RCA REVIEW

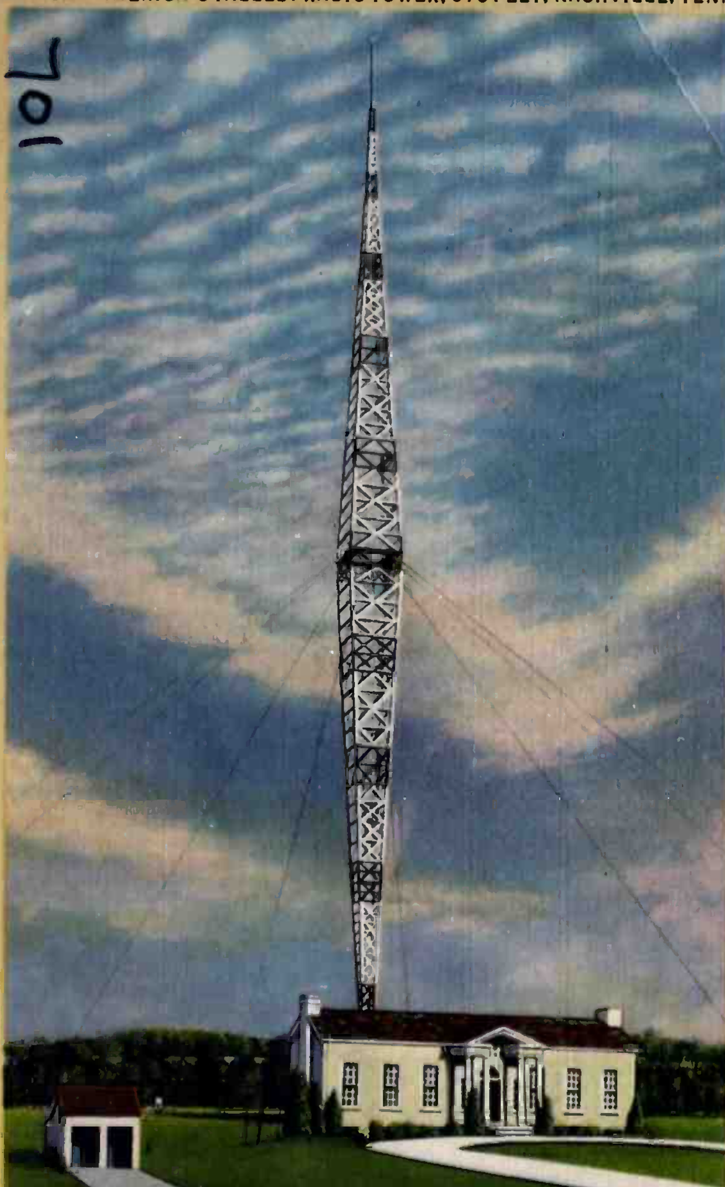
A QUARTERLY JOURNAL OF RADIO PROGRESS

VOLUME I July 1936 NUMBER 1

IN THIS ISSUE

RCA INSTITUTES TECHNICAL PRESS
A Department of RCA Institutes, Inc.
75 Varick Street New York, N. Y.

8—WSM—AMERICA'S TALLEST RADIO TOWER, 878 FEET, NASHVILLE, TENN.



323 FEET HIGHER THAN THE WASHINGTON MONUMENT

RCA REVIEW

A Quarterly Journal of Radio Progress

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RCA INSTITUTES TECHNICAL PRESS
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FOREWORD

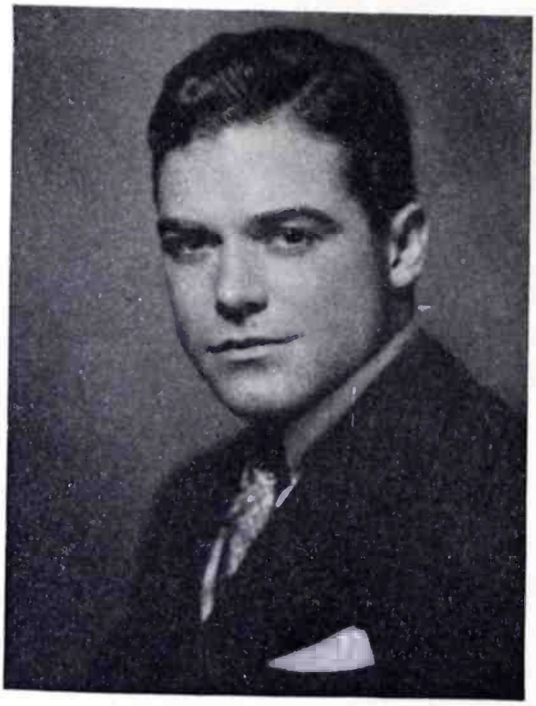
The RCA Institutes, the oldest school in the country for the training of students desiring vocational courses in radio technique, takes pleasure in announcing the formation of the RCA Institutes Technical Press.

The vast amount of new information on electronics which is constantly being acquired through the accomplishments of RCA executives and research engineers, has created a need for its permanent recording in easily available form. Through this new department of the RCA Institutes, much of this valuable material will be gathered, published and offered to students and interested observers in the field.

As its first effort, the RCA Institutes Technical Press offers the RCA REVIEW, which will contain many of the contributions which RCA research engineers are making in the related fields of the Corporation's activities.

J. G. HARBORD
Chairman of the Board,
RCA Institutes, Inc.

CONTRIBUTIONS TO RADIO RECOGNIZED



MR. B. J. THOMPSON

MR. B. J. THOMPSON was awarded the 1936 Morris Liebmann Memorial Prize given annually by the Institute of Radio Engineers for important contributions to the radio art. Mr. Thompson's contribution was in the ultra-short-wave field, and in particular his work leading to the present "Acorn" tubes. These are very small tubes, unconventional in design, but extending the usefulness of conventional principles of reception to wave-lengths of a meter or less.

Mr. Thompson was born in Roanoke, Louisiana, shortly after the turn of the twentieth century. He graduated from the electrical engineering course of the University of Washington in 1925. From 1925 to 1931 he was engaged in vacuum tube research and development in the Research Laboratory and Vacuum Tube Engineering Department of the General Electric Company at Schenectady. In 1931 he moved to Harrison, New Jersey, in charge of the Research Section, Research and Development Laboratory of the RCA Manufacturing Company.

Mr. Thompson's work in the field of vacuum tubes has been broad. He was associated in the development of the first commercial screen-grid tube and has made contributions to technical publications on such subjects as screen-grid tubes, tuned-radio-frequency amplifiers, electrometer tubes, push-pull amplifiers, and ultra-short-wave tubes. He is a member of the American Physical Society and of the Institute of Radio Engineers. Mr. Thompson has served on many I.R.E. committees. His energy, knowledge, keen analytical ability, and pleasing personality have enabled him to render outstanding service in committee work. At present, he is a member of the Standards Committee and chairman of the Electronics Committee of the I.R.E.

THE FUTURE OF RADIO AND PUBLIC INTEREST, CONVENIENCE AND NECESSITY

By

DAVID SARNOFF

President, Radio Corporation of America

Statement—Presented before Federal Communications Commission, Washington, D. C., June 15, 1936.

THE Radio Corporation of America welcomes the opportunity to testify at this informal hearing. We are deeply aware of the importance and urgency of the tasks before the Federal Communications Commission. We are pleased to place at your disposal the information and experience of RCA, gained from its operations in radio research, communications, broadcasting, manufacture and sales. These interrelated enterprises have enabled us to study and develop radio in ever widening fields of public usefulness.

In such a fast moving art as radio, government regulation must have wide powers of discretion. A strait-jacket of rigid rules would cripple its energies. In the Radio Act of 1927 and in the Communications Act of 1934, Congress recognized this fact and wisely refrained from prescribing hard-and-fast formulas. Instead it set up a high standard for flexible regulation, the standard of "public interest, convenience and necessity." That standard gives your Commission the power, and therefore the responsibility, of judging issues on the basis of past accomplishments, of present activities, and particularly on the capacity for future progress.

It is in relation to this standard of "public interest, convenience and necessity" that I desire to summarize briefly the position of radio, both as an art and as an industry, and to call your attention to the new services which it is evolving and to prospects for its future development.

We of the RCA are especially conscious of the complexity of the problems your Commission must solve in the public interest. That complexity results from a number of circumstances unique to the radio industry.

First: It is the youngest of our country's great industries. Because of the aggressive and dynamic development of the radio art, it has reached its present proportions and its vast social significance in less than fifteen years. It has few precedents and no rules of thumb to formulate its policies. At every stage of its progress it must break new ground. It must always be a daring pioneer.

Second: It is an industry that functions in the present, although it lives also for a greater future. Important new radio services are ready today for practical demonstration. Tomorrow they will be ready to serve the public. Others are still in the laboratory stage of development. But beyond are widening perspectives of usefulness: the promises of further radio possibilities which may well outweight all the achievements of the past. These developments must be safeguarded against unnecessary restrictions. Radio progress must not be "frozen" at any point.

Third: We deal in radio with a public treasure that—for the moment—is limited in its extent. The frequencies which make up the radio spectrum constitute one of the nation's most valuable natural resources. Each of them must be made to yield its maximum of service under the stimulation of every new discovery.

These are the realities of today. But tomorrow, the pioneers in the radio laboratories may open up unlimited reservoirs of new frequencies and then your Commission must be ready to remold its rules to take advantage of the new opportunities, so that the public may benefit at once from these achievements.

We have no definite yardstick with which to measure radio as a civilizing influence, in the education, entertainment and progress of mankind. But we do know that life itself has been revolutionized by the speed and completeness with which radio has drawn the most distant places, the most forgotten lives, into the orbit of civilization.

In 1920 the United States had direct cable connection with only two European nations, Great Britain and France, and with a few countries in South America and one in the Orient. Today our country is linked by nine public service radio companies to more than 60 nations in direct radio communication which cannot be broken by any other nation. More than 5,000,000 paid messages are handled annually by the radio-telegraph carriers reporting to your Commission. This development of American radio communications has sliced one hundred million dollars from the bills of international telegraph users here and abroad.

Until the advent of radio, no communication service could cover the oceans—seven-eighths of the world's surface. In 1902, there was only one American merchant ship equipped with radio—the S.S. Philadelphia. Today some two thousand American ships have radio telegraph equipment. A ship with modern radio apparatus can maintain uninterrupted communication with coastal stations in the United States during its entire circumnavigation of the globe. Radio direction finders guide vessels at sea. A facsimile service providing weather maps to ships at sea is now being introduced.

Broadcasting has made even more dramatic strides. When the Harding-Cox election returns were broadcast in 1920, only a few hundred radio amateurs listened in. Today 23,000,000 homes in our country, more than 70% of the total, are equipped with radio receivers, and 3,000,000 American automobiles, more than 10% of all registered motor cars, are radio-equipped. If all receiving sets were tuned to the same program, 90,000,000 persons, approximately three-quarters of our population, could listen at the same time to a single voice. The United States and its territorial possessions have 623 broadcasting stations, representing in ownership a cross-section of American life: industrial organizations, newspapers, labor groups, colleges, cultural and religious institutions. Affiliated with the two major networks are 196 broadcasting stations. Of these 22 are owned and managed by the network companies. The rest are independently owned and operated.

Not only do the American listeners enjoy the finest broadcast programs in the world without paying license fees, but they are buying the finest radio receivers in the world at the lowest prices. No wonder, as Professor Allport of Harvard has declared, we spend a billion hours a week listening to the radio!

During 1935 it is estimated that the people of the United States spent seven hundred million dollars on radio—truly a figure which demonstrates the magnitude of the industry and its importance to the prosperity of the nation.

