply project the image on the mosaic of an iconoscope or upon the photo-sensitive surface of a dissector type camera tube instead of upon a theater screen. The problem is not so simple.

It is possible, however, to televise motion picture film without employing any intermittent motion of the film. This is known as continuous projection, in which the successive projected scenes are caused to dissolve, one into the next, upon the screen. The iconoscope camera is then simply focused upon the picture of the screen, the same as on an actual scene.

Speeding up ordinary motion picture film from its standard rate of 24 frames per second to the television rate of 30 frames per second would be highly unsatisfactory, for it would tend to make action in the film unnaturally fast, and would give the sound on the associated sound track an unnaturally high pitch.

Continuous projection, obviously, is the simplest and most direct method of solving our problem. In practice, however, this type of continuous projector offers certain difficulties, connected with the optics involved in the continuous film projector.

When an intermittent film projector is employed the difference in frame rates can be offset very ingeniously by projecting standard film in such a way that one frame is exposed to the television camera three times, at intervals of 1/60 second, while the following frame is shown twice, at intervals of 1/60 second. This means that each two frames are exposed to the camera a total of five times. Thus in one second, 24 frames sensitive surface of a dissector type camera tube instead of upon a theater screen. The problem is not so simple.

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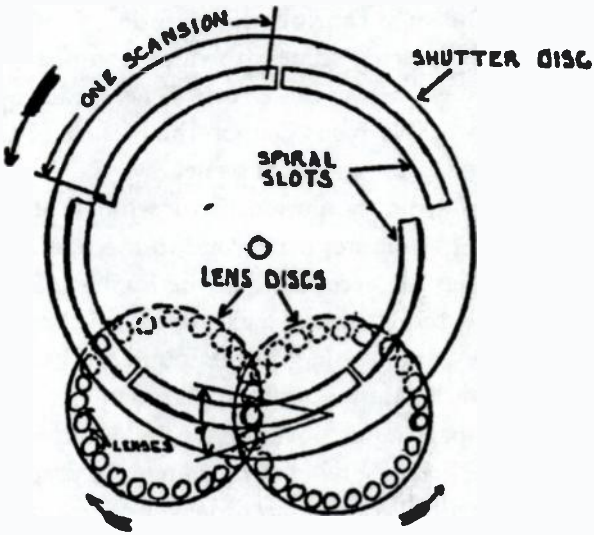


FIG. 1
Optical rectifier and spirally-slotted shutter disc used in a Farnsworth film projector of the continuous type.

non-intermittent type, but will cause increased wear on the film, particularly at the sprocket holes, as the excessive pull-down speed is damaging.

When a movie film is continuously pulled vertically upward or downward through a light beam which is focused onto a fixed mosiac screen by a fixed projection lens, the image on the mosaic will be real and inverted, and will move vertically in an opposite direction on the screen.

However, if the projection lens is moved in the same direction as the film and at a suitable speed a stationary image can be obtained on the mosaic even though the film is moving. A number of identical lenses are mounted on a disc and caused to rotate between the film and the screen in such manner that when one lens and one frame reach the downward limit of travel, the following lens is in the correct position for the following frame on the movie film.

The diagram in Fig. 1 also shows a spirally-slotted shutter disc which revolves 24 times per second but produces the interruptions in the light beam which are necessary to give 60 fields per second. The three-slot section of the shutter disk follows one pair of rotating lenses and gives the required three exposure intervals 1/60 second apart, while the other two spiral slots follow the next pair of lenses and allow two exposures of the next frame, 1/60 second apart. Two lens wheels are used, each with 24 identical lenses, one for each frame per second when projection is at the rate of 24 frames per second.*

* The Goldmark Telecine Projector: Dr. Peter Goldmark, chief television engineer of Columbia Broadcasting System, has evolved an exceedingly ingenious projector of the continuous type, which appears to offer many advantages over other continuous projectors for television. The Goldmark machine uses five fixed, segmentary lenses for projecting the picture frame images upon an iconoscope mosaic. The film travels continuously downward at the rate of 24 frames per second. By means of a spiral-cut shutter, each frame is thus projected upon the mosaic five times, giving 120 exposures, or two for each frame scan, which means 60 alternate line scans, or 30 complete scans, per second.

We now have the televised picture reduced to electrical terms—an unconscionably rapid succession of minute electric impulses. These must now be amplified, without distortion or disarrangement, many millions of times. The first stage or stages of this amplification are in the so-called pre-amplifier, which is housed within the metal casing of the electron camera. Sometimes, instead of the grid audion amplifier tube, an electron-multiplier tube is first employed in this pre-amplifier. But even with the electron multiplier, one or more stages of tube amplification are necessary before the video signals are sufficiently strong to be piped through the flexible coaxial conductor from camera to the studio amplifying equipment and monitor control board.

THE VIDEO AMPLIFIER: The video frequency amplifier stages must be designed to have essentially uniform frequency response over the entire range from about 10 to 4,000,000 cycles. Resistance-capacity coupled amplifier stages are used for this purpose. But this type of coupling introduces a reactance which varies with frequency, causing a phase delay that varies with the frequency of the signal. This in turn necessitates compensation, or correction, which in turn involves a sacrifice in amplifier gain, which calls for more stages of amplification.

Before successful modulation of the ultra-high-frequency oscillation generator (by means of this amplified video current) can take place the television signal must be converted into an acceptable direct current form, so that "information" concerning the general background of the scene can be transmitted automatically to control the general brilliance of the kinescope screen at the receiver.

As to modulation of the ultra-high-frequency carrier currents by the amplified and corrected television signal, the usual (Heising) modulation used in an audio frequency or broadcasting transmitter, cannot be employed successfully in a television picture transmitter; the constant-current choke will not maintain a constant reactance over the wide range of frequencies being handled. Therefore it is necessary to employ "electronic injection" of the picture signal into the carrier signal. This usually is accomplished by means of the control grid feed, although screen grid or suppressor grid feed, or a combination of the two, might be employed.

Generating the Carrier Current: An accurate master ultra-high-frequency oscillator is required for generation of the carrier or radiated frequency. Since this frequency is above 50 megacycles, the use of a temperature-controlled crystal oscillator followed by frequency doubled stages is neither economical nor necessary. A carrier signal, adequately constant in frequency, can be generated by a self-oscillating circuit employing for its tuned circuit a transmission line or resonant coaxial cable constructed with material which remains essentially constant in physical dimensions despite variations in temperature. With this arrangement the master oscillator can be operated at a high level, eliminating the need for a large number of intermediate stages of power amplification.

The next step in the television broadcasting process is the low-loss coaxial cable to conduct the modulated radio frequency carrier from the television station to the radiating system. This antenna usually consists of horizontal doublet antennas resonant to the carrier frequency. But in order to secure a wide-frequency response and thereby insure uniform signal intensity for all side-band frequencies as well as the carrier frequency, these doublets are often given a special shape.

Here in America, horizontal transmitting doublets are employed in order that the radiated electric fields will be horizontally polarized. When the radiating doublets are located essentially in free space, high above all objects, two doublets positioned at right angles to each other will normally give adequate coverage of the service area in all directions. But when the doublets are mounted on a tower which is itself conductive, it is advisable to employ four sets of doublets arranged 90° apart around the tower, or a "turnstile" comprising six such sets, each one a half-wavelength above the other.

The transmitter used for the sound portion of a television program is entirely conventional in design, and need not be considered here. The carrier frequency for the sound transmitter is standardized at a frequency 4.5

m.c. higher than the carrier frequency for the television transmitter.

Although a coaxial cable is normally employed for feeding the picture signal from the studio to the transmitter, when either a temporary or permanent program source is at some distance from the studio and transmitter, an ultra-high-frequency radio relay link may be required. This remote pick-up equipment is generally installed in trucks or trailers. Either a telephone line or another radio relay link is used for the associated sound signals. Careful tests must be made prior to each remote pickup to make sure that no distortion is introduced by the radio relay link.

Recent newspaper publicity to the contrary, existing telephone lines generally are of questionable value for handling television signals even for short distances, except in special instances where the lines are isolated, heavily loaded and equalized to give the required wide response with constant time delay. Normally permissible "cross-talk" on a telephone line cannot be tolerated when video signals are being handled.

Resistance-capacitance coupled amplifiers are used between the camera output and the radio frequency modulator, and the direct current component is inserted into the picture signal at the final video frequency amplifier stage, just prior to modulation.

It would appear that a 60-cycle signal is the lowest which a video frequency amplifier stage would be called upon to handle, but unfortunately this is not so. You must not think of video frequency amplifiers as handling single-frequency signals, for most picture signals include sudden sharp changes, as well as long periods of constant signal level. One must consider the amplifier action for square-wave signals, and this involves a consideration of the amount of damping of the circuits.

The lower frequency limit for a video frequency amplifier is usually placed at about 10 cycles, even though the lowest predominating signal frequency is 60 cycles.

The total amount of time delay in a video frequency amplifier is the sum of the individual delays in each stage. Furthermore, the variation from a constant time delay is cumulative; thus, if one video frequency amplifier stage has a variation of 1 microsecond (one millionth of a second) in time delay over the video frequency range, 10 similar amplifier stages will have a variation of 10 microseconds in the time delay over the entire frequency range. When we consider that the maximum permissible variation in time delay for the entire amplifier in a television transmitter is about one-tenth microsecond, we get some idea of the problems which confront the television transmitter design engineers. That they have succeeded, is an incredibly fine achievement.

The radio frequency section of a typical television picture transmitter will have a master oscillator for generating the ultra-high-frequency carrier signal, followed by a buffer stage, an intermediate power amplifier, and the final power output amplifier. Modulation is usually accomplished by feeding the television picture signal into the grid circuit of the power output stage. (I am pleased thus to observe my original method of modulating a radio tube oscillator [grid modulation] again proving its inherent merits in this newest of the radio arts.)

A typical circuit for a high-power radio frequency section is shown in schematic form in Fig. 2. The function of each stage is identical with that of the corresponding stage in a conventional radio transmitter, but the physical appearance of the transmitter is quite different because we are here handling ultra-high frequencies. Of particular interest is the absence of conventional variable condensers and coils, with pipes being used instead. In this high-power system, all of the tubes are water-cooled; in a low-powered transmitter, air-cooled tubes are used.

With stages designed to handle a carrier frequency somewhere in the television range (50 m.c. to 108 m.c. or higher), every lead is a possible signal pickup element. Unless leads are eliminated or made in such lengths that they will not become parasitic absorbers of radio frequency energy, the efficiency of the transmitter will be very low.

Note that each stage in Fig. 2 employs a push-pull circuit. This is highly advantageous because when coaxial and parallel pipes are used in "tank" or "plate" circuits, the tuning elements are necessarily long and bulky. With push-pull circuits, it is relatively easy to balance the circuits, and grounding is not a serious problem, whereas with single-ended circuits the locating of satisfactory ground points becomes a difficult problem. The frequency of oscillation in this transmitter is controlled by the grid-tuned circuit.

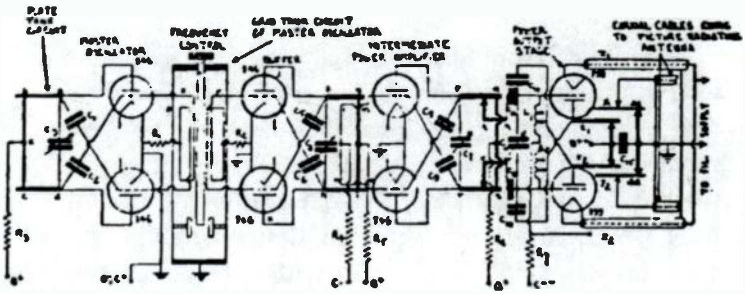


FIG. 2
Simplified schematic circuit diagram for the complete radio frequency section of a high-power television transmitter.

Parallel pipes *a-b* and *c-d* serve as the plate resonant circuit. The length of each pipe is slightly less than one-quarter wave at the carrier frequency. The pipes are mounted parallel to each other. The sketch in Fig. 3 shows some of the mechanical features of this master oscillator arrangement, which employs two type 846 tubes. The plate electrode of each of these tubes is a copper shell fused into one end of the cylindrical glass envelope.

The grid lead is brought out through the side of the glass envelope, and the two filament leads come out of the top. The pipes serving as the plate resonant circuit fit over the plate electrodes of the tubes, thereby eliminating any need for leads between the tube plates and points *a* and *d*. Water is circulated upward through the

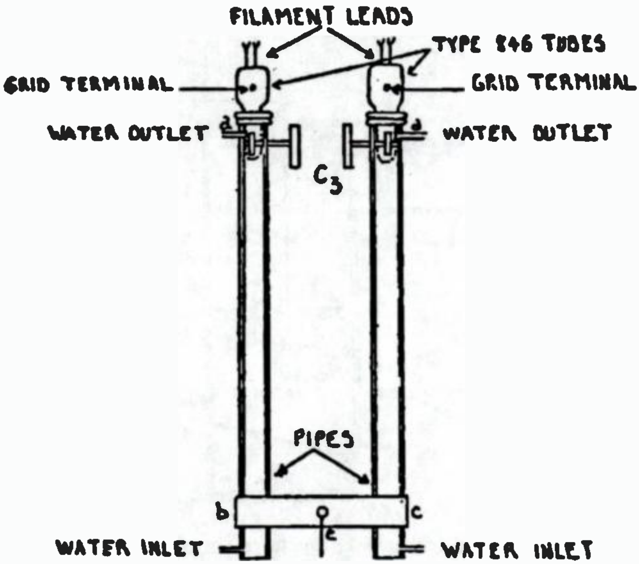


FIG. 3

pipes to the plates in order to keep the tubes cool during operation. The sliding binder rod *b-c*, which connects together the two pipes, is so mounted that it can be moved up and down along the pipes to vary their effective length and thereby vary the resonant frequency of the system.

At the plate ends of the pipe are two circular metal inner pipe, considerably smaller in diameter, is moved in or out by means of the adjusting knob at the top, to vary the line length and the capacity between this pipe and plates P-P on the outer pipe; this in turn controls the frequency of the master oscillator. The grids of the tubes are mounted opposite holes in the tank, and are

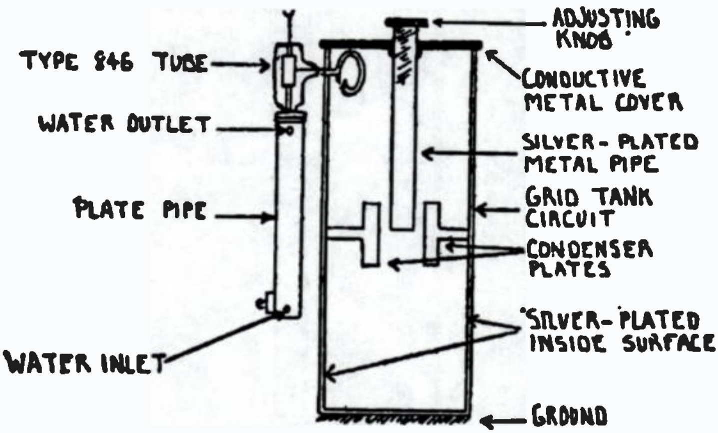
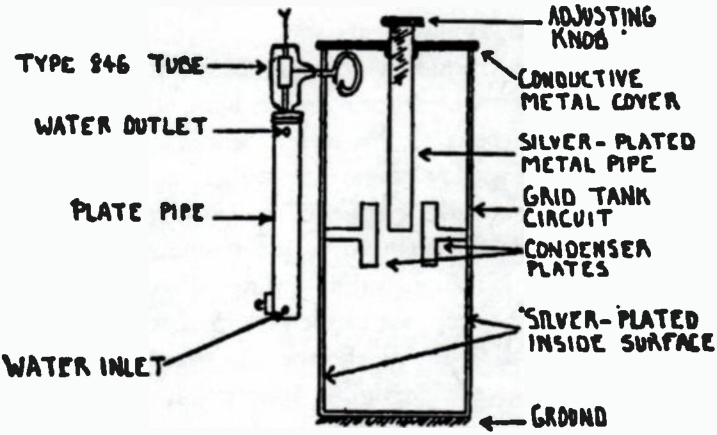


FIG. 4
Physical layout of the grid tank circuit for the master oscillator stage in Fig. 2.

connected to the ends of a conductive loop located inside the tank in such a manner that it intercepts the magnetic flux existing between the inner and outer pipes. The grid tank circuit of Fig. 4 is mounted directly in front of the plate pipes in Fig. 3.

Television transmitting antennas must be altered considerably when the antennas are mounted near large conductive objects. For this reason, the television an-inner pipe, considerably smaller in diameter, is moved in or out by means of the adjusting knob at the top, to vary the line length and the capacity between this pipe and plates P-P on the outer pipe; this in turn controls the frequency of the master oscillator. The grids of the tubes are mounted opposite holes in the tank, and are



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Television transmitting antennas must be altered considerably when the antennas are mounted near large conductive objects. For this reason, the television antenna system installed on the spire of the Chrysler Building by the Columbia Broadcasting Company required special treatment. A set of doublet antennas was placed on each of the four sides of the spire. The antennas on opposite sides of the spire are fed 180° out of phase, so that inward radiation is cancelled. Adjacent sets of doublets are fed 90° out of phase, giving for the complete antenna system the desired circular radiation pattern along the ground.

Although the frequency response of a doublet antenna is quite broad, some engineers believe that this response should be even broader (essentially uniform over a wide frequency range) for proper radiation of video-modulated radio frequency signals. Increasing the number of doublets employed in an antenna system and making them of slightly different lengths is one way of broadening the response of the system at resonance. Another method, involving the use of a shaped "turnstile" antenna, gives a negligible attenuation of signals over a frequency range of 30 megacycles.

Engineers have known for some time that when a circuit has values of L and C such that the expression $\sqrt{LC}$ is equal to the circuit resistance R, then the response will be infinitely broad (the circuit will handle all frequencies without attenuation). To secure an approach to this condition in a practical doublet antenna, it is necessary to shape the radiating element to a special design.

After building many experimental models, RCA engineers found that this condition was approached when the radiators were elliptically shaped, as shown in Fig. 5. The inner or feed ends of the elliptically

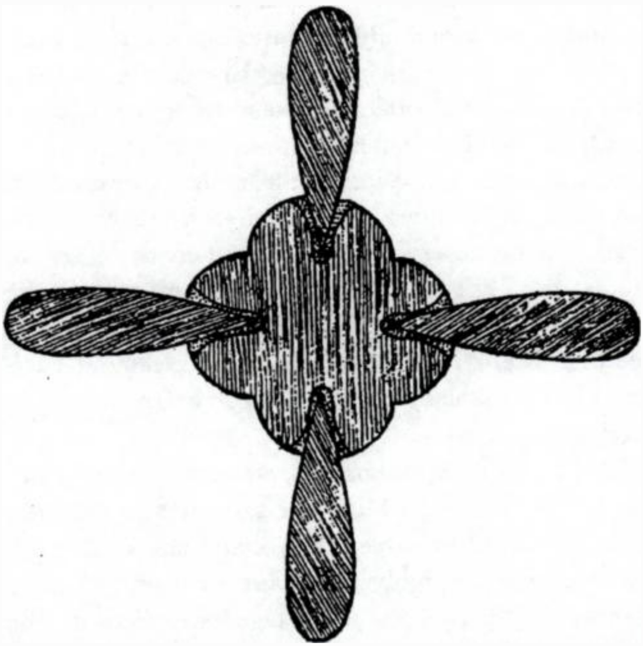

FIG. 5

Horizontal cross-section diagram of the elliptically-shaped doublet turnstile antenna system designed by RCA to give a wide frequency response, and used atop the Empire State Building.

shaped doublet elements are covered by shaped metal throats, so designed as to provide the proper match between the coaxial feed line and the radiating elements. Two such radiating systems placed at right angles to each other and fed 90° out of phase will produce a spherical radiation pattern and will have essentially uniform frequency response for a wide range of frequencies on each side of resonance.

The radiated impulses received at any point simultaneously from two doublet transmitter antennas must arrive there "in phase," to give the maximum effect. For if a positive electrical impulse from one doublet strikes the receiver antenna simultaneously with an equally strong negative impulse from the other doublet, then obviously the two will cancel each other, and no signal will be observed. Similarly when the negative impulse from one is only slightly out of phase with the positive, the cancellation will be less complete, the degree of concellation depending, as we electrical engineers say, upon the difference in phase between the two arriving impulses.

Thus it is readily understood, whenever two or more doublets are to be fed by one transmitter, why the phase relationship between the voltages supplied to the doublets becomes highly important. Any desired phase relationships between the voltages supplied to the doublets can be obtained by changing the lengths of the transmission lines which feed the doublets. Thus, a difference of one-quarter wave in the lengths of the transmission lines feeding two doublets will give a 90° phase shift; a half-wave length difference in line lengths will give a 180° phase shift.

It is possible to control phase relationships by adjusting transmission line lengths simply because each signal voltage peak at the transmitter travels along the transmission line at a definite speed (the speed of light). A voltage peak will therefore travel the distance of one wavelength in the time it takes for the source voltage to go through one cycle. This means that for each quarter-wave of length along the transmission line, there will be a change of 90° in the phase of the signal voltage.

If two doublets which are separated in space are to be fed in phase and one is connected directly to the transmission line, the other doublet must be connected to the transmission line through an additional line exactly one wavelength long, or a multiple thereof. If the second doublet is to be fed 180° out of phase with the first, then the additional line which connects the second doublet to the transmission line termination should be ½ or 3/2 of a wavelength long, etc.

Here is an extremely interesting fact, almost paradoxical to one not versed in the beautiful peculiarities of short electrical waves on wires, or copper tubes: when a metal rod, conductor or conductive support is exactly one-quarter wavelength long and has one end grounded, the other end will have a voltage loop (maximum voltage) and a current node (minimum current). This means that the ungrounded end of the ¼ wavelength line will have an extremely high impedance.

A ¼ wavelength line can therefore be used as *an insulator* for supporting open transmission lines, coaxial cables, or even doublet antenna elements; it is ideal for points where the mechanical load is so great as to make conventional dialectric type stand-off insulators impracticable. So a ¼ wavelength "metallic insulator" can be used anywhere along an open cable or a doublet, or

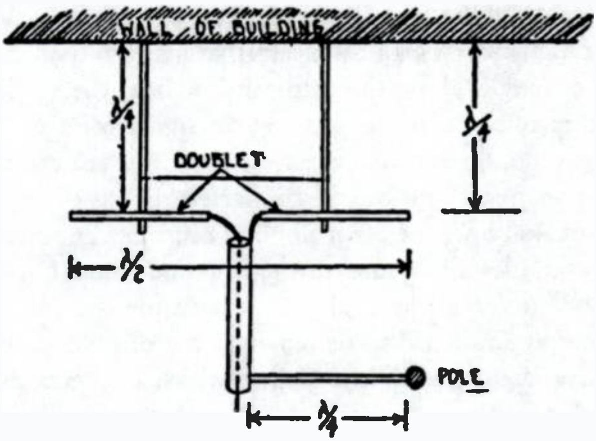

FIG. 6
Example illustrating the use of λ/4 conductors as insulators for supporting the radiating elements and the coaxial cable of a doublet television transmitting antenna.

even in the transmitter itself, without drawing current and without appreciably changing the distribution of current and voltage along the element being supported. An example is shown in Fig. 6.

In designing, locating and erecting the sound antenna for a television station every precaution must be taken to prevent interaction between the sight and sound radiating antennas. If both sight and sound antennas employ two doublets, with one horizontal doublet mounted a half-wavelength above the other, and both are fed in phase, there will be negligible vertical radiation and negligible interaction between the two doublets.

If a turnstile antenna like that shown in Fig. 7 is used for radiation of sight signals, an additional antenna

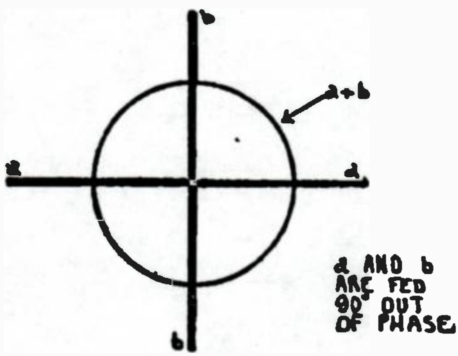

FIG. 7

system could be located above it and used for the sound signals. A better scheme, however, employed by RCA engineers, involves a horizontal loop type sound antenna located above the turnstile sight antenna. Interaction is minimized with this arrangement because the loop antenna has practically no radiation in the broadside direction, which is vertical in this case.

A loop antenna can be approximated by employing four ½ wavelength doublet antennas bent into arcs so that they form a circle, as shown in Fig. 8A. With this arrangement, the ends of the doublets (points *a*, *c*, *m*,

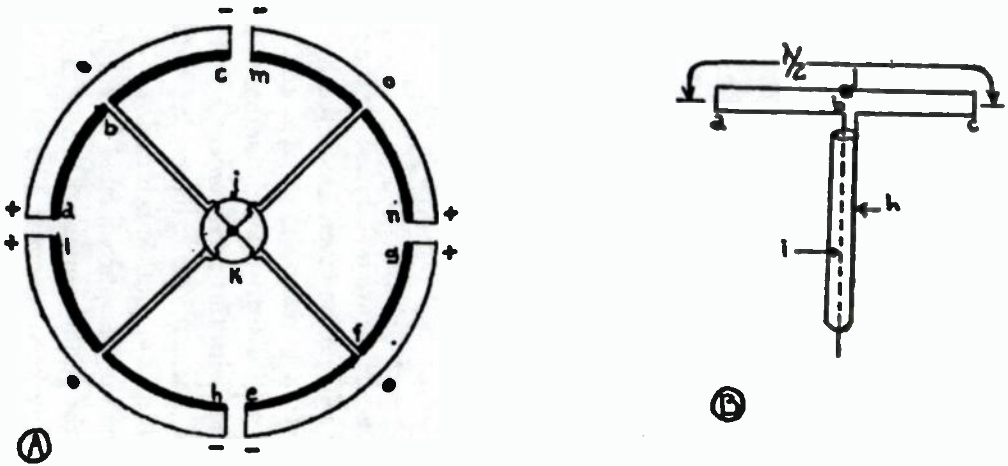

FIG. 8

At A is shown a method of arranging four curved doublets to approximate a loop antenna. The letter k applies to the common junction of the four leads at the center of the diagram. The arrangement used for supporting individual doublets in this system is shown at B.

n, g, e, h, and *i*) will be voltage loops (have maximum voltage). For a continuance of standing waves all around these doublets, adjacent ends, such as *c* and *m*, must of course have the same polarity at any instant. Ring *j*, which is the outer conductor of the coaxial feed cable, and lead *k* (the inner lead of the coaxial cable) are connected to the doublet by leads which are so phased as to make adjacent doublet ends have the same polarity.

Any upward radiation from the turnstile video antenna intercepts all doublets in this audio loop, it is true, but such intercepted signals are cancelled in traveling over the feed wires to the coaxial supply, or feed cable.

The problem of supporting a loop antenna like that in Fig. 8A to withstand high winds and ice can be solved mechanically without affecting antenna performance if certain electrical requirements are observed. Referring to Fig. 8B, observe that arm *a-j-c* supports the center-fed doublet *a-b-c*. Both the doublet and the supporting arm have voltage "loops" or maximum voltage at their ends, hence the supporting arm acts as a high impedance which is fed in parallel with the doublet and has the same voltage distribution. Current will flow in the same direction through both horizontal elements, and will not alter the characteristic radiation pattern for a single doublet. Point *j* on the supporting arm is at a voltage node (at zero voltage or ground potential), and hence may be supported by a pipe anchored to the vertical tower, without possibility of current drain to ground.

VIDEO CHECKS: A television video transmitter must be checked and adjusted at regular intervals in order to insure the highest possible image definition at all times. Only an approximate check of image definition can be made by watching the final image in a high-definition monitoring receiver, however, for opinions of different individuals will vary widely as to what constitutes acceptable image definition. A far more accurate determination of image definition can be made, therefore, by televising certain special geometric charts which are designed to indicate the so-called "resolving power" of the transmitter.

The horizontal definition of a transmitter can be estimated by televising a number of parallel vertical black lines and viewing their reproduced images on a monitoring television receiver which is known to have high image definition and is properly coupled to the output of the transmitter. Likewise, the resolution in a vertical direction can be obtained by televising horizontal parallel black lines. Charts for increasingly higher line definition (starting at, say, 100 lines per field and working up to 500 lines per field) could be tried. The chart on which the lines are just distinguishable corresponds to the resolving power of the transmitter. Resolving power also can be checked with a single chart having black lines converging in a wedge-shaped pattern. If the lines of the wedge are clear, even at the narrowest end, we know the transmitter has high definition; if only lines at the widest part of the wedge can be distinguished, the image definition is low.

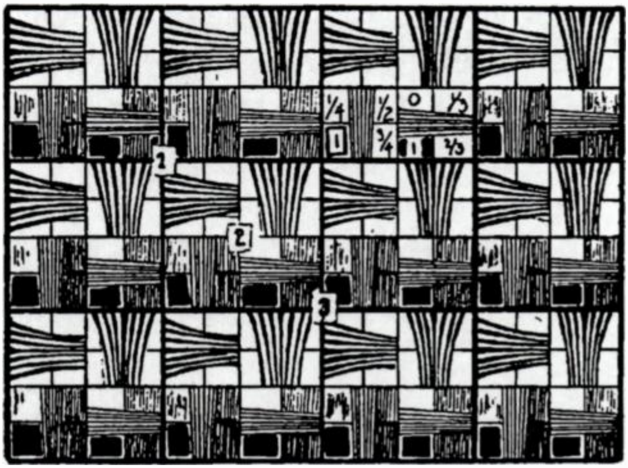

FIG. 9
Chart used for checking the image definition or quality characteristics of a television transmitter.

A resolution-checking chart is shown in Fig. 9; here we have twelve identical groups of geometric patterns arranged in three horizontal rows, with four different geometric patterns in each group. Thus, in each group there are two horizontal wedges, one for low and the other for high definition, and two corresponding vertical wedges. Failure to get sharp definition for a definite number of lines (441 per frame) indicates either poor interlacing, poor optical focusing on the camera tube or improper adjustment of the size of the electron beam in the camera tube (assuming that the monitor is right).

By analyzing all twelve areas on the monitor screen, it is possible to determine if the shading adjustments have been properly made so as to eliminate dark spots.

Fifteen: Receiving Antennas for Television

HOW TO MAKE, INSTALL AND TEST DIPOLES AND FEED LINES; LOCATION DIFFICULTIES.

UNLIKE the present practice in broadcast reception of hanging a wire in any location, position, or of any convenient length, the television antenna must be erected with utmost care, and an intelligent knowledge of the various factors, receptive and interfering, involved. As far as television is concerned we need fear no additions to the unsightly rats-nests of slovenly strung wires swinging from bed slats, curtain poles, and chimney pots which now decorate the flat roofs of apartments in our great cities. In this respect at least, television is a distinct improvement over radio!

Essentially, the television receiving antenna is an ultra-short-wave dipole similar to those used by amateur radio "hams" and others working on waves below 10 meters. Special precautions must be taken as to location, direction of the dipole, and of the transmission line leading down to the receiver, to prevent interference from ignition systems of passing automobiles, and multiple "ghost" images due to reflections of transmitted waves from various objects or surfaces.

Much of such interference from automobiles, fortunately, is in the form of vertically polarized waves. The horizontal dipole antenna at the transmitter and the correspondingly horizontal at the receiver largely avoid such disturbance. This is true if the receiving dipole is highly placed, and as far back from the street as possible. Do not infer from this that a vertical antenna or wire will not pick up any television signal. Horizontally polarized waves do not remain strictly polarized after travelling some distance, especially if they suffer diffraction or reflection from certain surfaces. This *may* produce rotation of the plane of polarization.

The simplest form of antenna is the half-wave dipole, consisting of a horizontal copper rod or tube, its length equal to one half-wavelength of the radiation to be received, and connected to the receiver by means of a transmission line—a twin conductor, preferably shielded, or a coaxial cable. Such an antenna receives best from a direction at right angles to the rod axis.

The transmission line can be coupled to the dipole either indirectly (Fig. 1) or directly (Fig. 2). In the first arrangement the few turns in the mid-section of the dipole increases its natural wavelength, or period of oscillation, which necessitates a corresponding shortening of the dipole's arms.

When the gap separating the two arms in Fig. 2 is made as short as possible, this antenna will match a transmission line of about 74 ohms (surge) impedance.

If the receiver be located at a considerable distance from the transmitter, correspondingly better pick-up and directional properties are required. This may be achieved by use of a second dipole arranged and connected parallel to the first, or a similar, insulated dipole

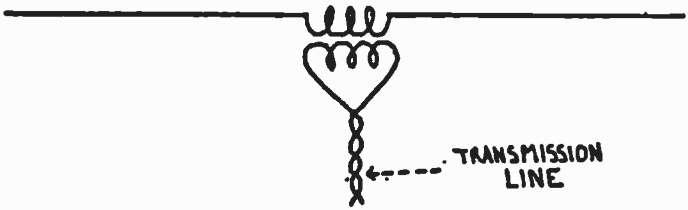

FIG. 1

parallel to the first. This reflects the received wave energy back upon the first to materially aid signal strength. Both remedies are recommended.