To show how important radio is to other industries, the owners of radio sets spent one hundred fifty million dollars last year for electric power to operate their sets—almost twice the amount which the broadcasting companies received for broadcasting the programs which these listeners heard. In the same year, this "wireless" industry consumed a million miles of wire in the manufacture of its apparatus. And the world's largest wireless broadcasting company, the NBC, was at the same time the largest customer of the world's greatest wire organization, the American Telephone and Telegraph Company. The annual telephone bill of the NBC for wire service exceeds three million dollars.

Probably the most striking figure in all the columns of radio statistics is the estimate that the American public has invested more than three billion dollars in broadcast receiving apparatus. This is more than ten times the investment in broadcasting stations and radio manufacturing plants. From this you will realize the extent of the general public's interest in the healthy development of radio.

No statistics, however, can suggest the magnitude of the future of the radio art. Each advance made by the laboratories into unexplored domains of the ether carries with it the possibility of creating even greater services. A few, such as television, and high-speed facsimile communication, are ready now for field demonstrations. Others are on the way, although further laboratory experimentation will be necessary before they are ready for practical use.

This research represents an immense investment in capital and an incalculable investment in human genius. It is fascinating as a conquest of the unknown, and thrilling because of its promise of increased human power, knowledge and happiness. Yet, considered coldly as an economic element, it is particularly significant at this time when the country is emerging from the depths of an economic depression. The new instrumentalities of radio hold the promise of new industries, new services productive of new wealth and new employment.

Of the future industries now visible on the horizon, television has gripped the public imagination most firmly. Technically, television is an accomplished fact, although it is not yet ready commercially. In this field American research holds the lead and America's supremacy, as in other fields of radio, is universally recognized.

To bring television to the perfection needed for public service our work proceeds under high pressure at great cost and with encouraging technical results. Other nations are accepting the standards and methods of RCA engineers and are applying them to the solution of their own television problems. Most of these foreign nations have been working with public funds. No such government subsidies of course have been available in the United States. None has been asked. But for more than a decade in years of plenty and in years of depression, a corps of RCA research engineers has been working unremittingly to give the art of television to the public. We are now entering advanced stages of that effort and will open an experimental television transmitting station in New York within two weeks. We believe that we have demonstrated again that private initiative can accomplish more in America than government subsidy has been able to accomplish elsewhere.

The television which is assuming shape in our laboratories will not, as many persons assume without warrant, replace sound broadcasting or make sound receiving sets obsolete. The present sound broadcasting services will proceed without interruption. Television must find new functions, new entertainment and new programs.

As soon as television has been brought to a point of practical service it will be made available to the American people. But to protect the public interest, television should not be launched until proper standards have been fixed. Television reception as we now know it differs from sound reception in at least one decisive technical aspect. In sound broadcasting every receiver is built to pick up any transmission within its range of reception. On the other hand, television represents an integrated system in which sending and receiving equipment must be fitted one to the other, as lock and key. We must avoid the danger of costly obsolescence which hasty commercialization might inflict upon the public.

We ask the Commission and the various government departments interested in radio to consider carefully the needs of this new industry. Frequencies should be made available not only for the expanded experimental and field demonstration work, but for the fullest measure of development toward a practical television service.

Radio broadcasting differs from all the other arts in that the service which it renders to the public is rendered free. There is no license fee for the use of radio receiving sets in the United States. And when television comes, it is my hope that despite the greater expense of its far more complicated program productions, there will still be no need for a license charge for television receivers.

Side by side with television, although in many respects nearer to final achievement, there is emerging from the field of radio experimentation high speed facsimile communication. By means of this new development, written, printed, photographic and other visual matter can be sent by radio over long distances and reproduced at the receiving end with amazing exactness. It is difficult to imagine limits of the use of such an invention. It should make the dot-and-dash system of telegraphy as outmoded as the pony express. Pictures, sketches, handwriting, typewriting and every other form of visual communication, will be transmitted as easily as words are now sent over a telegraph wire. Even in its earlier stages facsimile will be a medium for the instant dissemination of information of a hundred different types, from weather maps to statistics, from educational data to comic strips. Far from displacing the existing media of information—and particularly the newspapers—facsimile should contribute to their progress, providing them with swifter and more effective facilities.

In this new facsimile service we have also reached an advanced stage. R.C.A. Communications, Inc., has built an experimental facsimile circuit between New York City and Philadelphia, demonstrated publicly for the first time last Thursday. It uses ultra-high frequencies linked into instantaneous transmission by automatic relays. This circuit will demonstrate the possibilities inherent in facsimile transmission and should also contribute to solving the difficult problems of relaying television programs on these ultra-high frequencies.

One of the triumphs of this demonstration circuit has been its success in combining, for the first time in radio history, the simultaneous transmission of visual matter with automatic typewriter telegraph operation on the same radio channels. This ability to carry separate services simultaneously on a single frequency is of great importance.

To make possible the greatest public use of this new development, radio channels should be provided which will make room for healthy expansion in facsimile research as well as in service, and the "public interest, convenience and necessity" of this new achievement should be recognized in the allocation of frequencies for this purpose.

It is the mastery of the ultra-high frequencies which is bringing television and facsimile within the area of practical use. We are steadily pushing farther into the higher regions of the spectrum which only yesterday constituted a "radio desert", now being made fruitful. One example will illustrate the great possibilities in this direction: Ultra-high frequencies have a range which is limited approximately by the horizon so that the same frequency may be used over and over again by keeping the transmitters 100 to 200 miles apart. This means that a relatively few frequencies assigned for local broadcast use can be reassigned until every community in the land can possess a radio voice for its own local purposes.

This expansion of the useful radio spectrum has only begun. Beyond the ultra-high frequencies lie the "micro-waves"—frequencies that oscillate at the rate of a billion cycles a second, wavelengths measured in centimeters instead of meters.

Future developments in micro-waves may well prove revolutionary. In the past, radio operations have been confined to a limited part of the radio spectrum. Once we have conquered these micro-waves we shall have opened a radio spectrum of almost infinite extent. Instead of numbering the useable channels in a few scant thousands, the radio art will put millions of frequencies at the command of communication services of every kind. When that day comes—and I have no doubt that it will—there will be frequencies enough to make possible the establishment not only of an unlimited array of mass communication services, but of an unlimited number of individual communication connections. In that day each one of our millions of citizens may have his own assigned frequency to use wherever he may be.

Step by step we are working toward that far off goal. We are telegraphing and telephoning today by radio to and from ships at sea and planes in the air. There is no reason we should not also be able to communicate with moving trains, or for that matter with moving automobiles. We can almost say that without radio, aviation would be impossible. In approaching such potentialities we must not allow our imagination to be earth bound. Radio belongs to the new day—the search for service and wealth above the earth. The finding of a new range of frequencies is of more importance than the discovery of a new gold field.

Recently international broadcasting has been in the limelight. The European crisis made overseas events an important factor in our daily interest. The technique of this international broadcasting is being constantly improved. Although this use of shortwave radio is still in its infancy, it merits vigorous encouragement. International broadcasting should promote better understanding among nations and—from our own national standpoint—better understanding of the United States among the nations of the world. The growth of international broadcasting should increase all other forms of international communications and promote our international commerce. To make such an achievement possible, America's international broadcasting should be organized as a definitely functioning service and the available international frequencies should be utilized to their fullest extent.

From time to time there are suggestions that it is the duty of the Federal Communications Commission to protect the wire services of the country against the encroachment of radio. Even if the Communications Act which created your Commission had not prohibited such an attempt, by saying that your Commission shall "generally encourage the larger and more effective use of radio in the public interest," such an effort would be a futile one. Any effort to stop the progress of a new art in order to protect an existing art is bound to be futile.

Such a step would be contrary to the spirit of the country, contrary to the modern spirit of progress, and contrary to the whole experience of radio. For radio itself deliberately obsoletes today what is built yesterday. But for that fact, we would still be signally with long waves from great alternators instead of spanning the earth with short waves from vacuum tubes.

So long as there is an insufficiency of frequencies, it is proper for your Commission to conserve those frequencies by not using them needlessly to compete with wires. However, the policy which underlies such a decision should never have for its object the protection of wire services. It should always have for its object the protection of radio frequencies.

Your Commission will not be afraid of progress. Millions of dollars are being spent by the radio industry to invent new equipment and erect new stations which are made obsolete by the very things we learn from building them. The facsimile and television stations which the RCA has just built, for instance, may be made obsolete by the lessons they will teach us. We set up new systems and then we encourage our research workers to continue their experiments even if they supplant what we have created. Why? Because it is the only way to make progress. Such experiments call for enormous capital investments. They call also for imagination of the highest order and for courage to follow where that imagination leads. It is in this spirit that our laboratories and our radio scientists are diligently and devotedly engaged in a task of the highest service to humanity.

Radio research is so closely linked to the manufacture of apparatus that I feel warranted in explaining to your Commission the basic patent policy of the RCA, and particularly its application to the new fields of facsimile and television. It has been the policy of the Radio Corporation to grant licenses to its competitors engaged in the manufacture of radio broadcast receivers and tubes, and at the present time there are outstanding 52 such licenses for receivers and 13 for tubes. These licenses include the right to make and sell not only sound broadcast receivers and tubes, but also receivers and tubes for television and facsimile for the home, thus making available the results of our research in these fields to licensed manufacturers of the industry. In manufacturing and selling this apparatus the RCA licensees may utilize all of the inventions made or owned by the Radio Corporation, and all patents under which it has the right to grant licenses to others.

We are all proud of the fact that the United States has maintained freedom of the air while exercising flexible and intelligent regulation. We have succeeded in utilizing the motive power of private initiative while placing its achievements at the service of the whole population. In less fortunate portions of the world, we have warning examples of radio bound and gagged, along with other agencies of expression, its strength diverted to serve the autocratic purposes of dictators. Whatever else we do, whatever else your Commission may feel called upon to do, this valuable national possession of radio must remain, as heretofore, the instrument of democratic self-government and one of the important contributors to our national progress.

Measured by the advances made in other fields, radio in the last ten years has lived a century. Perhaps it may crowd a thousand years into the next decade. I am proud to be one of those who have participated in this development almost from the beginning. Next September

I shall have been in the service of radio for thirty years. That is a long time in so young a science. During these thirty years I have watched, naturally with the keenest interest, the unfolding of the radio art. I have seen technical revolutions in radio communication, radio broadcasting and radio entertainment, but I can say to you that never before have I seen so many developments emerging into practical achievement as the laboratories promise at this moment.

Out of this experience I should like to lay before you a number of suggestions. I trust they may be helpful to your Commission, and to the Government, in the task of formulating a basic and comprehensive radio policy. Such a policy is needed to maintain America's supremacy in radio and to fortify the independence of our country's position in this growing field. My suggestions, summarized, are as follows:

1. Because of the rapid strides of the radio art, advance reservations of frequencies should be made by the Federal Communications Commission to meet the needs of future services, such as television, facsimile and high-frequency broadcasting. This will enable these achievements of radio to give their greatest possible public service as soon as developed, instead of compelling them to contest with older services for adequate space in the spectrum.
2. Except for experimental purposes, no allocations to individual applicants should be made in these reserved frequencies until actual public service is possible. No one should be permitted to reserve frequency space for future use and then let it remain idle while others carry the burden of development.
3. In allotting frequencies the greatest economy and usefulness of the available channels should be promoted by requiring, so far as feasible, the multiple use of frequencies.
4. In determining precedence in the allocation of frequencies, consideration should be given to services on the basis of their comparative importance to the public, the urgency of the tasks to be performed, and the requirements of the public to be served. Radio has made possible outstanding progress in mass communication. Ample allocation should be made for the greatest use of this public service for the broadcasting of sight as well as of sound, nationally and internationally.
5. In time of war, or other emergency, all the equipment and resources of the radio industry, are by law placed at the disposal of the nation. The government departments interested in our national defense should, therefore, cooperate in making possible the greatest peacetime development of radio by limiting the number of frequencies requested for exclusive government use.

6. A fundamental and comprehensive communications policy should be formulated, not only for the guidance of the Commission, but of all government departments, to safeguard the independence of America's communication system in international relations. This is especially important because American communication services are at a disadvantage in dealing with monopolistic state-owned foreign communication systems.
7. In helping to determine the attitude of the United States in the International Communications Conference to be held in Cairo in 1938, the Federal Communications Commission should recommend a policy which will promote the greatest possible international use of radio communications. That Conference will be called upon to apportion the hitherto unallocated frequencies in the upper portions of the radio spectrum. In the international field as well as in domestic use these allocations should be safeguarded against any possibility of freezing radio development.

I thank your Commission for this opportunity to appear before you and to present my views. I have devoted myself to the general aspects of the radio art, rather than to its engineering details. With your permission and at such time as you may designate, Dr. C. B. Jolliffe, Engineer in charge of the RCA Frequency Bureau, will testify concerning the engineering phases of these problems.

The radio industry, let me say in conclusion, is convinced that the best interests of the industry coincide with the best interests of the public. We are content to submit our suggestions and recommendations to the standard of "public interest, convenience and necessity" prescribed by Congress for the guidance of your Commission.

THE NEW YORK-PHILADELPHIA ULTRA HIGH FREQUENCY FACSIMILE RELAY SYSTEM

By

H. H. Beverage

S. F. B. MORSE demonstrated his new telegraph system just 100 years ago, thereby making available to the world its first medium for rapid communication over comparatively long distances. It is a tribute to Morse that his teachings, with relatively minor modifications in principle, were used almost exclusively in the art of record communication until comparatively recently. While Morse's telegraph is still very widely used, it is gradually being supplanted by automatic printers for record communication over radio circuits as well as over wire lines and cable circuits.

The printer, as well as the telegraph, is generally limited in its operating speed due to the fact that operators must be used somewhere in the system. A message handed in for transmission must undergo some manual operation to prepare it for transmission. This may be the perforation of tape, the operation of a printer keyboard, or the manipulation of a telegraph key. Whatever this operation may be, the human element usually limits the speed per channel to about 40 or 50 words per minute.

Many years ago, Mr. Owen D. Young called attention to the desirability of removing this limitation.[1] Facsimile methods seemed to offer a promising solution to this problem. From a purely operating standpoint there should be no limit to the speed at which words can be handled since the customer's message may be directly scanned at the transmitting end and the reproduction at the receiving end may be delivered to the addressee.

For many years, experiments have been in progress to apply facsimile methods to long distance radio circuits. It has been found that facsimile may be applied to these circuits very successfully for handling photographs, sketches, and similar material at relatively low speeds. However, since the signals on long distance radio circuits are propagated by reflections from the conducting layers of the ionosphere, the signals arrive over multiple paths differing slightly in length. The result is that the signals traveling by the different paths arrive at the receiver at slightly different times, thereby producing an echo effect that smudges the received facsimile copy if the speed of transmission

[1] "Transmission and Reception of Photoradiograms," R. H. Ranger, Proc. I.R.E., April 1926.

is too high. For average transmission conditions on long distance radio circuits, as normally operated, the multipath echos limit the speed of message facsimile transmission to about 15 or 20 words per minute, which is considerably lower than the limiting speed set by the manual operation inherent with the telegraph and printer.

Frequencies above about 30 megacycles exhibit different characteristics than those below 30 megacycles. The very high frequencies are not turned back to earth by the ionosphere, so sky waves are absent. Propagation takes place by ground wave only, so there is fundamentally only one path for the signals to follow and there are no echo effects due to multiple path transmission. For this reason the very high frequencies may be used for such services as television and high speed facsimile. However, the ground wave is attenuated rapidly beyond the horizon and also fading sets in at distances appreciably greater than the optical path distance. The attenuation beyond the horizon increases as the frequency is increased. Consequently, for the very high frequencies, the distance for high quality service is practically limited to the optical range. It is obvious that the range can be increased by placing the transmitting and receiving antennas at the highest possible elevations. In fact, the distance of transmission is generally proportional to the square root of the respective antenna elevations, and the field intensity at a given point within the optical distance is directly proportional to the product of the transmitting and receiving antenna elevations.

Several years ago, the Radio Corporation of America set up an ultra high frequency relay station at Arney's Mount, near Mount Holly, N. J.[2] At Arney's Mount, 41 Mc television signals from the Empire State Building, 63 miles away, were picked up and retransmitted to the RCA Victor plant at Camden, N. J., 23 miles away, on a frequency of 79 Mc. Directive antennas were used at Arney's Mount for reception as well as for transmission. The 120 line television picture, used at that time, was clearly and reliably received at Camden during test schedules over a period of several months.

This one way television relay demonstrated the practicability of automatically relaying wide band transmissions. R.C.A. Communications undertook to develop a two way wide band relay system to determine its possibilities for handling traffic between New York and Philadelphia, particularly for facsimile methods. This relay system is now in operation.

It was decided to use frequencies above 85 Mc to avoid conflict with probable future television assignments. Since these high frequen-

[2] "An Experimental Television System," C. J. Young, Proc. I.R.E., November 1934.

cies attenuate very rapidly beyond the horizon, a survey indicated the necessity for adding a second relay point at New Brunswick, N. J., in addition to a relay at Arney's Mount. A relay near the New York

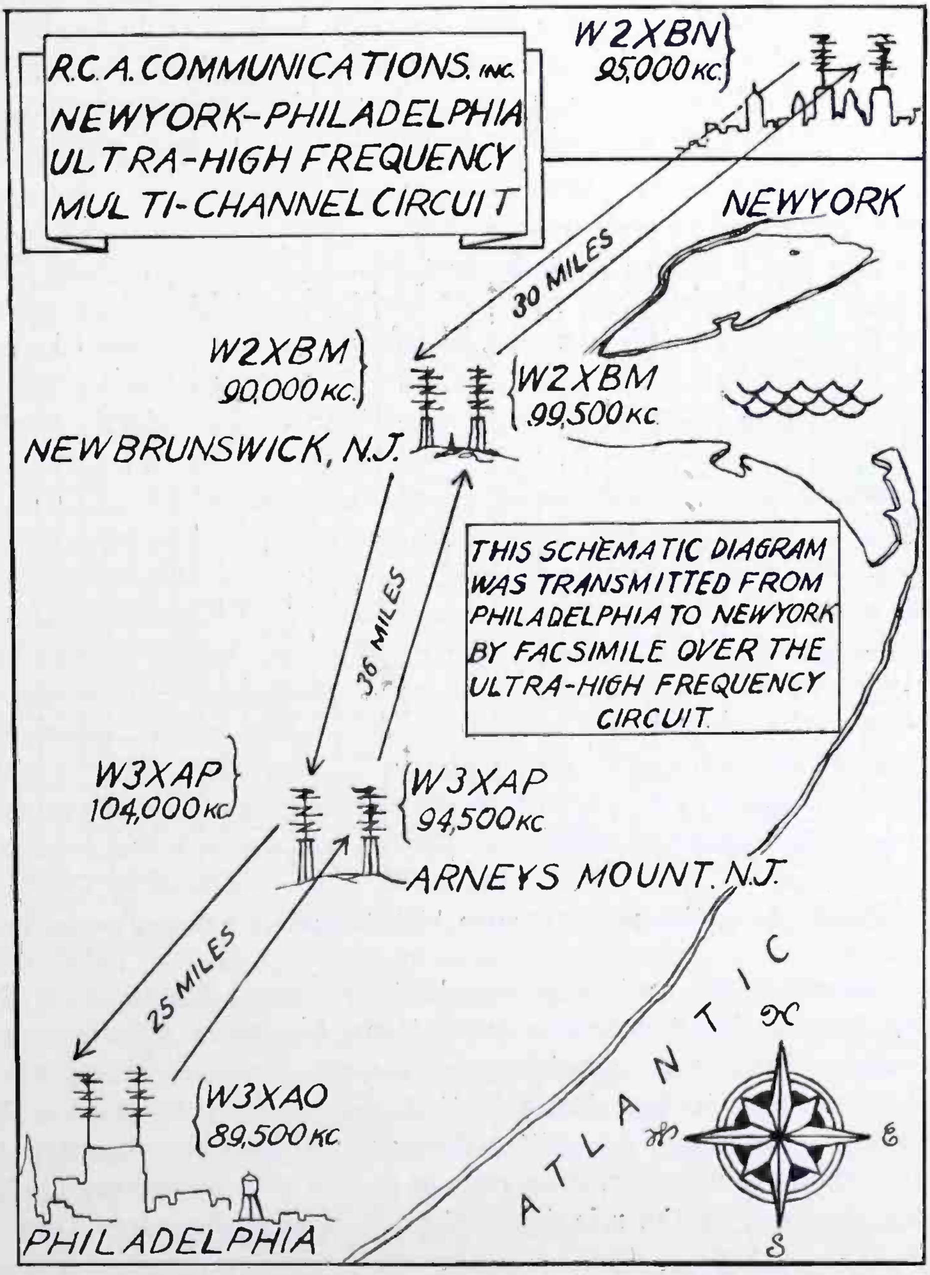


Fig. 1—Pictorial diagram of the New York-Philadelphia ultra high frequency relay system.

end was also required in order to lay down a strong enough signal in New York City to ride well above the high noise level experienced in urban areas. Fig. 1 shows the general arrangement of the relay stations.

It will be noted that at each relay point there are two receivers and two transmitters, one for the North bound relay and the other for the South bound relay. For economy, it was desirable to locate the North and South bound equipment, both transmitters and receivers, in the same building. It was also desirable to be able to locate the receiving and transmitting antennas in close proximity. This requirement introduced some special problems to avoid cross talk between the transmitters and to keep either transmitter from interfering with

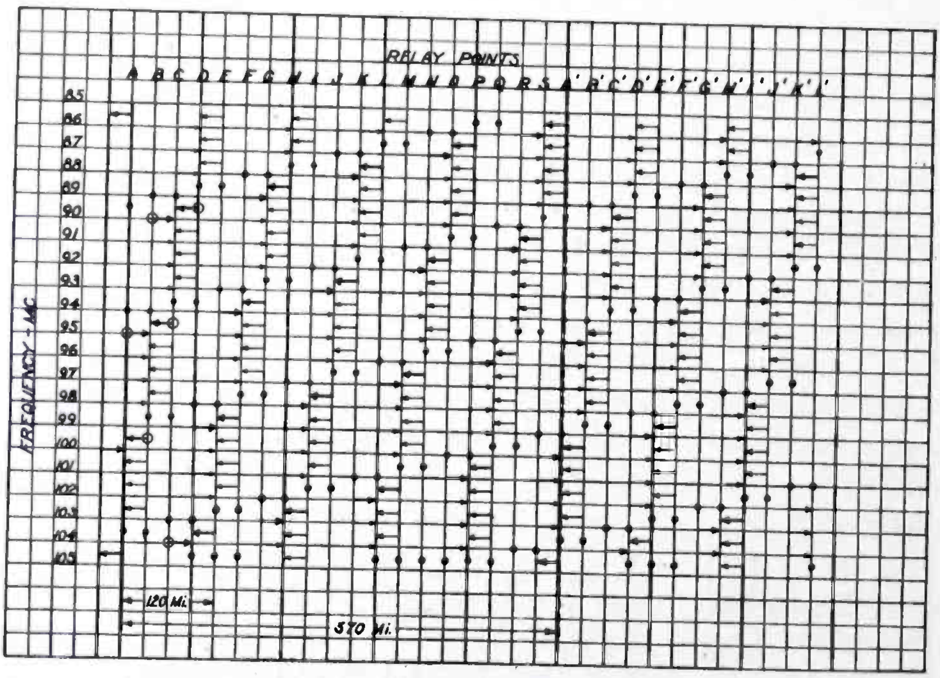


Fig. 2—Allocation plan for ultra high frequency relay system.

either receiver. To avoid any possibility of cross talk between the transmitters, without excessive precautions, frequency differences on the order of 10% were considered necessary. To avoid interference in the receivers, it was desirable that the received frequencies be about 5% from either transmitter frequency. It was also desirable to lay out the frequency allocation plan in such a way as to provide for future extension of the relaying system in several directions from a given city.