If the second insulated antenna lies behind the receiving dipole, it is called a "reflector"; if *between* the

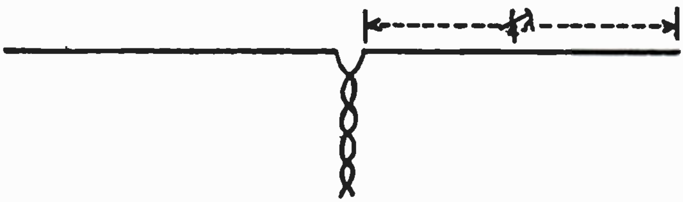

FIG. 2

receiving antenna and the transmitter it is called a "director."

The design, dimensions and location of such reflectors or directors must be such that the signal reradiated therefrom will arrive in phase with the original signal at the receiving antenna. Signals arriving from other directions, or different frequencies from the same direction, will suffer discrimination because the re-radiated signal will oppose the direct pickup at the receiving antenna.

According to the findings of G. H. Brown, as described in the *Proceedings* of the Institute of Radio

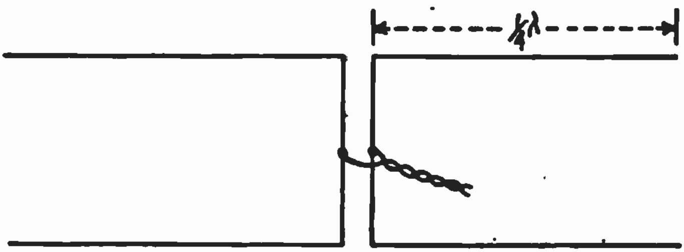

FIG. 3

Engineers, January, 1937, the maximum gain in signal reception due to a reflector or a director occurs when the receiver and the reflector antennae are 1/10 of a wavelength apart. The maximum gain thus obtained was 5 times.

A combination of two parallel dipole receiving antennae is shown in Fig. 3; and a combination of antenna and reflector is shown in Fig. 4. Reception is best from the two directions shown, in the plane of the two conductors. In one case the insulated rod becomes a reflector, in the other a projector. One popular type of television antenna comprises two such dipoles, and two reflectors.

In any actual installation maximum performance can be obtained by slight readjustment of the length or the location of the reflector or director.

It should be known that the correct length of a "half-wave" antenna actually is somewhat less than half a

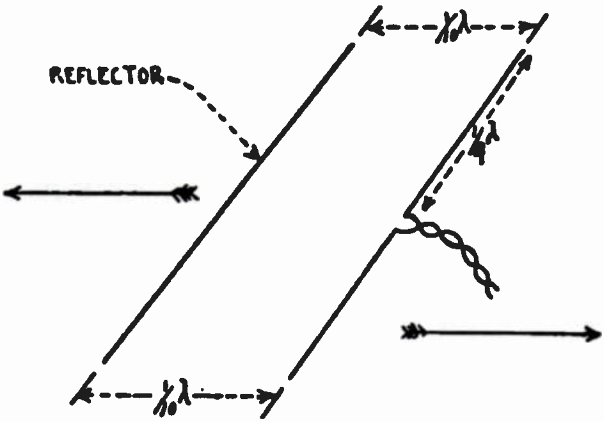

FIG. 4

wave of the wavelength to be received. This is because the velocity of the wave along a wire, or conducting tube, is slightly less than that in space (velocity of light). And also because of the so-called "end-effect." The total reduction in length due to these two causes approximates 7 per cent. However it is not necessary to determine this length very accurately because of the wide transmission frequency band to be received. A good rule-of-thumb to use is the following: Multiply the wavelength of the radiated carrier in *meters* by

18.3. The result is the correct length of a half-wave antenna in *inches*. Or divide 5440 by the carrier frequency in *megacycles*, which also gives half-wave in inches. For example, the correct length to use for the 50-56 megacycle band is 102 inches.

Conductors of large diameter, such as iron pipes, make good receiver antennas. The additional damping thus introduced is advantageous where a wide frequency band is to be received.

It is of great importance that the impedance of the transmission line leading down from the dipole to the television receiver be carefully matched to the impedance of the input circuit of the receiver. The theory of transmission lines shows that electric waves travelling along such a line (twisted wires or coaxial) will be completely absorbed by the terminating load provided this load matches the impedance of the line. If this is not the case there results a loss of power at the point of junction, and a reflection of the wave occurs, resulting in repeated reflections, with more loss of power.

And in television these returned waves may be so long deferred as to produce a "ghost" picture on the screen, slightly displaced from the original image. Obviously the prominence of this ghost image due to reflection will depend on the length of the transmission line; i.e. whether or not the delay of the twice reflected wave is an appreciable fraction of the time required for scanning a line of the picture.

If there are seven million picture elements laid down per second, then the effect of reflection will be visible if the delay exceeds one seven-millionth of a second; this will be the case where the transmission line is longer than 20 meters (about 65 feet). Such reflections from the transmission line can be eliminated by careful matching of impedance at the receiver end. With receivers purchased ready made, this matching will have been taken care of, but the prescribed transmission line must be used. For those amateurs who are building their own television receivers, the suggestions shown in Fig. 5 will be found helpful. (See page 272.)

But reflections other than those generated in the transmission line may arise. Metal structures, buildings, even of masonry or concrete, cause reflections, especially if the angle of incidence is large. Reflection may also occur from the ground, especially from a highly elevated transmitter antenna. At times these are received in greater volume than those directly from the transmitter. The shortest and most direct path through space between two points, transmitter and receiver, is called the line-of-sight path. It is always a straight line. But under certain conditions these ultra-short-wave signals from the transmitter will travel toward the ground at just the right angle to be reflected up to certain receiving antennas. This phenomenon must always be considered when erecting a receiving antenna. It is easy to cut out this earth-reflected wave if such is desirable, simply by arranging a grounded screen below and surrounding the receiver dipole.

Reflections cause phase interference between the two sets of signals, direct and reflected. These two, if nearly 180° out of phase (in opposite phase) may offer a serious problem at receiving locations near the extreme limits of the service area, where a slight reduction in signal strength might mean the difference between good and bad reception.

A maximum reduction in the strength of the desired signal will occur when the difference in signal paths is effectively a half wavelength at the frequency of the picture carrier. At 50 megacycles this would be a path difference of three meters (about 10 feet). When one signal is weaker than the other, the cancellation will be partial; when both signals are equal, there will be practically complete cancellation, and no image on the screen.

The installer can overcome phase interference either by placing the receiving antenna so it will accept signals from one path only, or by moving the antenna system to a new location where the phase interference will be such as to give reinforcement rather than cancellation of the desired signal. When there are several undesired paths, each can produce its own ghost image. Wherever the ghost image overlaps the main image, blurring of detail will exist.

The outlines of a ghost image are readily noticed if they are displaced 1/16 inch or more from the desired image. But if the displacement is less than this amount, the effect will simply be blurring.

The installing engineer or service man must determine by experimentation, trial and error, the optimal arrangement of the antenna and reflector in each particular instance. Obviously this work demands the services of two men, one at the receiver, and a temporary telephone connection between the two. Naturally such tests can be made only while the transmitter is in operation. The success of a television receiver installation depends to a great extent upon the knowledge and skill of the engineer who erects the receiving antenna system.

Even under ideal conditions, where there is only one television station in a locality and every part of the antenna system can be adjusted for maximum response to the signals of that one station, the erection of a completely satisfactory antenna installation often is a real problem. When there are two or more television stations in a given service area, the antenna problem becomes very much more difficult.

The minimum distance which a ghost image signal must travel farther than the direct signal in order to produce a genuine ghost image on a standard television picture screen ten inches wide is 390 feet. A lesser difference in the two paths than 390 feet will cause a blurring of the image. Ghost images can be eliminated by designing and positioning the television receiving antenna so that it will accept signals arriving only over one path.

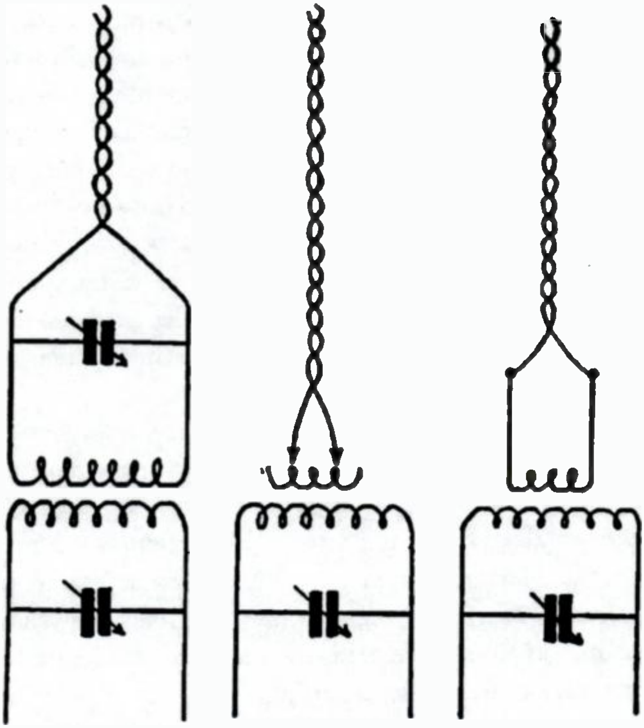

FIG. 5

The first step in eliminating such signal interference troubles is to shift the receiving antenna a few feet in some direction until a location is found giving maximum signal strength for the desired signal and no blurring or ghost images.

But, as pointed out above, phase interference, ghosts and blurring can be caused by an improperly installed and improperly adjusted transmission line, even when the antenna is properly positioned to receive signals over only one path. The television receiving antenna will ordinarily be of the conventional doublet type, connected to the receiver by a two-wire transmission line. This line may be made up of two parallel wires separated about two inches by insulators, or it may consist of insulated wire placed inside metal loom or metal pipe to give a rubber-insulated coaxial cable. It may consist of bare copper wire centered by insulating beads inside metal tubing to give a low-loss air-insulated coaxial cable; or it may be the conventional twisted two-wire transmission line. Regardless of its construction, a transmission line will give no trouble as long as it is properly matched at each end.

Only improperly matched open-wire transmission lines can produce signal interference, for signals reflected in ordinary coaxial lines and twisted lines are attenuated so greatly that their effect upon the desired signal after reflection is negligible.

With open-wire lines or low-loss coaxial lines shorter than 100 feet, the difference in path lengths due to reflection back and forth along the transmission line may not be enough even to cause blurring of the image.

We cannot solve our transmission line problems simply by avoiding the use of low-loss coaxial lines or open-wire lines. Television receiver installations near the limits of the service area for a given television station generally will require a lofty antenna and a long transmission line, to utilize the maximum amount of signal which reaches these locations. In these critical cases it is necessary to adjust line terminations for best possible impedance match. Only by having a thorough understanding of the characteristics of television receiving antenna systems can the engineer make successful television receiver installations near the limits of the service area of a transmitting station.

Although reception of radio signals at ultra-high frequencies is almost free from atmospheric interference and static, man-made interference in certain cases is particularly severe at these frequencies. Automobile ignition interference and radiation from neon signs are the outstanding offenders.

Until such time as laws and regulations are set up to make suppressors mandatory on automobiles, the installing engineer must provide ways and means for minimizing this and other man-made interference when installing a television system. One object in a television receiver installation, therefore, is the maximum possible signal-to-noise ratio, so the automatic volume control system may operate to essentially eliminate such interference "noises."

Fortunately, man-made interference is essentially vertically polarized near the ground. This means that a vertical television receiving antenna will pick up more man-made interference noise than will a horizontal receiving antenna. Furthermore, with a horizontal receiving antenna it is easier to eliminate phase interference, blurring, and ghost images, because the antenna then has horizontal directivity and can more readily be positioned to receive signals over only one path. Shielding, however, still may be essential.

The longest line-of-sight path from a given television transmitting antenna to a receiving antenna of given height is that along a straight line which joins the two antennas and just grazes the earth's surface somewhere between the antennas. This distance clearly depends upon the height of the receiving and transmitting antennas, and for level country can be computed by means of the following formula: Maximum line-of-sight path in miles $= 1.63 \times (\sqrt{h_T + h})$, where h_T is the height of the transmitting antenna in feet and h is the height of the receiving antenna in feet.

But when the terrain is uneven between the two points, or when the receiving antenna is at a different altitude above sea level from the transmitting antenna, any estimate of the service area of a station must be based upon a topographical survey of the locality, showing the heights of all hills which might block signals.

Reflection of signals from the ground or from buildings, and refraction of signals in the atmosphere, often will increase the theoretical maximum distance. Furthermore, locations within the calculated maximum distance will not always be satisfactory for reception purposes. In thickly populated areas having numerous high buildings, there may be dead areas where the signal has been absorbed by buildings and is consequently too weak for satisfactory reception.

The first step after a television transmitter is in operation is to make a thorough field survey to determine the field strength of the signals throughout the surrounding terrain. Such survey will give useful information as to the probability of satisfactory reception at any point, and the probable height of the receiving dipole which will there be required.

Below is a table showing the proper length of the horizontal dipole for optimum reception of signals having the various frequencies here listed, these being the seven Group A ultra-high-frequency channels now assigned for experimental (soon to be commercial) television purposes.

Freq.	*L*
50 mc.	9 ft., 10 in.
56 mc.	8 ft., 9 in.
72 mc.	6 ft., 10 in.
84 mc.	5 ft., 10 in.
90 mc.	5 ft., 5 in.
102 mc.	4 ft., 10 in.
108 mc.	4 ft., 6 in.

The most common transmission line, from dipole down to the television receiver, is the twisted pair or rubber insulated coaxial line. But when the losses thereby incurred are too great an open transmission line like that shown in Fig. 6 is recommended. Such a line will have a surge impedance of some 500 ohms. Consequently one cannot use a center-fed connection.

Instead, the voltage or impedance feed shown in Fig. 6 is employed. The transmission line wires are spread and connected to two points on the antenna which are about .15L apart and equally spaced on each side of the center of the single half-wavelength long rod which serves as the antenna. The impedance between these two points on the antenna is about 500 ohms, and con-

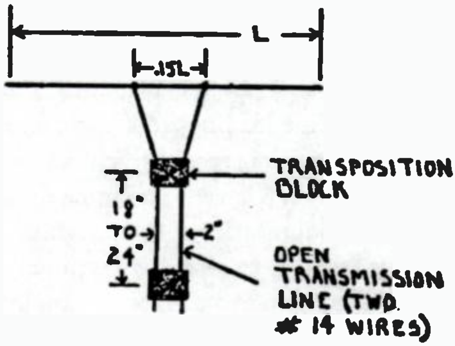

FIG. 6

sequently this connection gives the desired impedance match.

Transposition blocks must always be used with an open-wire transmission line, to minimize the effects of noise signals and station signals picked up by the transmission line. Transposing of the line wires at regular intervals also serves to maintain a balanced line and reduce reflection effects in the line. These blocks should be spaced about 18 inches apart.

It is essential to have a support which will prevent both the antenna and the transmission line from sway-ing in the wind. The support for a dipole antenna must be very rigid.

The reflector rod ¼ wavelength behind the dipole may conveniently be mounted to the same framework support, as can also the "projector" rod if this latter be desirable. The entire array may well be pivoted, so that if a second television transmitter be installed, the receiver can be directed toward either, as desired. Or two separate and distinct receiving arrays, one for each program (assuming the two transmitters are widely separated directionally) may be permanently installed. Then a transmission line leading from each, and a two-way switch at the television receiver will afford ready choice of programs to the viewer. The same dipole also serves to pick up the sound part of the program.

It is sometimes possible to obtain directional characteristics without the use of a reflector. A single dipole antenna, properly positioned with respect to nearby metal structures such as rain gutters, roof flashing, metal penthouses, etc., can give highly directional action. Experimentation, when installing a single dipole antenna, will indicate the best position.