A typical allocation plan is shown in Fig. 2. It will be noted that the received frequencies at a given relay point are separated by 0.5 Mc. One transmitter is 4.5 Mc higher in frequency than the nearest received frequency, while the second transmitter is 4.5 Mc lower than the nearest received frequency. The adjacent transmitter frequencies differ by 9.5 Mc. This meets the specification set up for avoiding cross talk and interference, and makes it possible to mount transmitting antennas and receiving antennas on the same tower. By assigning every half megacycle in a 20-megacycle band, four two-way networks may be operated from any one point, plus two to four one-way circuits (depending upon whether these same frequencies are used for one-way service at an adjacent relay point). In any given network, with relays spaced 30 miles apart, on the average, any one frequency is not duplicated until a distance of 570 miles is reached. If all four networks are used out of a single given point, the frequencies will not be duplicated closer than 120 miles, which is believed to be sufficient to avoid interference when frequencies above 85 Mc are used. The arrows with circles, shown in Fig. 2, correspond to the frequency assignments actually used on the New York-Philadelphia circuit, as may be noted by comparing Figs. 1 and 2, bearing in mind that relay point A of Fig. 2 corresponds to New York, B to New Brunswick, C to Arney's Mount, and D to Philadelphia.

The receivers were specially designed to fit this allocation plan. Triple detection receivers were used with a first intermediate frequency of 30 Mc and a second intermediate frequency of 5.5 Mc. These particular frequencies were chosen so as to avoid spurious response at the frequencies appearing in the allocation plan. These spurious response points might be expected to occur at 4.5, 5, and 10 Mc below the received frequency, and at 4.5, 5, 10, 14, and 14.5 Mc above the received frequency. Triple detection was used in order to provide high discrimination against image response while at the same time providing adequate adjacent channel selectivity with reasonable provision for frequency drift. The frequency drift of the high frequency oscillator was controlled to close limits by utilizing the stabilizing characteristics of an adjustable low power factor resonator. Low power factor resonators were also utilized in the high frequency pre-selection circuits of the receiver. The receivers are provided with flat automatic gain control so that the receiver output delivered to the transmitter modulator is held within close limits in spite of possible variations of the received signal due to fading, weather conditions, or variation in the transmitter power.

Fig. 3 is a photograph of one of the receivers showing the back of the receiver with the covers removed. The transmission line comes into the right side of the top compartment. The two horizontal pipes contain the low power factor resonators for providing r-f selectivity. The massive structure at the left center of the upper compartment is the low power factor resonator which controls the h-f oscillator. The frequency is varied by screwing a plate in and out which varies the loading capacity of the resonator.

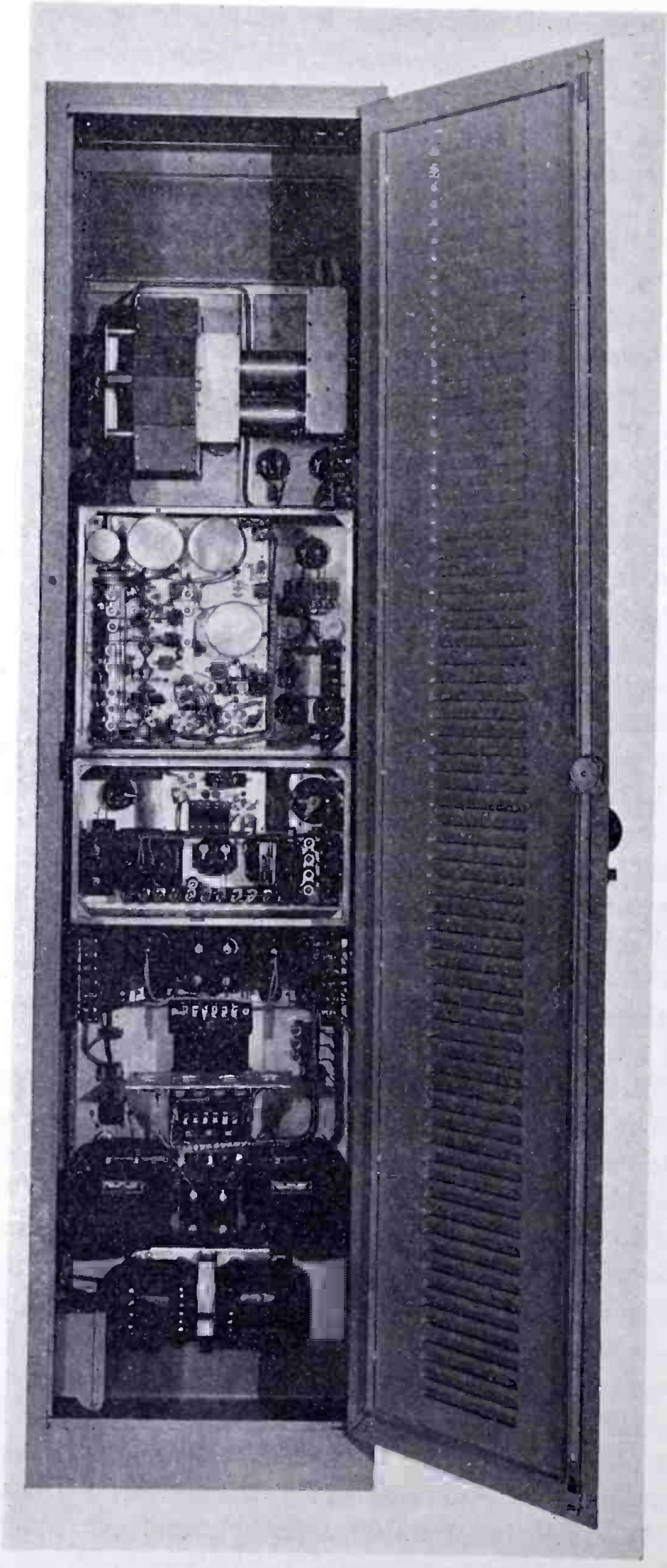


Fig. 3—Rear view of a relay receiver.

The oscillator utilizes an RCA 955 "Acorn" triode[3] which is contained in the casing of the resonator. RCA 954 tetrodes are used in the 30 Mc i-f amplifier.

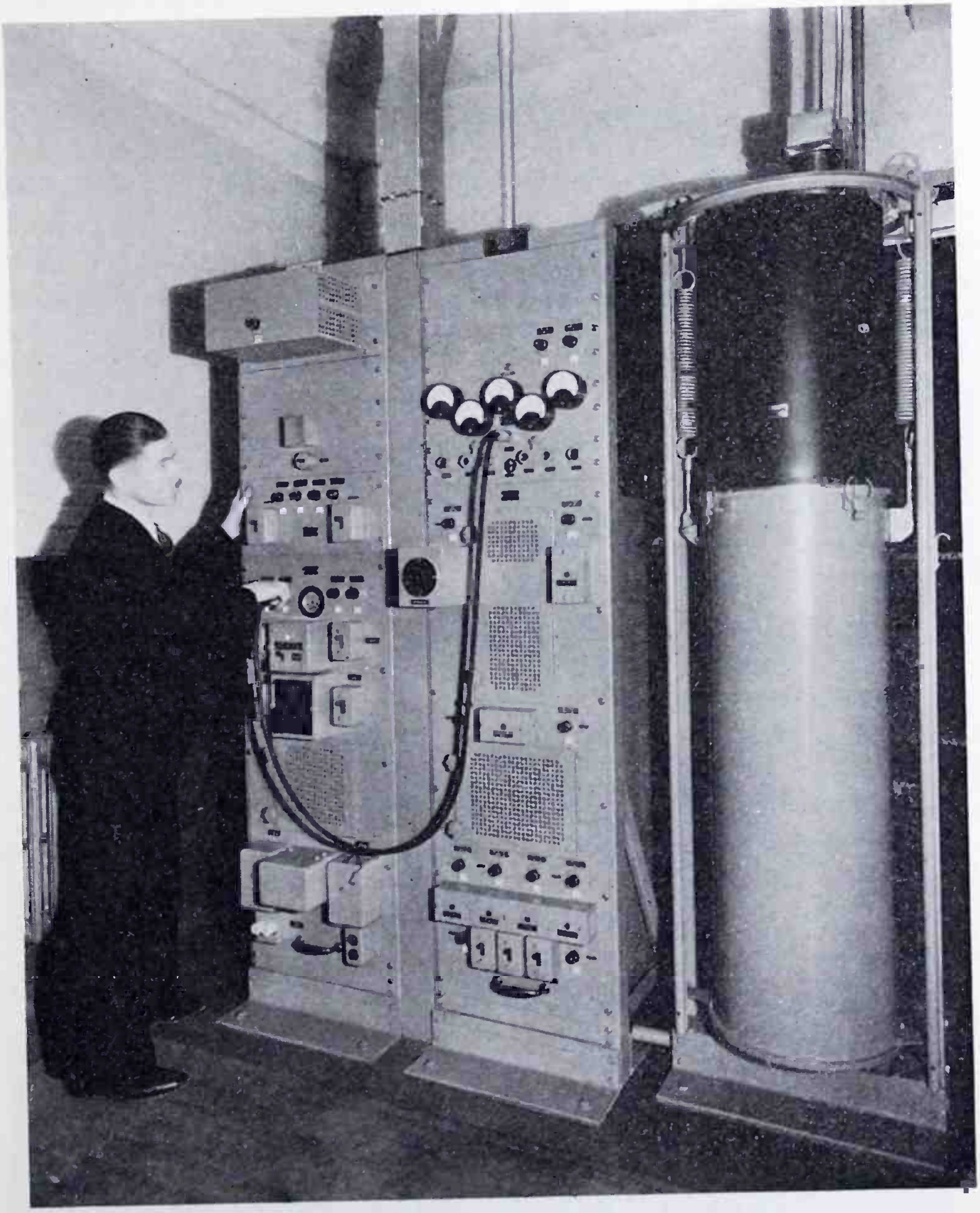


Fig. 4—Front view of a relay transmitter.

The frequency of the transmitters is held to close limits by resonant line circuits of the temperature compensated type.[4] The master oscillator consists of two RCA 834 triodes which drive four RCA 834 triodes

[3] "Vacuum Tubes of Small Dimensions for Use at Extremely High Frequencies," B. J. Thompson and G. M. Rose, Jr., Proc. I.R.E., December 1933.
[4] "Frequency Control by Low Power Factor Line Circuits," C. W. Hansell and P. S. Carter, Proc. I.R.E., April 1936.

in the power amplifier. The maximum carrier power is approximately 100 watts but ordinarily the transmitters are operated at about half power to increase the reliability of the transmitters at unattended stations.

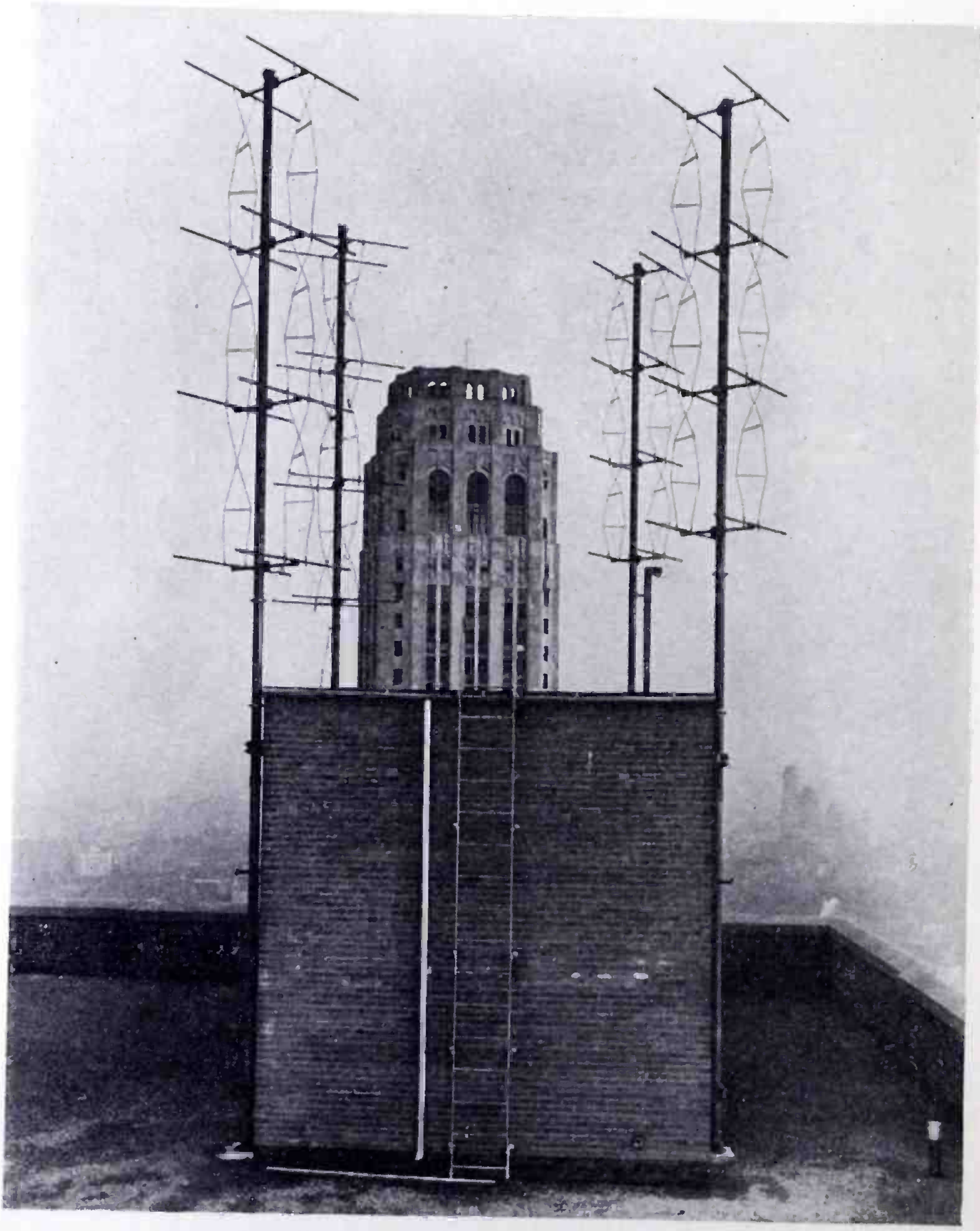


Fig. 5—The transmitting antennas at New York.

Fig. 4 is a photograph of one of the relay transmitters. The resonant line control, master oscillator and power amplifier are located in the circular tank-like stucture at the right. The panels at the left contain power supply, controls, and modulator.

Directive transmitting and receiving antennas are used. The transmitting antennas utilize a vertical array of horizontal dipoles with a similar array a quarter wave behind for a reflector. The transmitting antennas at New York are located on the roof of the Continental Bank Building at 30 Broad Street. Fig. 5 is a photograph of these antennas. The horizontal dipoles are approximately half a wavelength long and are spaced vertically half a wavelength. No insulators are used to support the dipoles, as they can be conductively connected to the supporting structure because the center of the dipole is at Zero r-f potential. It will be noted that the transmission line is reversed at alternate dipoles to allow for the 180 degree phase reversal in a half wave section of the line, thereby forcing all of the dipoles in the antenna to oscillate in phase. The reflector is adjusted in the same manner. Three of these antennas shown in Fig. 5 are directed on New Brunswick. One is for the South bound relay, and the other two are for other purposes. All three may be received at New Brunswick without interference. The fourth antenna is for experimental purposes, and is directed on Riverhead, Long Island.

The receiving antenna for picking up the North bound signals from New Brunswick may be seen in the background of Fig. 5 on the roof of the City Bank-Farmers Trust Building. This antenna is a duplicate of the transmitting antennas.

The gain of the antennas shown in Fig. 5 is about 10 db. At the relay points, the antennas are mounted on towers and seven dipoles are stacked vertically instead of four, so the gain of the antennas at the relay points is correspondingly greater. At New Brunswick, the transmitting antennas and one of the receiving antennas are supported by a 225 foot tower on fairly level ground. At Arney's Mount, a 165 foot tower on a 220 foot hill serves the same purpose. It was necessary to use high receiving antennas on the New Brunswick-Arney's Mount link to obtain an approximately optical path, on account of an intervening hill.

Fig. 6 is a photograph of the relay building and 225 foot tower at New Brunswick. The two transmitting antennas are mounted at the top of the tower. The right hand antenna is directed on Arney's Mount, while the left hand one is directed on New York. The horizontal diamond receiving antenna for receiving from Arney's Mount is supported from cross arms extending out from the tower. One of these cross arms may be seen just below the transmitting antennas. For receiving from New York, a large horizontal diamond antenna is used. This antenna is supported on wooden poles and is not visible in the photograph.

The transmitters and receivers at the relay points, and at Philadelphia, are located close together in the same building. The transmitter rooms are shielded from the receiver rooms in order to keep r-f potentials out of the control circuits and the receivers. All control lines passing from the receiver rooms to the transmitter rooms are

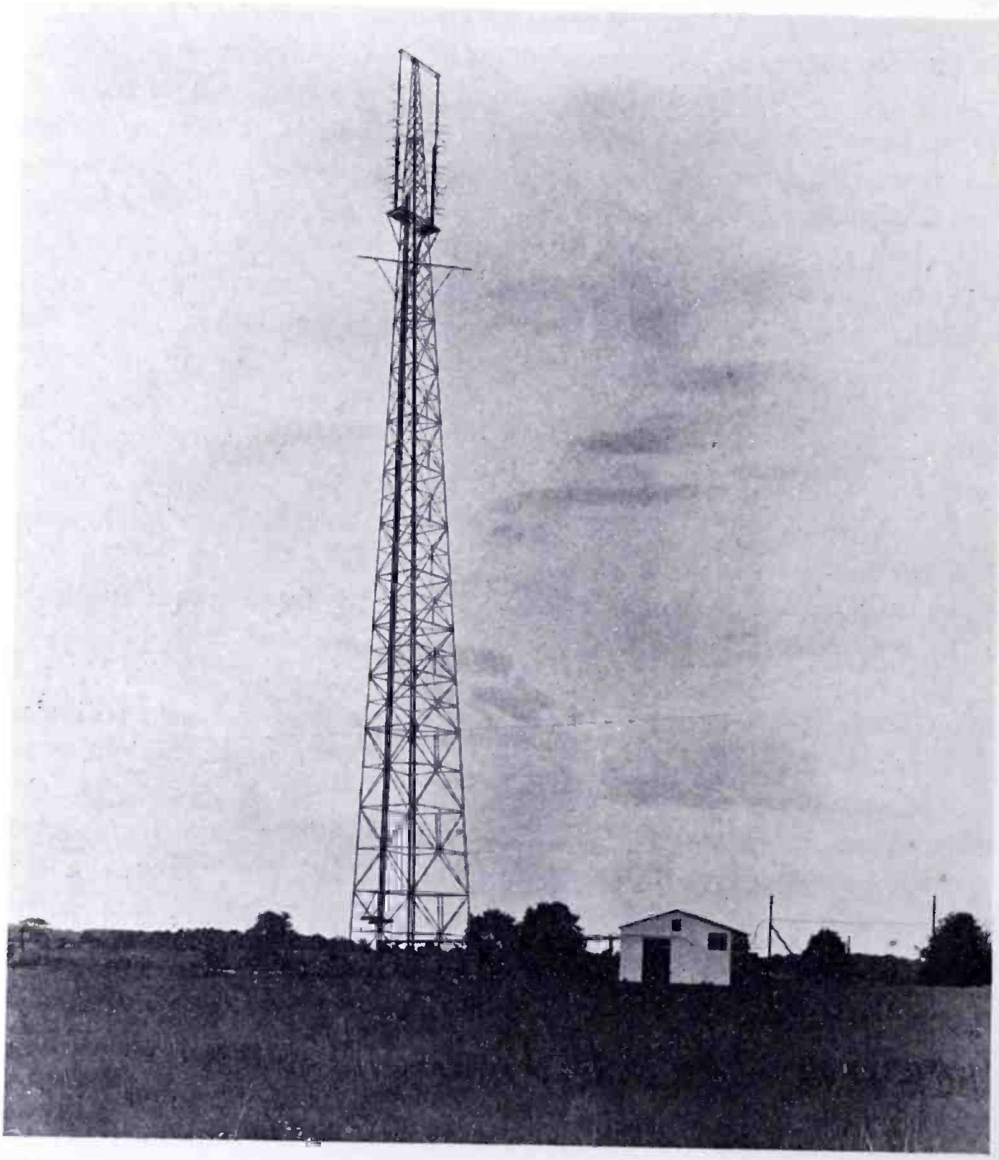


Fig. 6—Exterior view of the relay station at New Brunswick, N. J.

carefully filtered against r-f potentials. Fig. 7 is a photograph of the interior of the New Brunswick relay station. The transmitters are in the shielded room at the right. The equipment in the foreground is used for monitoring and switching operations. The other racks contain the receivers for North and South bound circuits and three receivers for other purposes.

The transmission lines for the transmitters consist of two wires completely shielded the entire distance from the transmitters to the antennas. The receiver transmission lines consist of two concentric lines in parallel. Both types of lines are arranged to be balanced to ground, and all antennas are symmetrical with respect to earth. These precautions were taken in order to confine all r-f cross couplings to that existing between the antennas.