If situated near the limit of good reception from a transmitter, the signal pickup may be considerably increased by use of a long, multiple wavelength antenna, such as shown in Fig. 7. Here the antenna is 8 or more wavelengths long, and pointed toward, but at a certain angle with the direction of the transmitter. This optimum angle varies with the length of the antenna, being about 20° for an antenna 4 wavelengths long. The free end of the antenna should therefore be tilted toward or away from the ground until maximum signal strength is obtained. It is also a good plan to ground the far

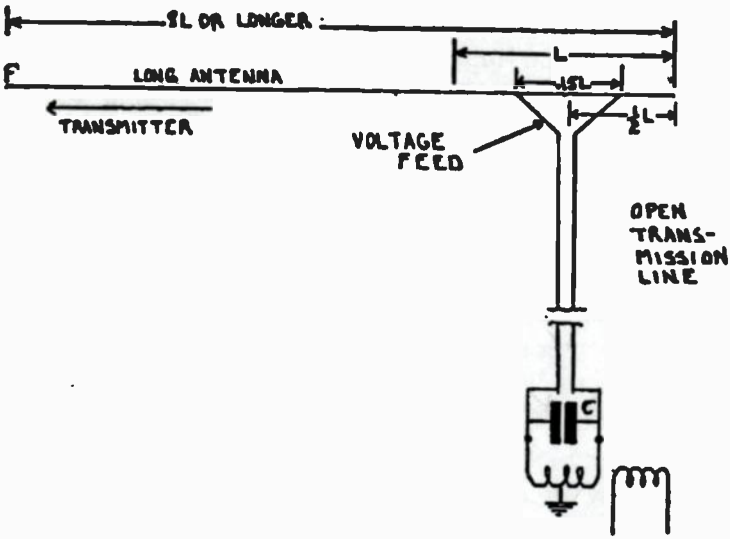

FIG. 7

end of such an antenna through a resistance (600-700 ohms) to prevent wave reflection from that end.

If an open type transmission line like that shown in Fig. 7 is employed, the input impedance of the receiver should be increased to about 500 ohms so as to match the line impedance. This can be done by shunting the receiver end of the line with a variable condenser having a maximum value of about 100 mmfd. The condenser is adjusted for maximum signal strength and the clearest possible definition. This tuning will automatically eliminate ghosts or other signal interference defects due to reflection back and forth in the transmission line. The variable capacity and the leakage inductance together form a parallel-resonant circuit which raises the input impedance of the receiver to about 500 ohms. It is useful to remember that the input impedance of a conventional television receiver can be increased by connecting a variable condenser across the input terminals and tuning for resonance.

The erection of an antenna system which will pick up signals satisfactorily from two or more stations brings new problems, the seriousness of which depend upon existing conditions. If, for example, all the telecasters in a given service area are closely grouped together, it will be possible to use a simple dipole antenna or a directive antenna which is designed to have a wide frequency response and is oriented in the direction of the group of stations. When the transmitters are widely separated in a metropolitan area, receivers in the center of this area must have antennas which will pick up signals from several desired directions. Many different types of television antennas will undoubtedly be devised to take care of the various conditions encountered.

Where directivity is unimportant, a simple dipole is adequate. The length of the dipole should be chosen to make it a half wavelength doublet for the highest frequency employed by any station in that locality, because such an antenna will have maximum current at its center for all stations. And when using a transmission line of several wavelengths long, the antenna system will be sufficiently broad for satisfactory reception over two or more bands.

For multiple frequency reception, multiple doublet arrangements may be satisfactory for television reception. These doublets may be arranged as shown in Fig. 8. As long as one doublet does not act as a load on another, they will be more or less independent and each will be resonant to its particular signal frequency. The doublets should be spaced about two inches apart.

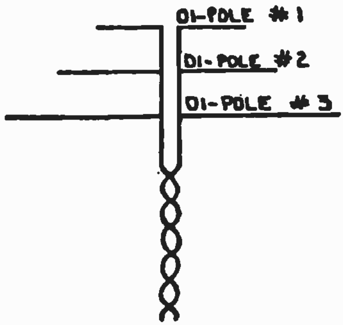

FIG. 8

Since the prime considerations for placing a television antenna are height above ground, and remoteness from the highway to avoid auto-ignition noises, locations involving transmission lines as long as 100 feet should first be tested to make sure that sufficient signal pickup will be obtained to overcome the transmission line losses. When a site has been selected, the antenna should be temporarily mounted, with the transmission line initially quite long, to permit moving the antenna back and forth at the selected location and to permit orientation for maximum signal strength.

If reception of the direct signal proves unsatisfactory, the antenna should be aimed at the ground or at some

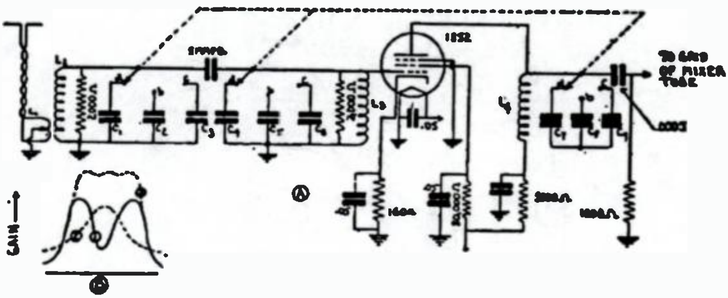

FIG. 9

nearby building in the hope of picking up a suitable reflected signal.

A brief consideration now of the television receiver circuits designed for use where any of several different transmitters is to be received, will be helpful. The radio-frequency tuning and band-pass circuits for such a receiver are typically shown in Fig. 9.

A wide pass-band in the pre-selector, or antenna-transmission line tuning circuits, means high picture definition and good coverage of the sound channel. From a practical standpoint it is here preferable to employ push-button or rotary switches which will introduce separate condenser or coil elements into each resonant circuit for each television transmitter. This procedure permits preadjustment of each tuning element to give the desired pass-band for each station.

The preselector arrangement here shown employs three tuned circuits, with the first two being tuned to different frequencies to give the double-peak pass-band response represented by curve 1 in Fig. 9, and the third being broadly peaked as shown by curve 2. The over-all response is therefore essentially flat-topped, as shown in curve 3.

Here coil L_4 can be tuned to any one of three different television channels by setting the station-selector switch to point a, b, or c; this inserts a preadjusted condenser C_7, C_8 or C_9 in the resonant circuit. The 1,000-ohm grid resistor in the following mixer stage loads this resonant circuit, thereby broadening the response.

Since it is standard practice to radiate the sound programs on a carrier frequency which is above the video carrier by 4.5 megacycles, and since the local oscillator in a television receiver is always operated at a frequency above the incoming video carrier frequency, the intermediate frequency sound carrier in a television receiver will always be 4.5 mc. below the video intermediate frequency carrier. For example, if the video intermediate frequency carrier is 13 m.c., the sound intermediate frequency carrier will be 8.5 m.c.

Some television receivers do not have a complete sound channel; instead, the output of the sound intermediate frequency amplifier is fed into the existing all-wave receiver in the home. When tuned to 8.5 m.c., the all-wave receiver completes the sound channel section of the television receiver. This gives a material reduction in the cost of the television receiver, but is at best an unsatisfactory make-shift arrangement.

COMBINATION ALL-WAVE TELEVISION RECEIVER: When a receiver is to serve for both television and all-wave sound reception, the regular sound channel of the television receiver may be so designed that it can be switched either to the television frequency converter section or to an extra preselector and frequency converter section of the all-wave type. In this way, all-wave reception can be incorporated in a television receiver at a minimum cost.

In a large city, where most television receivers will be located in apartment houses, many of them pocketed among or blanketed by higher steel-framed structures, the question of antenna location is a serious one. The most successful solution is to erect one or more master receiving antenna structures, as high as permissible, and lead these to master receivers and video amplifiers, common to the entire apartment building. Then with coaxial video frequency channels feed each individual receiver throughout the building. This of course entails much additional expense, even if only one transmission cable be led to each receiver down stairs. In the latter case an operator is required in charge of the master receivers, who will on telephoned request connect any kinescope and sound reproducer cabinet to any desired program which may be on the air at the time.

Sixteen: Sweep Circuits

FORMULAE; OLD AND NEW IDEAS, ETC.

REQUIREMENTS for a linear sweep circuit are:

1. The spot must move at a constant speed in the forward stroke.
2. The return stroke must be as fast as possible, occupying only a small part of the entire cycle.
3. The frequency must be easily adjustable.
4. The arrangement must lend itself to synchronization with the observed signal or with any other alternating voltage.

Most linear sweep circuits derive their "saw-tooth" wave-form from the charge and discharge of a condenser. During the forward stroke the voltage across the condenser is made to rise at a uniform rate by charging it through a constant-current device. When the charge reaches a certain magnitude the condenser is discharged suddenly by means of a gaseous tube or a vacuum tube. One of the oldest and simplest forms of such a circuit is shown in Figure 1. The condenser, C, is charged from a d.c. source through a high resistance, R. The voltage drop across the condenser then increases according to the well-known relation

$$e = E\left(1 - e^{-\frac{t}{RC}}\right),$$

E is the voltage of the power supply,
ε is the base of the natural logarithmic system, 2.718 . . . ,
t is the time in seconds, the duration of the charge,
C is the capacity in microfarads,
R is the resistance in megohms.

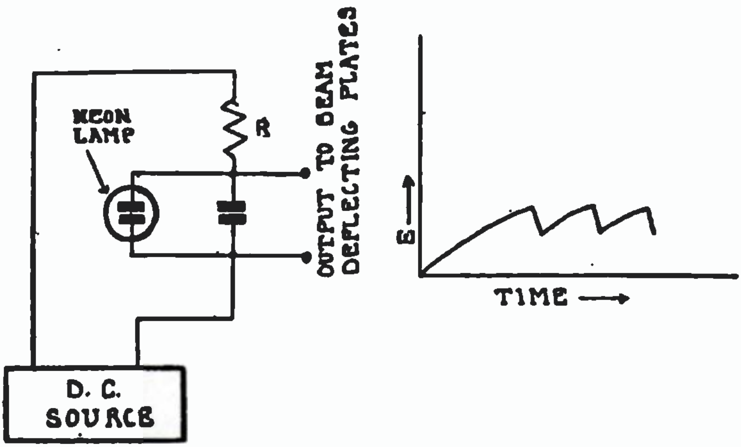

FIG. 1

When the voltage drop across the condenser reaches the striking voltage of the neon tube, the tube ionizes and discharges the condenser to the "extinction potential" of the tube. Then the condenser charges again and the cycle is repeated. The waveform of the voltage across the condenser is shown in Figure 1.

The required d.c. potential must be at least large enough to reach the striking voltage of the tube, but a somewhat higher voltage is advantageous.

This old circuit has several defects: (1) The forward stroke is not exactly linear but follows a logarithmic curve. (2) The output voltage is restricted to the difference between the striking and extinction voltage. (3) The tube constants are subject to variation with age and temperature, so that the same circuit constants will not always result in the same frequency.

There are two ways of making the forward stroke practically linear. The easiest one consists in utilizing only a small part of the logarithmic curve. A close study of the curve reveals that the lower portion of the curve—up to about 20 per cent of the full charging voltage—is nearly straight.

The time required for a single cycle in the case of a simple resistance in the charging circuit, is

$$T = t - RC \log\left(1 - \frac{e}{E}\right) \text{ seconds,}$$

where t is time required for discharge,

R is charging resistance in megohms,
C is capacity of condenser in microfarads,
e is maximum voltage across the condenser,
E is the supply voltage.
(Log is the natural logarithm.)

The frequency in cycles per second is then $f = 1/T$. The value of t depends on the tube and on the charge in the condenser and is in the neighborhood of

1/50,000 of a second. This quantity may be neglected at low frequencies. The equation then becomes the simple one of a condenser charged through a resistor. This was simply discussed in the Aerovox "Research Worker" for January 1938, where graphs are shown for the finding of T.

If a current limiter is used, the value of f is

$$f = \frac{1}{t + \frac{Ce}{I}} \text{ cycles per second,}$$

where t is the time for the discharge in seconds,

C is the capacity of the condenser in microfarads,
e is the peak of the condenser voltage,
I is the charging current in microamperes.

There is an infinite number of combinations of R, C and e or I, C and e to obtain a given frequency.

In order to make the time of the return trace as short as possible, the condenser C should be small since the maximum discharge rate is limited. A low voltage, e, also results in a shorter discharge time. There is a limit, however, to the reduction of capacity. When the condenser becomes too small, compared to the capacity of the wiring and the tube, the operation of the circuit becomes erratic, resulting in a distorted waveform.

In most cases the sweep voltage will have to be amplified. This is generally done with a resistance-capacity coupled amplifier. The amplifier must faithfully reproduce the saw-tooth wave. This means that the phase

	60 CYCLES	13230 CYCLES
R	2 Meg.	0.6 Meg.
C	0.25 Mfd.	0.001 Mfd.
R_1	0.22 Meg.	30000 Ohms
R_2	1.2 Meg.	27000 Ohms
C_1	3300 Mmfd.	820 Mmfd.

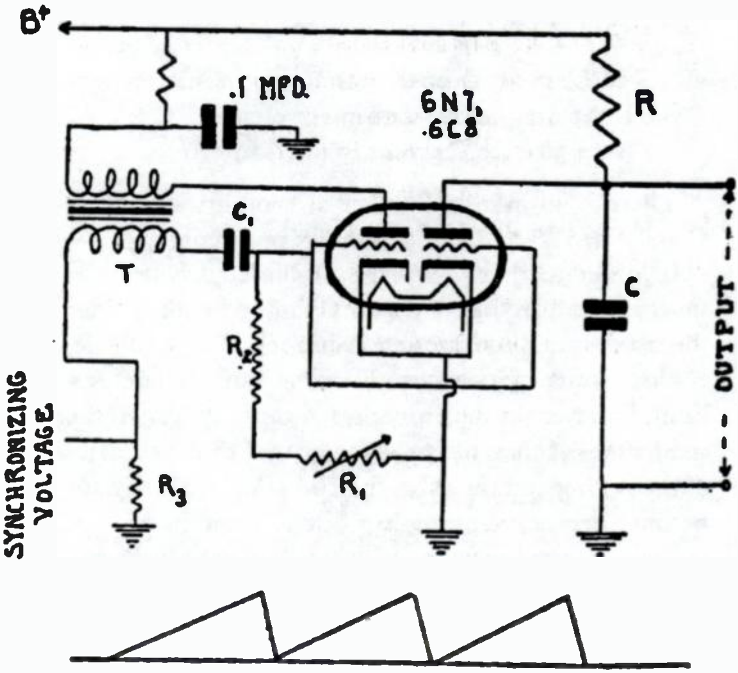

FIG. 2

relations between the fundamental and the various harmonics making up the saw-tooth form must remain the same. Such a requirement is not met by the usual audio amplifier especially at the lower frequencies.

An improved type of circuit, now employed in the RCA television receivers is shown in Figure 2. It requires two tubes but they may be in a single envelope, as in the 6N7 or 6C8.

The circuit consists of a blocking oscillator and a discharge tube. The first section of the tube is a blocking oscillator. Its natural period is in the lower radio frequencies and depends on the transformer. The waveform produced across the grid-leak is not used. However, the grid of the tube is negative and beyond plate current cut-off for nearly the whole blocking cycle and becomes positive for only a short pulse. Since the grid of the second section is connected to the grid of the first section, this second section is also beyond plate current cut-off except for one pulse at every blocking cycle. During this time, when the tube is non-conducting, the condenser C charges through the resistor R, again according to the logarithmic law, but the value of R and C are such that it can only charge to a fraction of the B-voltage before the tube becomes conducting for a short time and discharges the condenser.

The cycle then repeats; the frequency of the saw-tooth wave is dependent on the grid-leak $(R_2 + R_1)$ and condenser C_1 constants of the blocking oscillator, while R and C determine the amplitude and the waveform. The higher the ratio $RC/(R_1 + R_2)C_1$ the higher the amplitude and the less the linearity.

Synchronization is easily obtained by supplying a small synchronizing voltage across R_2.

Seventeen: The DuMont System

THE INDEPENDENT INVENTOR; THE UNIVERSAL SYSTEM; HIGHER PICTURE LINEAGE.

LARGE organizations are necessarily prone to over-systemization. Inter-departmental conferences, conflicting aims among different groups, repeated and lengthy analysis of reports, internal politics, more conferences, additional reports—all factors making for delays—are some of the penalties of greatness and massiveness.

The history of invention is replete with instances where the old fable of David and Goliath has been re-enacted in bloodless disguise. The slingshot of youth, equipped with courage, daring, an inborn skill at invention, has frequently outwitted the cumbersome sword and armor of gigantic capitalization. The temptation and tendency towards stasis, difficult for a large organization to avoid, is confidently disdained by the individual inventor, who runs circles around the over-organized, elephantine concern, however elaborately equipped with instruments, brains, and endowed with unlimited capital.

Thus we find the really great, epoch-making inventions wrought by individuals working almost alone and unaided, equipped only with their genius and resistless determination.

Witness Eli Whitney, of the cotton gin; Jacquard of the loom; Charles Goodyear and rubber, Alexander Graham Bell and his telephone, Thomas Edison and his incandescent lamp; Lee de Forest and his radio tube.