Fig. 8 is a schematic representation of the traffic office terminal equipment for one direction. Identical equipment is used for the oppo-

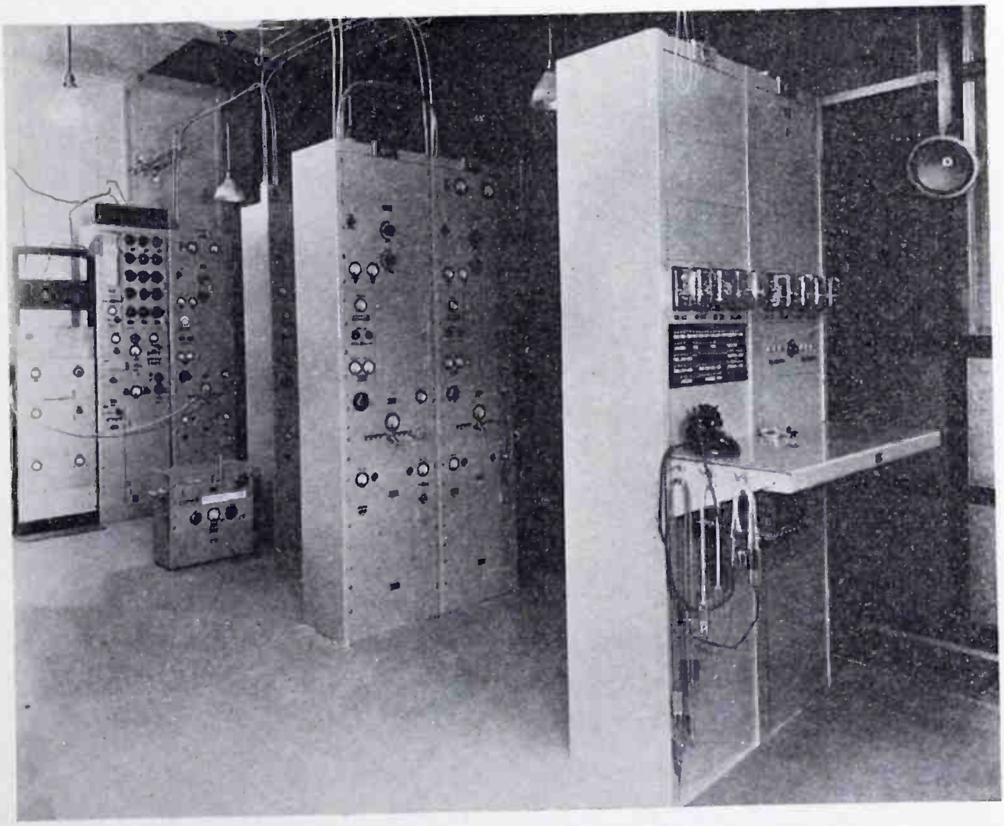


Fig. 7—Interior view of the relay station at New Brunswick, N. J.

site direction. The system is laid out to transmit, in each direction, two page facsimile channels, two printer channels, one telegraph channel, one cue channel, and a remote start-stop channel. The latter channel is for the purpose of controlling the transmitters at the remote relay points, as will be explained later. The cue channel is for the purpose of providing direct communication between the operators of the facsimile machines.

The transmitting terminal equipment at the left, in Fig. 8, controls separate sources of audio frequency by means of the converter circuits. The modulated tones pass through filters to a common line. The mid frequency of the filter bands are indicated on the filters. The lower five filters are standard voice frequency carrier filters with an effective band width of about 80 cycles. These filters are wide enough to handle the printer, telegraph, and control channels. The two upper filters are special high pass and low pass types which are combined to pass an effective band of about 7500 cycles for each facsimile channel. The combined tones, occupying a total band width of about 20,000 cycles, are passed to the transmitter over a wire line. The transmitter is modulated about 80 percent by the combined tones. At the transmitter, a small portion of the r-f output is rectified and passed back

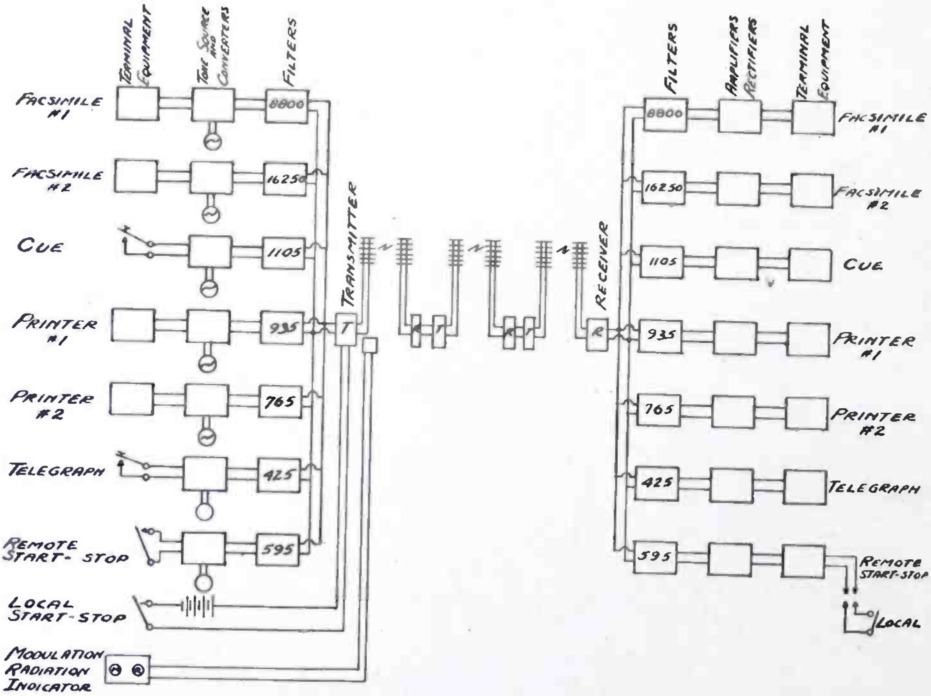


Fig. 8—Schematic diagram of terminal equipment for one direction. Duplicate equipment is used for the opposite direction.

to the central office over another wire line. Indicators are provided to show transmitter output and the percentage of modulation.

The modulations are passed on to the distant terminal via the repeater stations. The output of the terminal receiver is passed through corresponding filters which separate the modulated tones into their respective channels. These tones are then amplified and rectified and the rectified currents operate the corresponding terminal receiving equipment.

The control equipment at the repeater stations is shown in Fig. 9. The receivers at all points operate continuously. Let us assume that New York wishes to start up the South bound relay. The New York transmitter is started by d-c control, as indicated in Fig. 8. As soon as the New York transmitter is on the air, this fact is indicated to the control point by the radiation indicator. The remote start-stop switch is then closed, putting the 595 cycle tone on the line to the transmitter. This tone is picked up on the receiver at New Brunswick, and is passed through the 595 cycle filter shown in Fig. 9. The tone is amplified and rectified. The rectified current operates a small relay, which, in turn, operates a large a-c relay that applies 60 cycle power to the transmitter and its modulator. Automatic time delay relays turn on the plate power after the filaments have warmed up sufficiently. As soon as the New Brunswick transmitter is on the air, it, in turn,

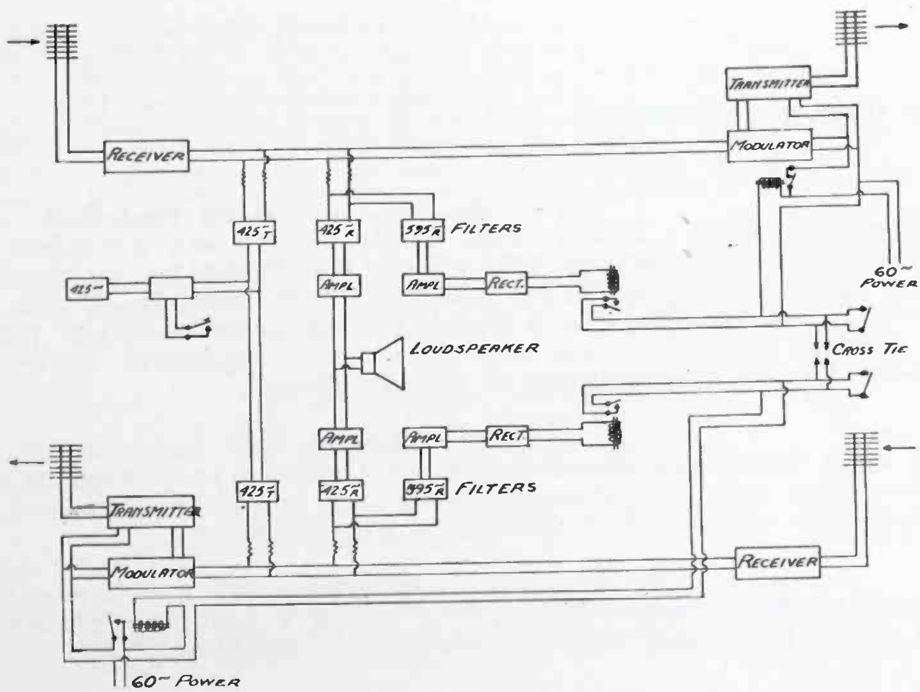
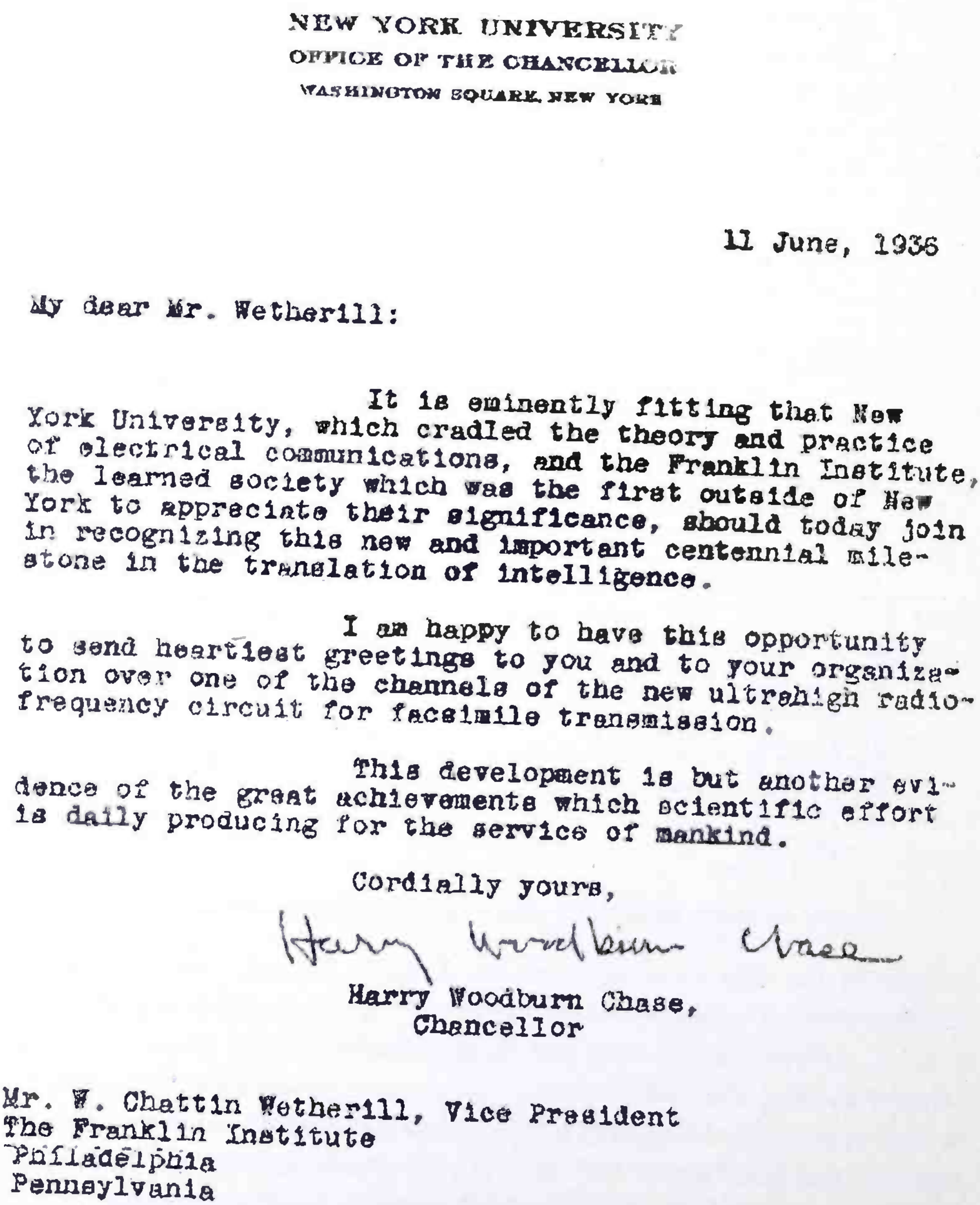


Fig. 9—Schematic diagram of a relay station.

transmits the 595 cycle tone on to Arney's Mount. As soon as the Arney's Mount transmitter is on the air, the tone is heard at Philadelphia. If desired, the tone can be tied back over the circuit at Philadelphia so that the North bound circuit can be automatically started in the same way. However, to save time, it is preferable to close the contacts marked "cross tie" in Fig. 9, which causes the North and South bound transmitters at a given point to start up together. With this arrangement, either New York or Philadelphia can start the entire circuit with a minimum of delay. The circuit is shut down by removing the 595 cycle tone.

Although the circuit is unattended, it is desirable to provide communication at the relay points in order to assist the service man in checking up the circuit when he inspects the relay stations or is called out to correct some difficulty. Fig. 9 shows the communication arrangements. The general telegraph channel uses a carrier frequency of 425 cycles. Each of the relay points are provided with a 425 cycle oscil-



NEW YORK UNIVERSITY
OFFICE OF THE CHANCELLOR
WASHINGTON SQUARE, NEW YORK

11 June, 1936

My dear Mr. Wetherill:

It is eminently fitting that New York University, which cradled the theory and practice of electrical communications, and the Franklin Institute, the learned society which was the first outside of New York to appreciate their significance, should today join in recognizing this new and important centennial milestone in the translation of intelligence.

I am happy to have this opportunity to send heartiest greetings to you and to your organization over one of the channels of the new ultrahigh radio-frequency circuit for facsimile transmission.

This development is but another evidence of the great achievements which scientific effort is daily producing for the service of mankind.

Cordially yours,

Harry Woodburn Chase,
Chancellor

Mr. W. Chattin Wetherill, Vice President
The Franklin Institute
Philadelphia
Pennsylvania

Fig. 10—Facsimile specimen transmitted from New York to Phiadelphia.

lator and a keying converter. The output of the converter is connected to both the North and South bound circuits through 425 cycle band pass filters so that the 425 cycle tone passes in both directions to the other relay points as well as to both terminal offices. If any other point on the circuit wishes to communicate with the service man, they can key their local 425 cycle source, which passes over the circuit, is amplified at the relay station, and is heard on the loud speaker. Any communication in either direction is heard on the loud speaker since

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
PHILADELPHIA

OFFICE OF THE PRESIDENT

June 11, 1938.

Dear Dr. Chase:

The Franklin Institute is particularly gratified to acknowledge the greetings of New York University on this the first public demonstration of the new Ultra-High Frequency Radio Circuit. Since 1824 The Franklin Institute has devoted itself to the promotion of science and the mechanic arts. It is, therefore, especially appropriate for us to join with New York University in appreciation of this new and important development.

A century ago, the Committee on Science and the Arts of The Franklin Institute in reporting on its examination of the Electro Magnetic Telegraph invented by Professor Samuel F. B. Morse stated in part:

"The committee beg to state their high gratification with the exhibition of Prof. Morse's telegraph, and their hope that means may be given to him to subject it to the test of an actual experiment made between stations at a considerable distance from each other."

Since that distant day, scientific research and a public appreciation of its contribution to human progress have made possible this epoch-making event in which we are participating today.

We send to you and your colleagues our kindest personal regards.

Cordially yours,
W. Chattin Wetherill
W. Chattin Wetherill
Vice-President

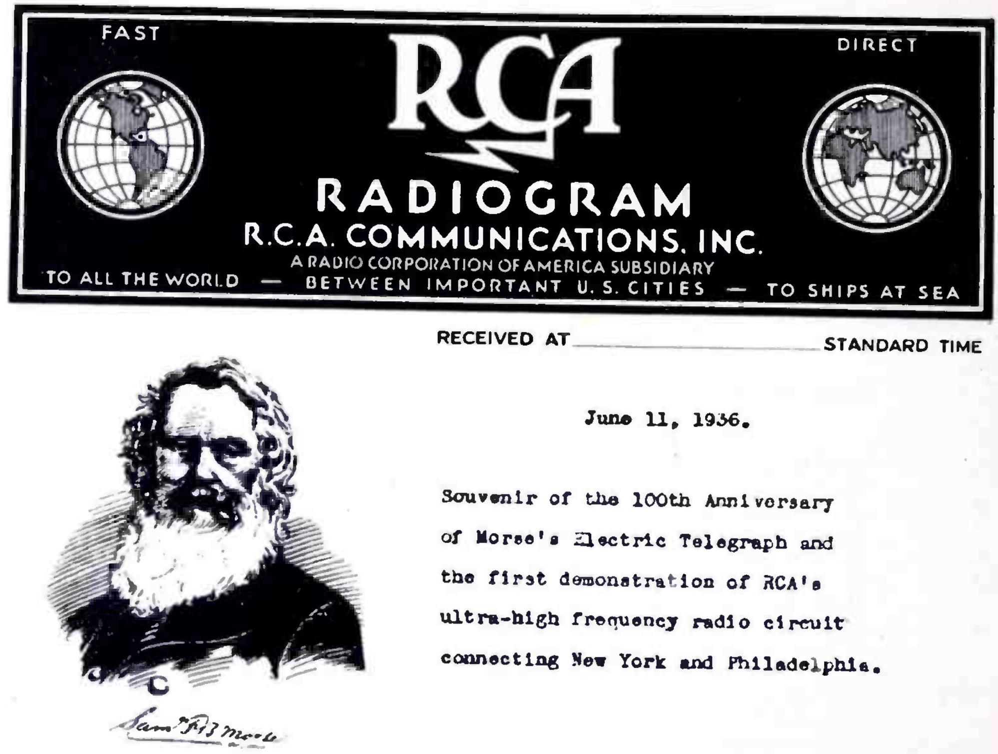
To-
Dr. Harry Woodburn Chase
New York University
New York City

Fig. 11—Facsimile specimen transmitted from Philadelphia to New York.

it is associated with amplifiers on both sides of the circuit. Telegraph sounders are used at the terminal offices rather than loud speakers.

Means are provided for observing the modulation and checking the signal to noise ratios at the relay points as well as at the terminals.

The communication center at New Brunswick is provided with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RCA

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RADIOGRAM

R.C.A. COMMUNICATIONS, INC.

A RADIO CORPORATION OF AMERICA SUBSIDIARY

TO ALL THE WORLD — BETWEEN IMPORTANT U. S. CITIES — TO SHIPS AT SEA

RECEIVED AT ________ STANDARD TIME

June 11, 1936.

Souvenir of the 100th Anniversary of Morse's Electric Telegraph and the first demonstration of RCA's ultra-high frequency radio circuit connecting New York and Philadelphia.

Fig. 12—Facsimile specimen showing black and white sketch of S. F. B. Morse.

monitoring facilities by means of which the emissions of all transmitters in the relay system are observed, and their frequencies accurately measured.

The facsimile equipment uses carbon paper recorders developed by C. J. Young of the RCA Manufacturing Company. The present operating speed is about 8 square inches per minute for each channel. Sheets up to about 8½ by 10 inches can be handled by these machines.

The relay circuit has been in operation since December, 1935. The first public demonstration was given on June 11, 1936 to commemorate the hundredth anniversary of the demonstration of the electric telegraph by Samuel F. B. Morse. In 1836, Morse gave the first demonstration of his new instrument to his colleagues at New York University. He gave the next demonstration outside New York City before the membership of The Franklin Institute in Philadelphia.

Fig. 10 is a facsimile of a letter from Chancellor Chase of New York University to Vice President Wetherill of The Franklin Institute. This facsimile was transmitted from New York and received at Philadelphia on the occasion of the public demonstration. Fig. 11 is a facsimile of the reply from Mr. Wetherill to Dr. Chase which was transmitted from Philadelphia to New York. Fig. 12 is another facsimile specimen received over the circuit which demonstrates the potentialities of this method of transmission for handling black and white sketches. Incidentally, the diagram of Fig. 1 was transmitted over the circuit from Philadelphia to New York.

At the present time, the New York-Philadelphia relay circuit is in operation 16 hours per day. Commercial traffic is regularly handled in both directions on the Printer Channels. The facsimile channels are operated experimentally. No definite date has been set as yet for offering the facsimile service to the public.

RCA TELEVISION FIELD TESTS

By

L. M. Clement and E. W. Engstrom

RCA Manufacturing Co., Camden, N. J.

FOR more than ten years RCA has been conducting research work directed toward application of television. This research has passed through many stages, beginning with early mechanical arrangements and developing to the present electronic system. In this step-by-step program, many new devices have been evolved—among them, the "Iconoscope" and the "Kinescope." Effort has been directed toward performance having lasting value and this has required studies of image characteristics, program possibilities and apparatus considerations. Execution of such a program on a logical, coordinated basis requires adequate practical tests from time to time. RCA has conducted several field tests to determine status and to indicate the course for further development, and is now beginning experimental operation of a system for another field test.

1931-32 Field Test

During the early part of 1931 it was decided to make practical tests on a cathode ray television system of the type being developed by the research organization of RCA. This project was entirely experimental in nature, but was so directed as to obtain operating conditions as nearly as possible in keeping with probable television broadcast service. The location chosen for these tests was the metropolitan area of New York. The studio and transmitter equipment was located in the Empire State Building with the antenna structures at the very top. Apparatus for this project was completed and installed during the second half of the year. Operation tests followed, continuing through the first half of 1932.

The equipment used for these experimental field tests was in keeping with the status of television development at that time. Two radio transmitters were used, one for picture and the other for sound. These were operated in the experimental television band, 40 to 80 megacycles. The picture and sound transmitters were widely separated in frequency to simplify the apparatus requirements. One hundred and twenty-line progressive scanning was used. The limit of 120 lines was established mostly by the signal-to-noise ratio for direct studio pick-up. The frame frequency was 24 per second. This was chosen so as to provide adequate continuity of action for objects in motion for studio programs, and to enable the use of standard motion picture film for film subject material. Synchronization was automatically maintained at the receiver by transmitted synchronizing impulses, one impulse for each line and one impulse for each picture frame. The line and frame impulses differed in character. "Mechanical" scanning equipment was used in the transmitter for both studio and film subjects.

The television receiver consisted essentially of two channels, one a receiver for picture with its cathode ray tube and associated circuits, and the other a receiver for sound with its usual loud speaker. Independent tuning arrangements were provided for each channel. The cathode ray tube was mounted in a vertical position and the reproduced image viewed in a mirror mounted on the inside of an adjustable top lid of the cabinet.

After the apparatus had been installed and placed in operating condition, practical tests followed. These tests were varied in nature and were intended to be as comprehensive as possible. A propagation study was made in the metropolitan area of New York. An analysis was made of electrical "noise" disturbances, sources of this "noise," and the resulting effect on television performance. Experience was obtained in the use of the terminal and radio transmitter apparatus which indicated existing limitations and conditions to permit greatest usefulness. Receivers were placed in many locations and the installation and operating problems were studied. Reactions of many observers were obtained.

Much valuable engineering information was obtained as a result of this project. An opportunity was available to design and construct apparatus for a complete experimental television system. Indications were obtained regarding the possibilities and limitations of the apparatus. Extensive operating data were accumulated. The project provided further insight and it broadened the perspective on that rather intangible factor "satisfactory television performance." An analysis of the experience and engineering information provided concrete objectives for continued research on television.

Some of the major findings and conclusions are of general interest. The frequency range of 40 to 80 megacycles was found well suited to television transmission. The greatest source of interference was from ignition systems of automobiles and airplanes, electrical commutators and contactors, etc. It was sometimes necessary to locate a favorable spot for the receiving antenna with regard to signal and sources of interference. For an image of 120 lines the motion picture scanner gave satisfactory performance. The studio scanner was adequate for only small areas of coverage. In general the studio scanner was the item which limited the program material most seriously. Study indicated that an image of 120 lines was not adequate unless the subject material from film and especially that from studio was carefully prepared and limited in accordance with the image resolution and pick-up performance of the system. To be satisfactory, a television system should provide an image of more than 120 lines. The operating tests indicated that the fundamentals of the method of synchronizing used were satisfactory. The superiority of the cathode ray tube for image reproduction was definitely indicated. With the levels of useful illumination possible through the use of the cathode ray tube, the image flicker was considered objectionable with a repetition frequency of 24 per second. The receiver performance and operating characteristics were in keeping with the design objectives.