Today, in gigantic industrial research laboratories, it is true that massed efforts by trained engineers take the place of the earlier "rugged individualism" of the lone wolf inventor and produce a highly perfected product utterly impossible in the old days and ways. But even today, in television invention, we find the grand old tradition in a measure carried out by such resourceful, determined young men as Philo Farnsworth and Allen DuMont.

Farnsworth led the way to an operative cathode-beam pick-up camera—the "image dissector," in which (unlike Zworykin later) he departed completely from the teaching of Campbell Swinton, to produce a radically new principle. Similarly with the electron-multiplier tube, Farnsworth has independently blazed a new trail. He has developed to practical form an old principle of secondary electronic emission, permitting significant simplification of television amplifiers, both in tubes and costs.

But DuMont, working almost alone and without the backing of a wealthy research organization, has had the wisdom to look afield and stay out of the ruts. He has had the commendable courage steadfastly to believe that a 441-line picture is not the *ultima thule* in television refinement, and that rigidly fixed sweep circuits at the receiver do not represent the best means for synchronized control between transmitter and receiver.

Further he sees no reason why a picture field must be scanned 60 times per second to eliminate flicker, and thereby increase by 100 per cent the width of the transmitted frequency channels. DuMont conceives of utilizing this extra band width to better effect, in greatly increasing the number of picture lines, thereby permitting a projected picture of twice or three times its present dimensions—and, incidentally, inducing the public to purchase television sets in numbers sufficient to make good program-sponsoring attractive to business. Thus he solves the great American television problem: "Can television be made to pay—and to grow to national dimensions?"

DuMont already has demonstrated before the FCC the transmission of a flickerless picture at 15 pictures per second, requiring only half of the wave band for a 441-line picture which a 30-picture-per-second requires.

And now the question: "What about cheap sets for all these possible viewers?" As the band width is reduced the cost of the set comes down. A 15-picture-per-second receiver should cost less than a 30-picture-per-second receiver. Furthermore, DuMont engineers have designed multiple-unit chassis, where each separate unit such as r.f. amplifier, sweep-circuits, video amplifier, power pack and amplifier, audio set, are each individually assembled by operatives skilled in just that particular unit. This greatly simplifies assembly costs, and testing, reduces error chances, and likewise simpli-

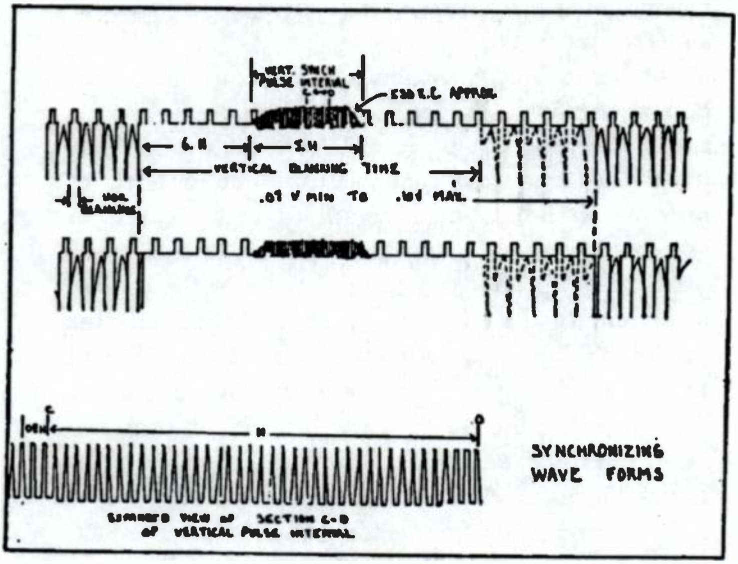

FIG. 1
Diagram of the standard synchronizing signals from a DuMont transmitter.

fies the service man's job. A defective unit can be quickly replaced, for return to the factory.

The DuMont receiver is universal—one which will operate on any number of pictures per second and any number of lines. All that is necessary to change over this receiver from a 441-line, 30-per-second picture from the NBC transmitter to a 567-line, 15-per-second picture is a small change in the electrical pulse which starts the picture off at the upper left-hand corner.

Automatic synchronization of the television receiver is here effected by utilizing a sweep circuit which is not of the self-oscillating type. In its place is substituted a discharge circuit which is always ready to operate whenever a synchronizing pulse is applied. Thereupon this circuit gives one, and only one, single linear sweep of the luminous spot across the fluorescent screen.

Clearly, with a circuit of this type the number of horizontal scanning lines per frame and the number of frames are both under complete control of the transmitter. Picture detail therefore may be increased from time to time as the state of the art permits, almost without the knowledge of the viewer, except by a noticeably better picture.

Thus, obsolescence of television receivers disappears automatically, except as it may exist in sound radio receivers today. Moreover, the sets which would operate on 400, 600, or 800 lines can all be built alike, and an approach made to mass production methods in the factory.

The DuMont receiver employs the saw-tooth deflection of the beam for both horizontal and vertical directions, as with RMA standard sets. However the circuits in which the saw-tooth waveforms are generated are non-oscillatory and depend on transmitted synchronizing impulses for each sweep discharge. Thus these circuits follow the transmitted frequencies automatically, and no synchronizing adjustment is necessary by the viewer in the event of a change in scanning frequencies at the transmitter, or when he tunes his receiver from one television transmitter using 441 lines to a higher-definition transmitter radiating say a 567-line picture. A simple adjustment controls merely the time of discharge of the non-oscillating sweep circuit, not an oscillatory period of recharge and discharge. Therein lies a very fundamental advantage, the value of which it would be difficult to overestimate.

As to segregating the synchronized (sweep) impulses from the picture elements, this is done in the DuMont system by amplitude selection, in a manner somewhat similar to RMA standards. However the vertical pulse is separated from the horizontal by means of tuned circuits. This method possesses a number of advantages among which are:

(1) The r.f. (sinusoidal) type of pulse, as distinguished from the flat-top type, is more readily separated from the video horizontal synchronizing pulse and most noise components.

(2) The r.f. type of pulse can be substantially eliminated from the horizontal synchronizing pulses and makes possible the use of circuits which can be designed to follow the various transmitted line frequencies automatically.

Demonstrations have been made before representatives of the FCC, in which a motion-picture film transmitted from the NBC Empire State Building station and received in the DuMont laboratories on a translucent screen was projected alongside the identical picture from a 16-mm. film projector. The definition on the television screen was 441 lines. That on the small motion picture screen was probably 1,000 or 1,100 lines, or of the same order as that of theatrical projection in good motion picture theaters. In unusual moments one found himself looking at the motion picture screen rather than the television screen, simply because of the greater degree of detailed definition there.

Thus the need for greatly increased definition in television pictures, especially in the adequate dimensions which will be demanded by the public, was convincingly demonstrated. In the face of such obvious and indisputable facts as these it is difficult to understand why authority should desire even for one year to fit this rapidly growing and already husky infant into a narrow, 441-slat crib.

And yet a definite and rigid set of specifications has been written by the Radio Manufacturers Association, limiting all television transmissions to the public in the future to a predetermined set of standards which determine picture quality only in terms of present development. While today's small television pictures may appear to be quite satisfactory, they will seem worthless by comparison with those possible within the next ten years.

Transmission from a DuMont transmitter of a flickerless picture at only 15 pictures per second has further astonished visiting engineers. Heretofore it had been thought necessary to transmit 30 pictures per second to eliminate flicker, but DuMont engineers have so balanced luminescence and phosphorescence on the tube screen as to eliminate flicker with only 15 pictures per second. Not more than this number are necessary to catch the motion observed in every-day life.

Such a method for flicker elimination places the burden on the human eye, rather than on the receiving equipment; and, since transmission band-width is related to repetition-rate, it demands no greater band-width than is necessary for the proper transmission of moving objects.

The problem of band-width has been, and probably always will be, a difficult technical and economic problem. It is difficult for the engineer since it imposes demands upon circuits which are obtained only through sacrifice and compromise. It is difficult economically because there is only a finite number of radio channels available, and whenever a channel is occupied by one station, that station monopolizes all the frequencies within that band to the exclusion of all other stations within its service area. If a television station, therefore, utilizes a smaller band-width, more stations can be built to serve the public. Conversely, with a given band-width the picture detail is determined, to a great extent, by the method of transmission.

DuMont's method of image transmission will permit a picture having the same detail as that provided by the RMA system for transmission (441 lines) but which will require a video frequency-band of only 2.0 megacycles. This is accomplished by reducing the field-frequency from 60 fields per second, as proposed by the RMA, to 30 fields per second.

It is apparent from this discussion that the RMA system for television transmission imposes an undue frequency-band requirement upon the system by virtue of transmitting pictures at a repetition-rate higher than necessary to satisfactorily stop motion, merely to eliminate undesirable flicker.

Further, pictures of detail corresponding to 567 lines, at a field frequency of 30 per second, with interlaced scanning, have been transmitted and found superior in quality to those transmitted according to the RMA standards, *and yet the required frequency-band is cut almost in half.*

Utilizing this same principle, it is possible to transmit a picture with the same detail as provided by the RMA standards with a band-width of only 2.0 megacycles; or a 325-line picture may be transmitted on a 1.5 megacycle band. Either of these transmissions would prove useful in providing a nation-wide or world-wide and 30 megacycles. With such a wider coverage, many of the present economic problems may possibly vanish.

Further, with a wider market for television receivers, big production would eventually bring them within reach of a very large percentage of our population.

Simple changes in television receiving equipment now designed for reception in accordance with the RMA standards may be made to accommodate the synchronizing signal above illustrated. When once this change has been made the receiver will accept, just as dependably, signals transmitted on 441 lines, 30 frames per second. These modified receivers will respond to transmissions utilizing frame or line frequencies anywhere between 400 and 800 lines.

Field tests have definitely shown that automobile interference and other types of static are likely to interfere with receiver-synchronization when the RMA vertical synchronizing pulse is employed. The synchronizing pulse proposed here, however, is far more positive in its action, and therefore "rides" more readily through various types of interference.*

From both technical and economic requirements, it is desirable to stay within a 6-megacycle band for television transmission; but it is also desirable to provide for more definition within this assigned band than is now available with the proposed standards of the Radio Manufacturers Association. It is also conceivable that some transmitter operators may wish to send pictures having the present definition of 441 lines at a reduced band-width by virtue of fewer frames and thereby real-

* 500 Kc vertical synchronizing pulse.

ize a considerable saving in initial transmitter investment. And receivers designed for reception of the full definition of the proposed standards will nevertheless operate satisfactorily on those stations operating on a narrower band-width.

We realize that it is desirable, at this time, to decide upon a television transmitting system which will permit the manufacture of receivers technically capable of responding to signals from stations having medium definition, also to signals from other stations transmitting higher-definition pictures in keeping with the progress of the art.

The customer, who pays for a receiver, expects a reasonable life of satisfactory service on the several stations in his vicinity even though such stations may desire to improve their transmissions. His receiver may not perform, after a few years, to newly released equipment, but it is necessary that those who manufacture such instruments see to it that the receivers continue to provide reception at least as good as the performance upon which the original sale was made.

To look at this question broadly—at this time is anyone in a position to say that nothing beyond the 525-line definition of the proposed RMA standards will be required? We all know, only too well, that since 1926 the standards have risen from 48 to 60, to 120, to 240, to 343, and now to 441-line definition.* In my

* The National Television Standard Commission has recommended that the F.C.C. standardize line frequency at 525.

opinion, the present 441-line picture can still be classed as low-definition. A direct comparison with motion pictures will bear this out. As we progress to larger pictures, this deficiency will be still further apparent—so why should we "freeze" the art at 441 (or even 525) lines, 30 frames per second, when a flexible system can be provided, at no additional cost to the consumer, which will make none of the present equipment obsolete?

It is believed by the writer that this transmission system offers much to the engineering profession in establishing a balance between rigid, restricting, fundamental definition, at the same time providing the most flexible frequency-band limitations consistent with an extensive service to the public.

Unquestionably here is an American television transmission system, unlike any adapted from Europe, which may solve many serious problems, economic as well as technical.

Eighteen: The Priess Television System

USE OF RESONATOR WITH MIRROR.

ITS inventor, William H. Priess, formerly chief engineer of the De Forest Radio Company, is internationally known as a skilled and trained engineer and inventor in the field of radio communication and manufacturing. He was the inventor of the "reflex" receiving circuits, and many important devices for the United States Army and Navy.

The Priess system embodies a radical departure from all other types of mechanical scanning systems. He takes advantage of the sharply marked resonance of a short round rod or wire of highly tempered steel, or nilvar, tightly clamped at each end, and carrying at its midpoint a small (usually one-quarter inch square) metal mirror. To the underside of this mirror is brazed a small "fin" of iron which can swing back and forth in the narrow air-gap between the two pole pieces of a small electromagnet in such a way that as it swings, it sets up tortional vibrations in the spring wire to which it is welded.

Through the coil of this electromagnet flows a small alternating current. When the frequency of this current is made exactly the same as the frequency of the tortional rod with its attached mirror and fin, the latter mechanical system is set into wide-angle oscillation. Thus a beam of light from some fixed source thrown upon the vibrating mirror is caused to sweep back and forth through quite a wide angle.

But when the frequency of the applied voltage departs ever so little from this identical frequency, the vibration of the mirror system falls to a negligible amount. A more beautiful and startling example of the similarity of action and laws between a mechanical and electrical oscillating, or vibratory, system has never been demonstrated.

It is easy to see, therefore, how exact synchrony between several such mechanical vibrating systems, all driven from a common source of electrical oscillations or impulses, can be used in a scanning system for television. Obviously the pick-up camera system must employ a mirror vibrating system identical with those of all the receiving systems.

It is to be understood that in the Priess system the motion of the scanning beam is wholly unlike that followed by the cathode beam, or by the "flying-spot," or scan, of the older mirror-drum or scanning disk systems. For the motion in the Priess system is strictly "harmonic," or sinusoidal. It follows the law of motion of a pendulum, or vibrating spring, starting from zero velocity at one end of its swing, increasing its velocity to a maximum as the spot of reflected light crosses the mid-point of its path, and gradually reducing to zero at the far end of its swing, where the direction of its next motion is reversed.

Thus, the horizontal line scanning is from left to right and back from right to left. Instead of beginning each new line from left to right, with a very rapid, invisible fly-back as in the cathode-beam tube, Priess also uses the return swing in his scan. This harmonic method has certain advantages over the other (linear-velocity) scanning systems. And certain disadvantages, the exact nature of which it is unprofitable to discuss here.

Thus far I have described only the horizontal or line scanning method of the Priess system. By a very ingenious, remarkably clever construction, Priess mounts his simple, almost zero weighing vibrating mirror system in a light dural cradle which also is welded to form the center of a rocking system. This also possesses a marked tortional frequency of its own—but one very much lower than that of the vibrating mirror itself.

The tortional rod members of this second swinging system lie in a direction at right angles to that of the first described rod. In this way, as the horizontal line sweep of the spot of light reflected from the little mirror makes, say, 5000 complete excursions from side to side, the lines are spread out over the viewing screen from top to bottom, and then from bottom to top, following the same harmonic type of motion, but at the slow rate of, say, 25 complete excursions in the vertical direction. All this occurs in one second.

In other words the screen is scanned 10,000 times per second horizontally, and 50 times vertically, which is ample for the "high definition" requirements at the present time for television.

Obviously at the receiver the beam of light at some point between the source and the vibrating mirror must be modulated by the incoming video signal. This necessarily involves a large loss, whether a Kerr cell with polarizer and analyser, or a super-sonic, piezo-electric light valve be employed. Such losses range from 50 to 80 per cent of the light available from the source, plus all the losses involved in the necessary optical system.

Unfortunately where harmonic, rather than straight linear velocity, scanning is employed, it is impossible to take advantage of the multiple-spot projection representing a large portion of an entire picture line which is had with the supersonic light valve when a mirror drum is employed (as with the Scophony system).

As a consequence the light available upon the screen in the harmonic-scanning system proves to be altogether inadequate for screen areas of the order of 18 inches square, even where a high-intensity, super-pressure mercury vapor light source is employed.

One obvious remedy is to increase the area of the vibrating mirror. But as the size, and weight, of this mirror is increased, the natural period of its vibrating system is rapidly increased. This means that to brighten the screen, picture detail must be sacrificed. In the "old days"—when a 100 line picture was considered adequate—this would still have given the Priess system very genuine advantages over mirror-drum and scanning disk systems, with Kerr cells and polarized light modulators.

But, even today, for television in navigation and aviation purposes, as a simple light-weight scanning system for use with infra-red light, the Priess scanner appears to offer unique, highly practical advantages over the others. For the scanner alone weighs less than five pounds and occupies only a few cubic inches of space. It is extraordinarily rugged and can be relied upon to continue in operation under severe conditions where more delicate and intricate apparatus might fail.

In such navigation and military fields, high picture definition is quite unnecessary. The identical scanner can be used both to scan, or pick up, the invisible infra-red rays emanating from some warm, fog or night-enshrouded object (airplane engine, ships funnels, hull, etc.) and by the same movement reflect upon the observer's screen a scanning beam transformed into visible light, modulated in accordance with the simultaneous variations of the infra-red rays from the distant scanned object.

Between these two operations of infra-red pick-up and reflected, visible light projection must intervene: a photo-electric cell sensitive to the very long waves of the infra-red spectrum (10,000 to 20,000 Ångström units), and a high-frequency amplifier (preferably including an electron-multiplier tube) grid excited by the output of the infra-red cell, and feeding into and modulating a glow-tube (neon or argon gas with mercury vapor). The visible light from this glow-tube, reproducing the modulations of the infra-red light, is so located with reference to the same vibrating scanning mirror and its optical system as to project its focused beam spot upon a small viewing screen conveniently situated in front of the pilot or navigator. Obviously no question of synchronization between transmitter and receiver scanner is here involved; the same scanner mirror serves for both purposes. Simple little tube oscillators and amplifiers suffice for driving the scanner in both directions.

Such a simple, compact, rugged and reliable adjunct as this Priess scanner should prove of inestimable value in aviation and navigation. For facsimile purposes, where a photographic reproduction of the transmitted image is advisable, the Priess system also offers peculiar advantages.

Nineteen: Magnetic Focusing and Deflection

THEORY; BEAM DEFLECTION; IMAGE SIZE.

In 1902, Ryan found that a magnetic coil surrounding the neck of the cathode-beam tube had a focusing action upon the electron beam, and that by varying both the position of the coil and the value of the current through it an exceedingly sharp spot could be obtained upon the fluorescent screen.

The fact that an electron in motion in a vacuum is the equivalent of a current, and is producing magnetic lines of force, makes it possible to employ a magnetic field for focusing a divergent stream of electrons to a point.

A typical cathode-beam tube employing magnetic focusing is shown in Fig. 1. At the left end of the tube is a conventional electrostatic "lens" made up of a heated cathode, a negatively biased control grid and an anode which serves both for focusing and for accelerating the electrons. This electrostatic lens focuses the emitted electrons to cross-over point x. From this point the electrons spread out into a cone, and are focused to a spot of the desired size on the screen by the magnetic field produced by the focusing coil which surrounds the neck of the tube. The magnetic lines of force produced by this coil are essentially parallel to the principal axis of the tube and are distributed uniformly through the neck of the tube.

The path taken by an electron leaving point x at the angle θ with the principal axis (Fig. 1) is shown as a long sweeping curve, first away from the principal axis and then toward it. Actually, however, the electrons are

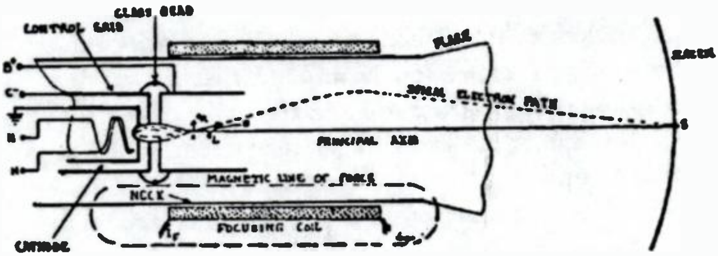

FIG. 1

twisted around the principal axis in a spiral manner at the same time that it is moving away from or toward the axis.

Motion along the axis is not affected by this magnetic field, whereas radial motion through the magnetic field forces electrons to bend back to the principal axis.

The electrons are thus moving longitudinally along the axis toward the screen and at the same time moving radially away from and back to the principal axis in a spiral motion. If the radial motion back to the axis can be completed by the time the electron has reached the screen, the desired focusing is secured.

When a wire carrying current is placed at right angles to a magnetic field, we know that there will be interaction of magnetic fields and a resultant force tending to move the wire (principle of the electric motor). Electrons traveling at right angles to the focusing magnetic

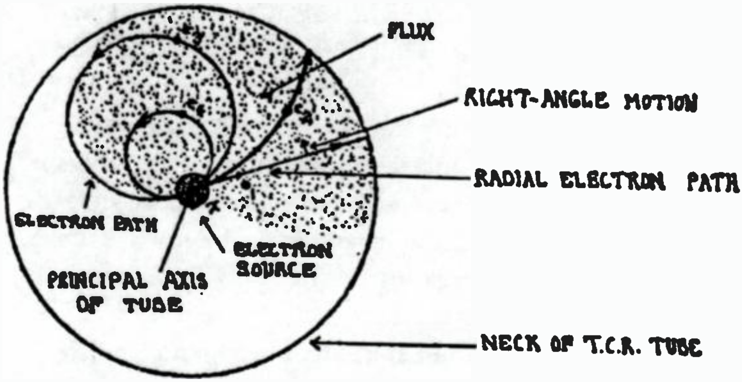

FIG. 2

field in a cathode-beam tube are acted upon by a resultant force in much the same manner.

An electron traveling perpendicularly to a magnetic field is forced to move in a direction at right angles to both its original path and the original magnetic field. The velocity component of the electron is not changed by the magnetic field. It will be helpful to look at a cross-section diagram through cross-over point x of the cathode-beam tube (Fig. 2) while considering this action.

Assume that electrons are moving radially away from cross-over point x, which is the electron source. If there were no magnetic field in the vicinity, these electrons would move radially out to the neck of the tube, as indicated by path e_1. With a focusing magnetic field here, at right angles to the electron path, these electrons are given a side push at right angles to their original path, with the amount of this push depending upon the flux density.

For a low flux density the electrons would therefore take path e_2, and for increasingly greater flux densities they would take paths e_3 and e_4 respectively. In a system of magnetic focusing, the magnetic field density is increased simply by increasing the value of direct current through the focusing coil.

Note that paths e_3 and e_4 in Fig. 2 are both complete circles which bring the electrons back to the principal axis. For a given initial electron velocity, increasing the magnetic field density shortens this circular path back to the principal axis.

By adjusting the field strength until the electrons travel this circular path back to the axis in the same time required to travel longitudinally along the axis to the screen, we can make electrons hit the screen at the principal axis even though they leave the cross-over at an angle.

Varying the focusing coil current I_F in Fig. 1 changes the magnetic field strength; therefore, in a cathode-beam tube employing electromagnetic focusing, the focusing coil current is varied in order to focus the electron beam.

It is not essential that the focusing coil enclose the entire distance from the cross-over point to the screen. A short coil located near the cross-over point will give electrons the essential twist back to the principal axis, so they will focus to the desired spot size at the screen.

There is a definite relationship between the velocity of the electrons at the cross-over point and the magnetic field strength required for correct focusing. The greater the electron velocity, the greater must be the flux density in order to secure the desired focusing. Any change in electrode voltages in the first electronic lens changes the electron velocities, making it necessary to readjust the focusing coil current in order to maintain the desired sharply focused spot on the screen.

In cathode-beam tubes employing magnetic focusing, the control grid is so designed that it essentially controls only the number of electrons in the beam. The first anode, aside from its action in focusing electrons to the cross-over point, determines the velocity of the electrons at the cross-over point. With this arrangement, there is a minimum of defocusing when the electron beam is modulated with a television signal.

Beam Deflection: Having passed the focusing structure (a bi-potential lens or electromagnetic focusing coil), the electron stream travels to the screen in the form of a pencil-like beam along the principal axis of the tube. For the 441-line picture this electron beam must be swept horizontally across the screen 13,230 times per second, and must be swept vertically up and down the screen 60 times each second, with each sweep consisting of a linear forward travel of the spot and a more or less linear but very fast return of the spot.

There are three methods for accomplishing this sweeping of the electron beam across the screen: 1. Electrostatic deflection, in which the beam passes between charged parallel metal plates which attract or repel the electrons to produce the desired bending of the beam; 2. Electromagnetic deflection, in which an electromagnetic deflecting yoke produces a magnetic field which interacts with the magnetic field of the electron beam to produce the desired bending; 3. Combination electrostatic and electromagnetic deflection, in which charged metal plates produce one sweeping action and an electromagnetic yoke produces the other sweeping action.

When an electron stream passes through a magnetic field at right angles to the lines of force, the stream is bent at right angles to both the lines of force and the original path. As long as the density of the magnetic field is constant, the bending action will be uniform at all points in the field, and the electron stream will follow a circular path. Once electrons emerge from the field, they again travel in a straight line.

When an electron stream travels through a uniform magnetic field, the velocity of the electrons is not altered by the magnetic field. Increasing the flux density in the magnetic field shortens the length of radius of curvature of the beam's path, thereby increasing the amount of deflection. The higher the velocity of the electrons in the stream, the greater must be the flux density in the field in order to secure a given amount of deflection, because a stiff (high-velocity) electron beam is not bent as readily as a low-velocity beam.

In a television receiver tube of the magnetic deflection type, the magnetic field is produced by an electromagnet, the poles of which enclose the tube's neck. The electron beam will be deflected at right angles to the line between the pole faces. Thus, the pair of magnetic poles which serves for vertical deflection of an electron beam will be mounted horizontally, and the poles which give horizontal deflection will be mounted vertically.

A simple electromagnetic deflecting yoke which provides both vertical and horizontal deflection is shown in Fig. 3. Note that the vertical deflecting poles V are arranged horizontally, and the horizontal deflecting poles H are arranged vertically. The yoke is constructed from laminated sheet steel, with the coils wound on bobbins or forms which slip over the poles. Opposite coils are connected in series in the correct manner to give opposite polarity.

Although the simple electromagnetic deflecting yoke in Fig. 3 will give a spot deflection which is essentially proportional to the deflecting-circuit current, it also will produce defocusing and pattern distortion. This is due to the fact that the magnetic field between opposite poles is not uniform, but rather has curved lines of force. When electrons travel through a non-uniform magnetic field the circular beam is flattened out to an egg-shaped cross section, giving an egg-shaped spot instead of a round spot on the screen.

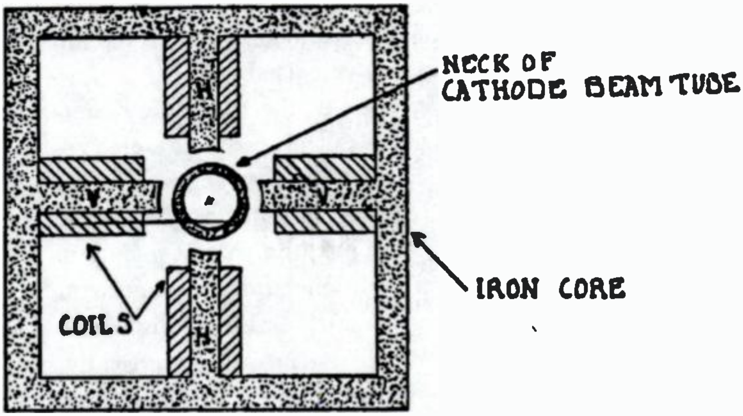

FIG. 3

When the fields for both horizontal and vertical deflection are non-uniform in density and are curved, pattern distortion occurs.

In the improved type of electromagnetic deflecting yoke used with modern cathode-beam tubes, rectangular coils are wound in such a way that they fit inside one another as shown in Fig. 4A. The windings for each coil are connected in series, then bent into the half-cylinder shown in Fig. 4B. Two such systems of coils are placed around the neck of the cathode-beam tube and are connected together in series in such a way as to produce poles of opposite polarity.

A pair of coil systems like this produces the desired uniform straight magnetic field. One pair of coils is placed directly over the neck of the tube and made to serve for horizontal deflection, and the other pair is placed over the first pair and made to serve for vertical deflection as shown in Fig. 4C. The entire coil assembly is encased in a soft iron shell in order to reduce the reluctance of the magnetic circuit, prevent stray magnetic fields from affecting the deflection circuit, and prevent the magnetic fields of the coils from affecting the focusing field of the cathode-beam tube.

In an electrostatic deflection system, the sweep *voltage* applied to the deflecting plates must have a true saw-tooth characteristic. In an electromagnetic deflecting system, the *current* through the deflecting coils must have this same saw-tooth characteristic.

Image Size: The size and shape of the reproduced image is controlled by the amplitudes of the sweep voltages in an electrostatic deflection system, and is controlled by the amplitudes of the sweep currents in an electromagnetic deflection system. Thus, to increase the width of the image on a cathode-beam tube employing electrostatic deflection, the horizontal sweep volt-

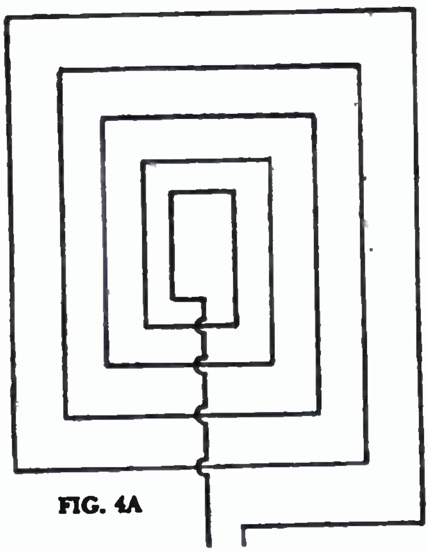

FIG. 4A

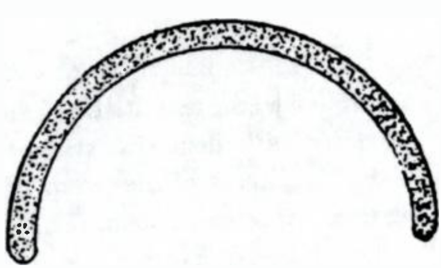

FIG. 4B

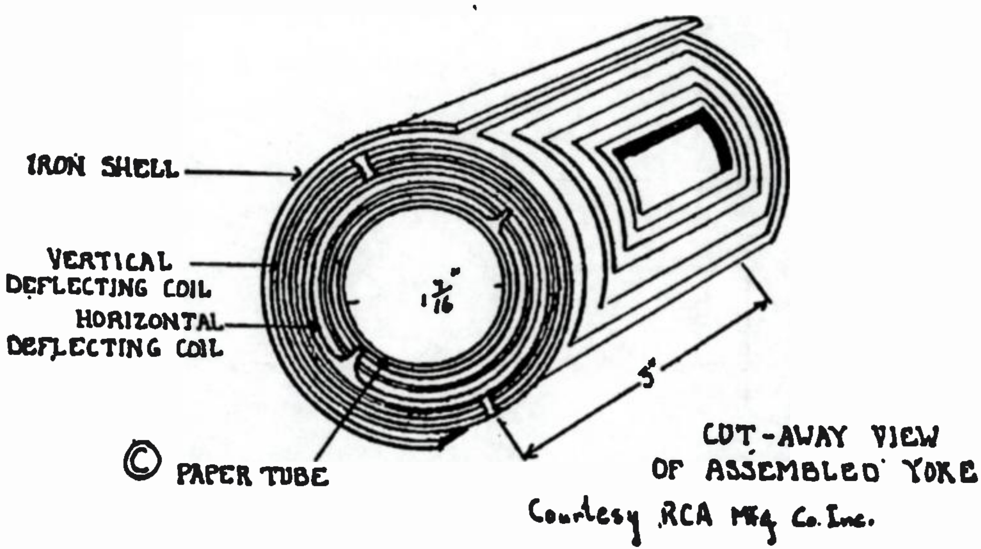
IRON SHELL
VERTICAL DEFLECTING COIL
HORIZONTAL DEFLECTING COIL
© PAPER TUBE
1 7/16"
5"
CUT-AWAY VIEW OF ASSEMBLED YOKE
Courtesy RCA Mfg Co. Inc.

FIG. 4C

age would be increased. And similarly for its vertical sweep.

The amplitudes of the sweep voltages or currents must be adjusted until the reproduced image has the desired aspect ratio of 4/3, with the width being greater than the height. This is the standard aspect ratio for motion pictures. The controls which give this adjustment in a television receiver need not ordinarily be touched once the correct image size has been obtained.

Twenty: Television and Frequency Modulation FM

FM AS AN AUDIO CHANNEL IN TELEVISION; OTHER POSSIBLE USES.

WHAT promises to become a revolution in short wave radio telephony is known as Frequency Modulation, now very much under discussion in all radio and television circles. Already in operation are several frequency-modulation transmitters, and more are under construction, notably in the east.

The idea of modulating the radio carrier waves by changing their frequencies instead of varying their amplitudes is by no means new. Nearly 20 years ago Dr. J. R. Carson of the Bell Telephone Laboratories analyzed mathematically the frequency-modulation principle and showed that if the frequency band were kept within the limits then allowed for sound amplitude-modulated carriers, bad distortions would result. Interest in the idea was accordingly largely abandoned. Recently Major Edwin H. Armstrong, working entirely in the short or ultra-short wavelength regions (less than 10 meters wavelength), demonstrated that with frequency bands 10 or 20 times *wider* than those permissible with amplitude modulation astonishingly fine results could be obtained. Such wide-band frequency modulation gives reception practically free from static and man-made electrical noise, or disturbances.

It is not appropriate here to go deeply into the physical reasons for this noiseless reception of radio transmission.

But due to the fact that wide-band frequency-modulation can be practised only in the short wave bands, the distances of reliable communication are logically limited to little in excess of the line of direct vision from the transmitter. These same range limitations, as we have seen, hold for television transmission also.

Inasmuch as television reception is prey to man-made electrical disturbances more than is audio-radio transmission using ultra-short waves, the question arises: Why not apply frequency modulation to our television radio carriers and thus avoid all such troubles? But when we consider that the present high-fidelity television picture demands a frequency-band four million cycles wide, even with amplitude modulation of the carrier, it is evident at once that with frequency modulation, demanding frequency bands ten or more times as wide, there would not be room over the entire radio short-wave spectrum for more than one such transmission in any given locality. Not only would all other simultaneous television transmissions be ruled out, but radio services using high frequencies, such as police, aviation, amateur communications and the like, would suffer.

Therefore, there appears no hope of adopting frequency modulation as it now is practised, to eliminate troublesome noise and disturbances from our television video reception. Frequency modulation, however, may be applied to the audio transmission.

There is, however, good reason for expecting that before long some method may be found of modulating our television carrier waves other than by varying the amplitude of their swings to create video signals.

It is as yet premature and unfair to the inventors involved, to go deeply into the detail regarding such solutions. But skilled and resourceful minds are at work upon this vitally important problem, and, in theory at least, one or two promising solutions already have been found. That the not too distant future may disclose a satisfactory method for rendering our television picture immune to static and noise is a hope apparently justified. Of that I am confident.

But while on the subject of frequency modulation in relation to television it might be pointed out that when Police and other short-wave communication services widely adopt frequency or other "noise-proof" modulation—as I feel they assuredly will—then those services not only will be immune to disturbances as from short-wave therapy machines, etc., but themselves will be incapable of disturbing or being disturbed by television transmissions. And when Congress shall allot exclusively to short-wave therapy a certain wide frequency band, or bands, no more complaints need be heard against the use by physicians or their patients of this benign new application of Radio.

Twenty-one: The Television Profession

ECONOMICS—FILMS VS. DIRECT PICKUP; VAST OPPORTUNITIES DISCUSSED.

WHEN in 1900 I first began experiments in wireless telegraphy, I had but vague ideas as to how far the infant art would extend its opportunities for employment. Years later, when our Navy began to order audion detectors and amplifiers in large quantities and radio amateurs besieged my manufacturing plant in Highbridge, N. Y., for more and ever more audion bulbs, I began to foresee that this new industry, radio, was destined to offer means of employment for small armies of skilled men and women in our largest cities; that in time its employees might far outnumber those engaged in the wire telephone industry. In the late '20's, only a score of years after the three-electrode tube was born, this situation actually came to pass.

Today the radio industry in all its branches and ramifications—telegraph, telephone and broadcasting operation and maintenance; servicing, program talent, writers, actors, advertising solicitors; plus the gigantic manufacturing plants, such as RCA, Philco, Crosley, Zenith, with their hordes of engineers, technicians, mechanics, assemblers, and salesmen scattered throughout the country—represent in payrolls and financial turnover, directly and indirectly, an estimated annual expenditure of more than a billion dollars. I speak of the United States alone. Limited to sound transference alone the radio industry is steadily growing larger and more mighty.

So, forecasting what television will eventually mean to the modern world in terms of employment and industrial wealth, we have a precedental yardstick. Our imaginations must be given wide sway, however, to encompass fully the enormous horizons of the radio vision of tomorrow.

It appears certain that the growth of television will not to any great extent render obsolete or put into discard, aural broadcasting. Television, necessarily, is limited to semi-darkened rooms; it demands concentrated attention. The older instrumentality laughs at sunshine, is life to the blind, serves as a background, musical and soothing (or nerve-twinging and maddening) to housework, conversation, reading, or bridge. Each has its own especial field to fill. The younger will not destroy the elder. Side by side they will continue to develop industrial empires, and the minds and hearts of mankind.

So we shall see radio manufacturing plants double their acreage and employee armies. Consider now how employment has risen in the radio industry—paying higher wages to workers, musicians, artists, and performers. It is estimated that radio today gives employment to 500,000 people in the United States, with an annual payroll in excess of $500,000,000.

Employment by the RCA organizations alone had risen in 1939 by approximately 15 per cent, with a total of 23,500 employees at the end of that year. Other large radio enterprises exceed even these large figures.

In spite of higher wages and rising material costs the radio manufacturing industry passes along to the public the results of technological advances in terms of lower prices and greater values than ever before. More than 860 broadcasting stations, including four national and various regional networks, compete with broadcast programs as varied as the entire range of human interests.

Short-wave programs from America now enjoy preference among South-American listeners, because of their entertainment value and freedom from propaganda. The use of radio equipment in the home, in the school, by business, by government, by the motion picture industry, by aviation, by shipping, by broadcasting companies is continually growing. And by the same token I foresee television entering into all of these fields, not in competition, not to supplant, but to supplement, enrich, complete.

The motion picture in the home, large as its application may be today, has never attained the scope for which it was thought destined. The physical difficulties of ever-renewed film supply, of setting up and taking down projector and screen, of threading and rewinding film—sheer laziness, if you will—plus the continuing expense involved, have greatly limited its popularization.

But hereafter the motion picture will be presented for two hours nightly in every home equipped with a television receiver, with no more physical effort than the turning of a switch—no other expense than the electric current consumed.

David Sarnoff has announced the intention of RCA to bring about network television over wide areas by means of small power hyper-high-frequency relay stations located atop hills or eminences, one within sight range of the next in line. Each station will include a beam transmitter pointed towards the station, or stations, next in the chain, and also a receiver attuned to the same or a slightly different frequency, with its antenna system (perhaps a simple metal horn) pointing back towards the relay transmitter next nearest to the originating studio.

Such a system of multiple, wholly automatic relay stations, is entirely feasible. Each must be supplied with electric power—either by line, or storage battery, or small gas-engine generator. The existing coaxial cable between New York and Philadelphia has demonstrated the supreme reliability of those clever little, man-hole buried, repeater stations, their tubes burning and operating continuously and without attention for years. They demand no supervision nor supplies, save a constant flow of electrons through their feed lines.

Obviously, if overhead power wires are strung to feed these television relay stations, it may be found that the wires themselves serve as extremely efficient "wave-chutes," or guides, for leading the transmitted waves, short though they be, directly to the next repeater station.

In any case consider what wealth of investment (translated into terms of employment) a thousand of such relay stations will entail—in fabricated steel, in insulated copper, in lead plates and acid, in generators—in servicing the system and its supply lines.

Whether or not future methods, aerial or metallic, connect together hundreds of television transmission stations, it is certain that their installations and servicing, quite aside from the question of program maintenance, will mean employment for many thousands.

Speaking of long-distance coaxial cables, the longest of these in America is now under construction, extending from Stevens Point, Wisconsin, to Minneapolis, a distance of 195 miles. Its cost is estimated at $2,000,000. It provides for a frequency band width of only 3 megacycles, insufficient for the highest definition television pictures of today's standards, but the cable will carry 480 telephone circuits for which it was designed.

Quite outside of the realm of broadcasting, television is destined to be applied to many useful purposes. It is easy to appreciate the importance of being able to inspect at a distance various objects, such as legal documents, individuals in distant locations, for example, by the police. Applied to industrial purposes, it is frequently highly desirable for a superintendent at a central observing office in a large manufacturing plant to be able to inspect operations taking place in various locations. In congested city streets it will be advantageous for the director of traffic police to be apprised of the piling up of traffic at "bottleneck" locations, so that he can direct additional officers to the spot and have general supervision.

In medical schools or hospital clinics, during hours of instruction in surgery, students and internes will be enabled to watch intimately the progress of operations without causing congestion around the table; without risk of infecting the patient. An iconoscope suspended from above, which can readily be directed and focused from a distance, will render such observations practicable. Obviously all of the above television information should be transmitted over coaxial cables or heavily loaded and relayed telephone wires.

No imagination is required to recognize the enormous possibilities of television for military and naval purposes, notably from observation planes. When the history of the present war is written, it will probably be found that this novel application had been tried out on many fronts. By the use of photoelectric services, rendered especially sensitive to long infra-red rays, distant visualization through fog and storm and night of approaching steamers, or the hot engines of airplanes, will be made possible to the navigator at sea or in the air.

Many another application for television, yet unthought of, will arise throughout the development years ahead to aid the radio industry in the elaboration of its youngest branch and to encourage continuous research.

In television, even more than in radio, opportunities will be offered the economist for rigid control of program costs; opportunities for highly trained and talented program producers, liaison men of tact and personality for the maintenance of cordial cooperative relationships between television broadcasting groups, and motion picture producers and exhibitors. Also for the truly efficient "efficiency expert" who can intelligently reduce costs of receiver instruments, and of their installation and servicing.

Armies of service men with some careful engineering training will be needed, especially in the early years of television's introduction. As I have pointed out in another chapter, each individual installation presents an individual problem. Such groups must be trained by experts to operate simply and efficiently at reasonable costs. Furthermore these men must be able to educate the home audiences in the best methods of locating the receiver, how to operate it and concentrate the attention upon program. Obviously, the inducements which keep cinema theater audiences quietly attentive will be largely lacking in the free and friendly atmosphere of the home.

Consider forthcoming problems of studio and traffic control in television, similar but far more intricate than those daily facing the program producers in radio today. The viewing hours will be far fewer than today's radio hours; but the problem of suitable program material involves such factors as personal appearance, makeup, and a letter-perfect performance calling for long, dutiful rehearsals. No scripts before the "ike," as now before the "mike," will be permissible. Also, the selection of suitable actors will be far more difficult.

Assuming a television network, the clearing of program traffic demands close and relentless contact with all stations and the handling of much detail. Station reports on quality of program transmission are always indispensable. Emergencies must be foreseen and provided for. Schedules must be prearranged, but with a flexibility permitting sudden alteration or substitution.

As in broadcasting, television must cultivate its public contacts by publicity through the press, magazines, agencies, and advertising, by release of information concerning programs and artists in advance of their presentation. The building of good will in public relations will be even more incumbent upon television than at present in sound radio. The act is much more intimately brought within home walls than is the audition. Accordingly, more tact in selecting program material and interpreters will be demanded from the producer. The opportunities here for gifted writers in the studio or publicity agency, will be large and alluring in their novelty.

The television inventor has already given employment to hordes of patent attorneys, the gentry who unfailingly profit from inventive brains. Already our patent office archives are crowded with patents directed to television. Research in scores of well equipped laboratories is directed intensively towards solving television's endless problems. Individual inventors, lone wolves, or those employed in other branches of industry, are burning midnight "juice" to add their bit to the sum total of television technology. Thanks to the Securities Exchange Commission and blue-sky laws, however, the curb broker and stock promoter of late have found little comfort in the investing public's interest in television.

As I have endeavored previously to point out, the cost and difficulties of presenting perfectly rehearsed live acts by competent actors—a different performance each night in any given locality—will inevitably persuade the telecasting organization toward the use of motion-picture film at the transmitter. The cost of "road showing" by a film is incomparably less than by the traditional method of trouping. Occasionally, of course, road showing, even barn-storming troupes travelling from station to station, will be in sufficient demand to justify the costs.

Except where public or athletic events, such as inaugurations, races, prize fights, ball and hockey games and similar exciting contests are involved, the value of simultaneity in television has been vastly overrated. Better, any time, a good motion-picture presentation than a poor show. The millions in nightly attendance in our cinemas prove that the public's interest in a good story is not one whit lessened by the thought that they gaze upon mere shadows of what transpired months before. The success of the newsreel testifies that the factor of simultaneity does not enter largely into the question of human interest.

Mark my words, aside from special events as outlined, the syndication in television programs will be largely by means of film transportation. It is doubtful if the value of occasional simultaneous nation-wide televised events will justify the heavy expense involved in the construction and servicing of general television networks, whether by overhead wire chutes, automatic ultra-high-frequency relay stations or coaxial cable. Local acts, locally beheld, plus film-transported syndication will solve this economic problem superbly.

Television in rural districts probably offers an exception to the conditions outlined above. And it is very probable that automatic relay stations located at distances of 20 to 50 miles from each other, depending on the intervening terrain, appear to offer simple and not too costly means for transmitting to small local broadcasting stations programs which originate in nearby metropolitan districts. In fact, it will not be difficult to combine one of these relay posts with an automatic television broadcaster, the latter operating on the conventional five to seven meters, whereas the relay links themselves are operating at much higher frequencies, of the order of 500 megacycles (3/5 meter wave length).

Around the main studios must be organized systems for sales promotion, marketing of program time, planning programs suitable alike to sponsor and the audiences; stories, scripts, and scenarios, in quantities likely to stagger the men now on the movie lots. The telecaster must keep contact with agency, client, author, artist, studio personnel and owner of copyrights. Long ago motion-picture authors foresaw the advent of radiovision and have been protecting themselves against any piracy of their wares by televisionists.

The courageous pioneer spirit which nobly distinguished early efforts in wireless telegraphy and radio broadcasting has thus far continued into the technically far more difficult field of television. Only through a continuation of such spirit and optimistic perseverance can be attained great success which should attend the proximate development of this latest and greatest achievement of the practical scientist and technical engineer.

Twenty-two: Suppose Television Is Your Job

HOW APPARATUS IS USED; ENGINEERS, MASTER CONTROL; SCENERY, ETC.

TO AID in forming a concrete idea of what falls within the line of responsibility for studio engineers, assume for the moment that you are one, transmitting a program featuring outstanding motion picture performers, and your camera suddenly had stopped working. You see a red light indicating the camera is out of order, but another telecamera operator is carrying on. The station director, of course, expects you to be back in service in a few minutes.

There are many possibilities of trouble. You must use your head. You must use your previous knowledge and experience—you must be so well acquainted with that camera that you can smell the trouble, or feel it, instead of having to analyze it.

You might have a variety of television cameras to work with. Perhaps you have the RCA telecamera, or a DuMont, or General Electric. Fundamentally, all the various makes of telecameras are alike under the cover. The chassis of the DuMont telecamera presents an impressive appearance. It looks simple and durable, as does any well designed device. The lower part looks like a radio chassis, but the upper section is different from any electrical or optical device ever seen elsewhere. There is the mirror for the operator to see how sharp the focus on the plate of the iconoscope may be. There is a motor in the upper right corner to permit remote-control focusing by the studio operator. Some of the equipment is familiar, but the entire television camera has a strangely fascinating appearance, very much like something from another world—something that belongs to Buck Rogers or Flash Gordon, to *Amazing Stories*, or science fiction. To a large degree, television is science fiction made real. To most of us it has come as a dream—out of the laboratory, fully perfected. It might just as well have been given us from another planet. It did not "grow up" slowly, it has happened all within five years, fully perfect almost at once.*

Let us look in where the telecamera man is at work in a studio, one of several operators.

Observe there are lights, a sound microphone at the end of a long boom, so it can be moved closer or farther away from the performer as desired; there are light and sound technicians, directors, and even perambulators or dolly pushers. The perambulator is the device upon which the cameraman rides. It is moved nearer or farther away from the scene as required.

There is scenery. It must be designed to produce the desired impression. Actors in the television studio must

* Relatively speaking!

have a knowledge of how to move and perform properly before a television camera, and just how much or how little they must exaggerate their motions in order to produce the proper impression for the telecamera system.

Of course the television camera is only the beginning of the television system. Focused in the television camera and converted into electrical signals, it goes down through the cable from the television camera into the master control room, around and around through switching systems until seen as an image by the master control operator, who passes it around and around once more and on to the radio-television transmitter.

There is a large group of master operators who adjust the picture quality. The master control man must know just how to feed in certain signals to get the best effect. He must compensate for any distortion. He must exaggerate any shadings that do not appear to have enough contrast, and above all, be able to recognize whether or not the system is performing up to normal at all times. He checks the telecamera operators, the telecameras and amplifiers between his picture and the telecameras. He is responsible to the director.

Master control has to know more than the telecamera man. He makes the performance what it is. He is the highest-paid man in the television operating profession. Of course, the general director in the master operating room is the highest paid man in the station, for he must be a combination technician and artist in the direction of television performances.

As a master control operator you must be interested in the sweep circuit generators, fundamental impulse signals, shade compensation and frequency compensation circuits, and in the effect of lighting technique. You must be familiar with many effects. You may have to create the illusion of darkness in a scene, even though the scene is brilliantly illuminated; you may have to create the illusion of sunshine in the studio, even though the scene is taken in ordinary lighting. You have to know whether distortion in the picture, if any, develops from the iconoscope, image dissector, electron multiplier, amplifier, amplifier power supply, or from many other different causes.

Of course the television performance can't stop in the studio with the master control operator—the performance is only started on its electron path when it leaves him. It has gone from the television camera down to the master control panel, but now it has to go around once more to the main line operator who feeds the signals into the coaxial cable to the television transmitter. The line operator watches many meters. If the meters do not read right, this man does a considerable amount of telephoning until the meters do read right. He does not need to be nearly so well informed as the other operators, but he has great responsibility and must be vigilant at all times to see that the signals stay within certain levels. Otherwise, the line operator knows that distortions will occur in the receivers.

He is in a very responsible position, and also has to know about amplifiers, attenuation, line compensation, amplitude overload, regeneration, degeneration, and other jaw-cracking names that go with the profession. It is the one comparatively unromantic phase in the television system. It is about the same as working in a broadcasting station. You look and listen to all the programs. You earn a good salary, but you don't meet anybody—and you have the unpleasant task of heckling everybody over the telephone to stay within the limitations provided.

The signal travels from the studio through the hands of the master control operator, out to the line operator and over to the television radio transmitter, which may be several miles away from the studio. The signal is then checked by another line operator at the radio station to see that the picture is coming out in proper shape to enter the radio transmitter.

The final control operator checks all signal levels on oscillographs before him, and feeds the signals carefully into the radio transmitter. Real power is dissipated into this electrical transmitter and another operator carefully watches the meters that tell the details of operation. The signal is emitted by a special antenna which does not look like an ordinary radio broadcasting antenna at all. The sound goes right through along with the video signals. One section of the antenna system emits the sound signal, while the other part of the antenna emits the television signal. Of course, both are radio signals when out in space.

Television antennas are placed on the highest spots available and lightning rods protect them and the television transmitter. So well designed are these systems that the lightning may strike frequently during a program without upsetting the performance. Indeed, man has so organized the electrical sciences that he can discharge full-fledged lightning bolts around his television transmitters without seriously interrupting the program.

Many engineers are required to design and build this apparatus, and to design the installation of the transmitter equipment. The radio television engineer must know how far his station will reach, how much power it must emit to pass around hills and buildings and other obstacles, and he must know how far beyond the horizon his station will give service.

Many other factors must be employed in the television studio, for a full performance. There is, for instance, the television motion picture operator, for filmed plays will be a large part of every show. The film does not need to be shown on a screen and then picked up by a television camera. Instead, the film is put directly into a television projector, so arranged that the picture is sent directly to the master control operator, and the person at the receiver sees either a newsreel, or a popular motion picture, or a studio play.

What about baseball games and other sporting events, such as boxing? Portable equipment is taken to each important event and the local section is connected up by the telephone wire, special cable, or by radio television link. Telephone wires, properly relayed and compensated, will carry television signals over short distances.

Today's radio station contributes little to the television program. The sound devices and the amplifiers used for television are more advanced than those employed in the *average* radio broadcasting station because of the wide frequency bands allotted for television. High-fidelity sound transmission unknown to the older radio broadcasting programs is demanded, hence the actual radio transmitter is of no value in television. Even the present radio studios are not properly designed for television performance. Therefore, the television business is really open today to everybody mentally and temperamentally equipped. The beginner does not have far to go to catch up with men similarly situated in other professions.

Each succeeding generation has had problems to face in order to preserve American freedom. Today the greatest threat to our American system is the young man who is unable to find prosperity in this rich Nation. It follows that our national security is in danger unless young America finds worthy employment and adequate income.

Fortunately, during these unrestful hours and at this important crossroad, this new industry has the capacity to employ more people than others which have flourished since the railroads were built. Not only men, but women, may find their future in this magnificent achievement of Science in television.

Twenty-three: Television's Future and Its Influence Upon Society

POSSIBILITIES FOR WORLD-WIDE TRANSMISSION DISCUSSED.

OFTEN has it been said that no invention since the discovery by Gutenberg of the art of printing by movable type has so profoundly influenced the manner of speech and thought and our daily lives as has radio. This later revolution has been realized within a generation, instead of 500 years.

It is scarcely fair, however, to expect that radio's favorite child, television, will be given powers for achieving anything so radically new. For in the meantime radio, through her now ubiquitous amplifier tube, has brought the long-distance telephone, the talking picture, the public-address system, and the perfected phonograph. Each of these powerful instrumentalities has been exerting an ever-widening influence upon our homes and our gregarious tendencies. Social life is not only instantly extended to national and world-wide boundaries, but we are constantly inspired, degraded or depressed by the thought, the genius, the purposes of the rest of the world.

Thus no radically new or hitherto vacant field remains today to be preëmpted by radio's latest miracle, her wonder child, television. Yet there awaits for television a mission which none of her brilliantly conceived predecessors can ever accomplish. Primarily she brings into our homes all these other gifts, the broadcast, the long-distance telephone, the public address—the theater and cinema themselves—and in a manner so versatile, so attractively staged, so insinuating, so easily and comfortably displayed, that our innate love for button-pressing luxury beguiles us unwittingly into utopias none the less compelling because they are fleeting and ephemeral.

It would be difficult to overestimate the future influence of television on the home life of all who dwell within sure range of her transmitters. They may have had the 16 m.m. motion picture projector, but whoever owns one knows the feeling of inertia which keeps it in the closet and so we postpone the home cinema for some other evening. But when we need simply open the cabinet doors, swinging a small screen into position, turn two knobs, and dim the lights—then will we be content to linger in the family circle through hours of solid comfort and satisfying entertainment.

The picture I have here drawn of television is today no long-range vision. In and around New York City it is an actuality. This year will see citizens of a half-dozen cities similarly situated.

And what, in addition to the home fields, has television to offer? In the realm of school education no great imagination is required to depict its usefulness. Today the Columbia School of the Air brings daily to 10,000 class rooms the engaging message from teacher authority, frequently from picked groups of students who have journeyed to the town's broadcasting station, there to discuss with animation the carefully rehearsed lesson in history or economics or politics.

What then must be the appeal of television as an educational medium. From a central studio competent lecturers, authorities in their special subjects, may reach simultaneously large school audiences, giving visual demonstrations of experiments in physics, chemistry, mechanics. Eventually we may expect color transference by television, which will still further enhance the resistless appeal of this future aid to education.

Television for the school will tend to utilize the daylight hours when the demand for it in the home will be minimum. But the shut-ins, and those held from school by illness or storm, may share at home the lessons prepared for the school room.

All this, of course, is predicated upon the advent of large-screen television for use in the class and lecture room. For such fields it would seem that the high-fidelity optico-mechanical systems previously described may quite probably find themselves especially well adapted.

Assuming now that we have finally realized this stage in the development of television, no wide range of imagination is needed to depict the changes in our manner of life and thought which will result therefrom. Foremost in significance will be the strengthening of the home ties, especially for the younger set. If the program directors of television do well their part it will no longer be difficult for parents to induce their children to spend evening hours in the family circle. "Fireside Chats," not all emanating from the White House, nor generally of political interest, will be of nightly occurrence.

Why should not this altered attitude toward our home life eventually work to the betterment of our national life? It is conceded already that aural radio has gone far in enhancing home ties. True, much of our programs are banal, moronic—"bed-time stories"—to which are directly attributable neuroses among our children. But the good far outweighs the evil. In television the criterions of merit will inevitably be placed high. One may dare a blind song, venture a wisecrack, a banality—the artist well knows this could not be tolerated if he were beheld by his listeners. I foresee that self-censorship in television programs will be severe.

Obviously the sponsor's advertising message must be much more politely, tactfully administered, a much smaller pill, more sweetly coated. Here the Chinese proverb, "One picture is worth 10,000 words," will be abundantly proven true.

I foresee therefore a far wider acceptance and proportionately larger influence and usefulness for visual than for mere aural broadcasting. By this I do not mean that more television than radio receivers will be found in American homes, but that the influence of the program combining sight with sound will be deeper, more engaging, better understood and longer lasting.

"In ordinary life," writes S. C. Gilfillan,* "the eye is used more in perception than the ear. It has been suggested, therefore, that visual broadcasting when perfected will have even more important effects than aural broadcasting. Such an idea must be accepted with caution. From the social standpoint, the most significant development took place when radio made it possible to send news, music and propaganda through the air into the home. Six years ago the authors of the chapter on 'Invention' in *Recent Social Trends* were able to list 150 social effects of radio in its aural form. It does not seem likely that television will introduce a new list of social effects which is longer or more important.

"Addition of sound to pictures doubtless produced relatively few new social effects of the cinema. Addition of pictures to sound should be more important in the case of radio, because of the greater use of the sense of vision than of the sense of hearing. Yet it is likely that the main impact of television will be to intensify the social effects which broadcasting already is producing."

Television is destined to bring into the home total means for participation in the sights and sounds of the

* S. C. Gilfillan, "Social Effects of Inventions," in Technological Trends and National Policy. Report of the National Resources Committee, Washington (1937).

entire world. When it projects the instantaneous present rather than the past it will be more realistic than the motion picture. That sense of being actually present as a living witness of distant events as they transpire is one utterly unique, unlike that in viewing a newsreel picture, far more exciting than merely to hear some broadcaster's ofttimes epileptic exclamations as he attempts to interpret what he may think he is witnessing at a football game or a prize fight.

In considering the adaptability of the television medium to the presentation of the drama, David Sarnoff has said:

"Radio already has made significant contributions to novel dramatic forms and materials. Experimentation is constantly going on, under the daily pressure of providing ever-changing programs. Famous dramatists, actors and producers are turning in increasing numbers to radio as a new and important medium, and the intellectual standard of much radio drama is in the best tradition of the legitimate theatre. With the advent of television, a new impetus will be given to this form of art, and we may expect it gradually to take the place of some other types of programs which now occupy a large part of radio time.

"A first-class radio program is like no theatrical or motion picture presentation that ever was. It is a new thing in the world. Similarly, it is quite likely that television drama will be a new development, using the best of the theatre and motion pictures, and building a new art-form based upon these.

"It is probable that television drama of high caliber and produced by first-rate artists will materially raise the level of dramatic taste of the American nation, just as aural broadcasting has raised the general level of musical appreciation."

Notwithstanding the fact that today long-range radio vision, carried over short or ultra-short waves is utterly unreliable due to fading and atmospheric disturbances, I have already seen too many "impossibilities" reduced to reliable practice by the radio engineer and scientist to justify any pessimistic forecast regarding eventual television pictures from across the wide seas. It is at least technically conceivable that by use of a new modulation method and multiple diversity reception we may live to behold a coronation in Westminster Abbey, a parade past the Arc de Triomphe, or the inauguration of a President of the United Nations of Europe!

One hundredth of one percent of the human effort and treasure now being spent over there on mass murder might very easily bring this miracle into being. Television may help the human race learn how to live, rather than to die.

Inasmuch as the ultra-short, or quasi-optical waves used in television travel in straight lines, it is self-evident that far greater distances may be covered when operating between an airplane and ground station, or between two planes, than is possible over the earth's surface. Hence we at home may expect to witness many engrossing pictures as a plane passes over regions of scenic grandeur. Aerial views of the Grand Canyon, Zion National Park, the Yosemite Valley, or aerial views of yacht regattas, and fleet maneuvers far out at sea.

As an aviation aid, in obtaining views of a landing field transmitted from the earth to the approaching fog-bewildered pilot, television should prove of incalculable worth. As a direction guide and terrain altimeter, we may see the television cathode tube a standard instrument upon the pilot's panel. For purposes of aerial warfare, from observation planes to headquarters, for aerial torpedo direction and control, its varied applications already have been cited.

Passengers on de luxe express trains will be privileged to witness television programs at great distances from the city of origin, by virtue of the effective "wave chute" guide afforded by the trackside wire networks to which the video carrier signals have been inductively delivered. Because of the keen interest aroused by television the whole subject of electron optics, the control of electron streams by electric and magnetic fields is today intensively studied. New vistas in optics are thus opened. Already Dr. Skellett of the Bell Laboratories has given to astronomers a device whereby the glories and the physical peculiarities of the sun's corona flames may be observed on any clear day, by means of a television scanning device, without awaiting the rare occasion of a total eclipse.

By means of a spiral scanning disk, photo-cell and amplifier—that magical passkey which unlocks to scientists many enticing portals otherwise hopelessly closed against their peering eyes—the translated image of this regal phenomenon may now be directly viewed in the laboratory. And some day this rare spectacle, never seen in the heavens by millions of men, will be thrown upon their television screens at home. What thrilling lectures on solar physics will such pictures permit!

The electron microscope, another outgrowth of television research, possesses power to magnify and analyze cellular and even molecular structures lying far beyond the power of our most powerful optical instruments, even when using ultra-violet light. The new fields of knowledge in metallurgical, chemical, physical, and biological research thus being opened are of immeasurable extent.

So many of us go through life unaware of the satisfaction derivable from appreciation of fine paintings. Yet great art is simple and easy to understand when its subjects are delineated and lucidly explained. Even when illustrated in black and white (eventually in color) still art reproductions can be made entrancing. All the gamut of human emotions are there depicted, not only his feeling but the artist's intellect may be understood and appreciated when a competent interpreter opens our eyes to their expression.

What then could be a more fitting theme for a weekly half-hour of television than a quiet parade through some famous art gallery, pausing a moment before each masterpiece (as pictured photographically in the studio) while the gifted commentator dwells briefly upon its characteristics, explains its meaning, recounts the story of its creation, its creator? What could be more richly entertaining, more uplifting, than such experience? For such sallies into fields of art, aural radio is utterly inadequate, but we shall find in time how intimately television may be wedded to fine art.

In crass commercial fields this instrument of science's magic, television, will find wide demand for advertising or display in department stores, for picturing merchandise or models in show windows, from a central point. As a medium for showing to the housewife at night the models of dress and hat to go on sale next morning, television will prove the most effective sales agent in the history of merchandising. And if shapely mannikins parade or cavort before the iconoscope the male element of the household will also sit up and take lively interest. Tight pursestrings will be relaxed!

Can we imagine a more potent means for teaching the public the art of careful driving safety upon our highways than a weekly talk by some earnest police traffic officer, illustrated with diagrams and photographs? Or in lessons in administering first aid, by some competent surgeon? Television in home and school will prove a priceless element towards the saving of life.

So much for some of the more immediate applications of television and its influence upon society. Can we foresee its more general influence in the far future?

The trend of social and industrial development today is consistently towards a shortening of the hours of labor, with correspondingly more of leisure. Coupled with this is an indication of a gradual elevation of the average intellectual level in America. Such is evidenced by the quality of many radio programs (supposedly barometers of the public's brain)—scarcely perceptible in others which we hear.

From a full-time average labor week of 60 hours fifty years ago, the average has diminished to 40 hours today. Coupled with this increase in leisure time has been a general increase in wages, even when measured in terms of values equivalent. This industrial trend, with all resultant social changes, will undoubtedly continue.

The hope begins to dawn that eventually a static balance between production and a population capable of profitably consuming its production may be achieved. To this end active political and social education directed by clear-visioned, firm-minded leaders will be necessary.

It is definitely clear that the average age of our population is increasing. The 1930 census showed 23 percent of our people were over 45 years of age. It is estimated that by 1980, 35 percent of Americans will be in that age group. Thus we are steadily tending towards a population predominantly elderly and middle aged. Coupled with this is the definite tendency towards decentralization of industry and industrial populations, from the congested cities to the metropolitan and surrounding rural districts. The hey-day of the cloud-scraping towers in the city has passed its meridian. Henceforth you will note a gradual razing of these ridiculous structures, no more to be proudly exploited. Those impressive skylines must eventually subside.

We are learning that the automobile offers more comfortable transportation than elevators or subways. We will gradually learn that free air in the suburbs and country makes better breathing than does city monoxide. Short working hours and improved highways enable city populations to expand laterally, rather than vertically. Thus will their new leisure hours become of value, rather than boresome and baffling.

A population which once more centers its interest in the home will inherit the earth, and find it good. It will be a maturer population, with hours for leisure in small homes, away from today's crowded apartments. Into such a picture, ideally adapted to the benefits and physical limitations of television, this new magic will enter and become a vital element of the daily life.

This new leisure, more wisely used, welcoming the gifts, entertaining, cultural, educational, which radio and television will bestow, shall eventually produce new outlooks on life, and new and more understanding attitudes toward living.

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