1933 Field Test

The previous field tests indicated many of the objectives for continued research in the laboratory. In order to make practical tests on the next stage of television research, a complete system was built in Camden and operated during the first several months of 1933.

In the New York tests the major limitation to adequate television performance was the studio scanning apparatus. This consisted of a mechanical disk, flying-spot type, for an image of 120 lines. Even for small areas of coverage and for 120 lines, the resulting signal amplitude was unsatisfactory. In the Camden system, an "Iconoscope" was used as the pick-up device. The use of the "Iconoscope" permitted transmission of greater detail, outdoor pickup, and wider areas of coverage in the studio. Experience indicated that it provided a new degree of flexibility in pickup performance, thereby removing one of the major technical obstacles to television.

The picture characteristics for this experimental television system included 240-line progressive scanning, 24 frames per second. The choice of 240 lines was not considered optimum, but all that could be satisfactorily handled in view of the status of development.

In the earlier New York tests the picture and sound transmitters were widely separated in frequency to simplify apparatus requirements. In our analysis of television systems, it had been judged desirable that there be two transmitter carriers, one for picture and one for sound. It had further been concluded that the picture carrier should include the *video* signal, synchronizing impulses, etc. On this basis, the problem of television reproduction requires the reception and utilization of two transmitted carriers with their respective modulations (one for *video* and control signals and the other for sound), without interference from each other and without interference from other television stations. These considerations plus a study of station allocation in a national system, receiver design and tuning problems, and other related factors, indicated that the two carriers for one station should be adjacent, with their spacing being dependent upon image detail, and transmitter and receiver selectivity characteristics. For these tests it was assumed that a television channel for picture and sound should be 2,000 kilocycles wide and that the picture and sound carriers should be spaced by 1,000 kilocycles. This particular channel width and carrier spacing were not decided as optimum, but rather

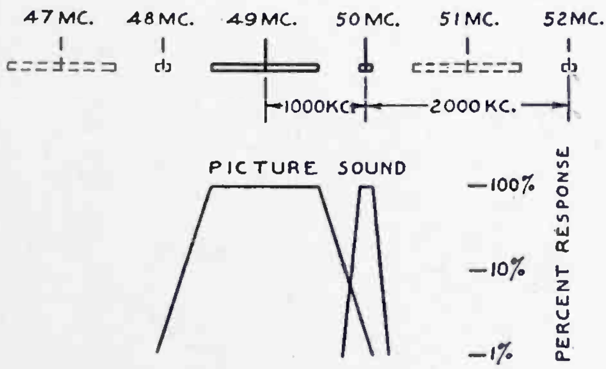


FIG.1-OVER-ALL TRANSMITTER AND RECEIVER SELECTIVITY CHARACTERISTICS

Figure 1.

as practical limitations for the tests. The picture carrier was at 49,000 kilocycles and the sound carrier, 50,000 kilocycles. Diagrammatically, a television channel of this type is shown in Fig. 1.

Since the tests were essentially for the purpose of obtaining experience with the system fundamentals and with the terminal apparatus, the picture and sound transmitters had nominal outputs. The two transmitters were located in one of the RCA buildings in Camden and the antennas on masts above the building. The studio and control apparatus were located in another building about 1,000 feet direct-line distance from the building housing the transmitters. Most of the receiving tests were made at a point four miles from the transmitter.

One of the problems in television is to provide facilities for program pick-up at points remote from the studio and transmitter. In this experimental system a pick-up point was located approximately one mile from the studio. Here an outdoor program was televised and relayed by radio to the main studio and transmitter. Figure 2 illustrates the Camden system.

Another problem in television is to tie groups of stations together for network service. The interconnecting link might be either a special land wire or radio. In this experimental system, tests were made on

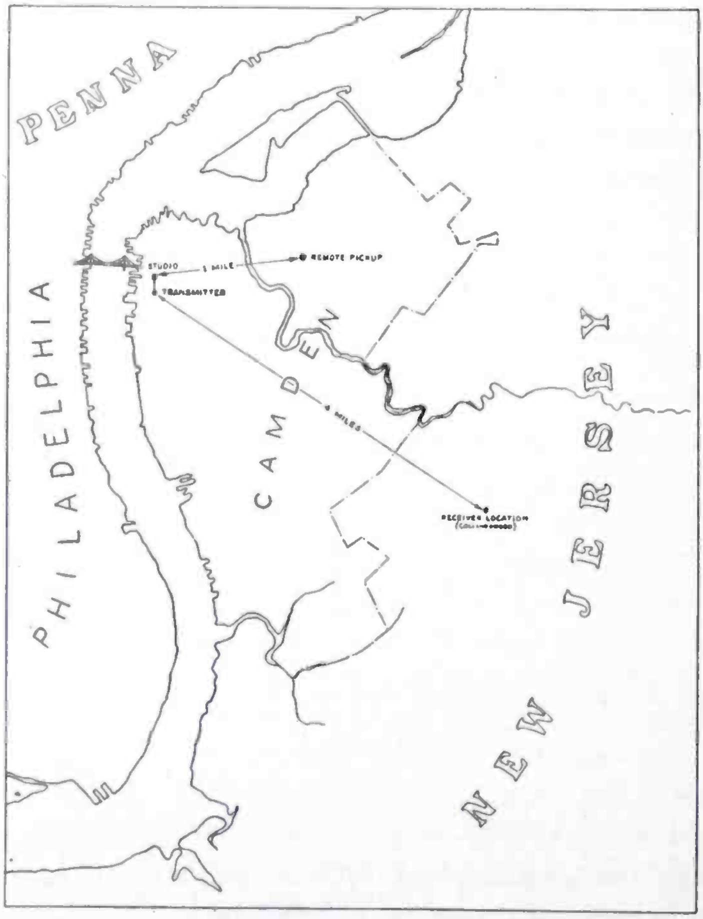


Figure 2.

radio relaying of television programs between New York and Camden. A program originating in the Empire State Building studio was transmitted by radio, relayed at an intermediate point, received and broadcast in Camden. For these tests 120-line scanning was used, since this was the standard for the New York equipment. Figure 3 illustrates the complete system.

The increase of image detail (from the New York tests—120 to 240 lines) widened very considerably the scope of the material that could be used satisfactorily for programs. Experience with this system indicated that even with 240 lines, more image detail was desired for much of the program material. The desire was for both a greater number of lines and a better utilization of the detail capabilities of the system and lines chosen for the tests. The "Iconoscope" type pick-up permitted a freedom in subject material and conditions roughly equivalent to motion picture camera requirements.

As in the New York tests, much valuable experience was obtained in constructing and placing in operation a complete television system

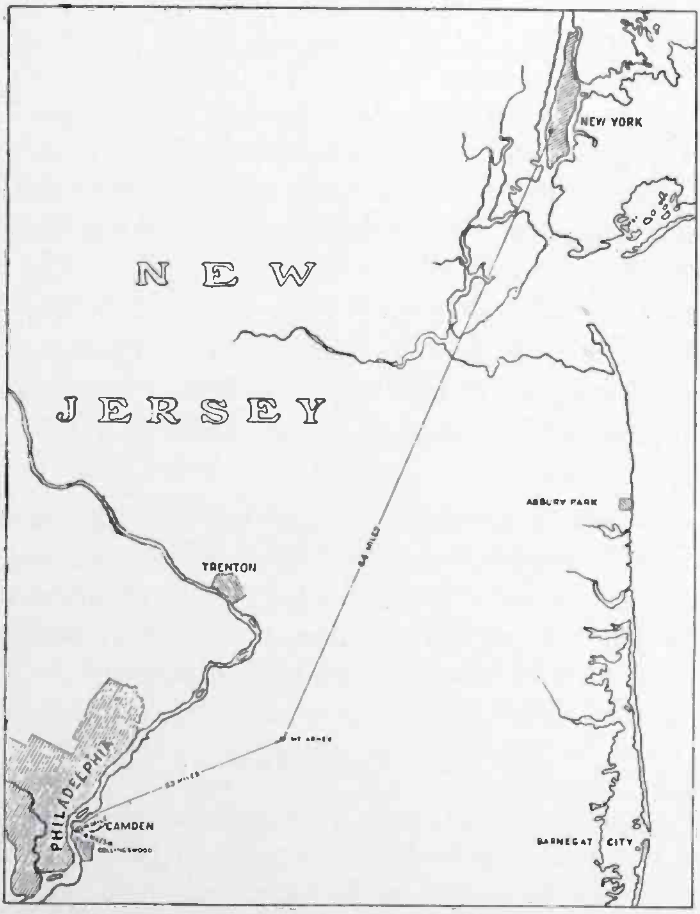


Figure 3.

having standards of performance abreast of research status. Estimates of useful field strengths were formulated. The need for a high power television transmitter was indicated. Further studies were made of interference caused by automobile and airplane ignition systems. Consideration was given to receiver antenna problems. Technical and lay opinion was obtained on receiver operation, image characteristics, and entertainment possibilities. Some work was done on program, studio, and pick-up technique. Again the tests indicated directly, or as a result of analysis, the objectives for further research.

1934 Field Test

In order to make field tests on further advances as worked out in the laboratory, an improved system was set up in operation in Camden during 1934. Since the major items under test related to terminal apparatus, low power transmitters were used. Scanning lines per frame were increased to 343. Previous field tests and laboratory work had indicated the seriousness of flicker at frame frequencies in the order of 24 per second. For these field tests interlaced scanning was used—a frame frequency of 30 per second and a field frequency of 60 per second. Former systems tested made use of a mechanical-optical synchronizing generator. With the increase in number of scanning lines, with the requirement of extreme accuracy and with the need for fairly complicated waveshapes, an electronic synchronizing generator was developed and used. This removed the last mechanical element from the system.

The tests that followed gave further evidence of the desirability of an all-electronic system. The effectiveness of interlacing as a solution to the problem of flicker was conclusively demonstrated. The increased number of scanning lines permitted further flexibility in program possibilities.

As the next step a development program was undertaken on relatively high power transmitters. The outstanding technical characteristic of television is the very wide range of modulation frequencies. This development of higher powered transmitters resulted in the design used in the field test about to be undertaken.

1936 Field Test

During the early part of 1935 RCA explored the possibilities of a further field test so that subsequent steps might be based on additional experience. It was decided to make additional field tests. Operating standards were chosen which were in keeping with apparatus considerations and which were adequate for the field test determinations. The essential items are:

(1) Number of Lines 343
(2) Frame Frequency .... 30 per second
Field Frequency .... 60 per sec. (interlaced)
(3) Aspect Ratio 4:3
(4) Picture Carrier .... 49,750 kc
Sound Carrier .... 52,000 kc
(5) Channel Width .... 4,000 kc
(6) Polarity of Transmission .... Negative

A brief description of the system follows. Provision is made for studio and motion picture film programs. An NBC sound studio at Radio City has been adapted for television. Three studio cameras using "Iconoscopes" have been provided together with three *video* channels and the necessary control and monitoring facilities. Apparatus flexibility has been included so as to permit varied experimentation with programs and lighting.

Two special motion picture projectors and "Iconoscope" cameras for use with these projectors provide for continuous programs from 35 mm. film.

A common generator of synchronizing impulses supplies the entire system. The composite *video* and synchronizing signals are made suitable for transmission by line amplifiers and control units. There are two means of sending these signals to the transmitter, one by cable and the other by radio relay. The radio relay operates at a frequency between 150 and 200 megacycles. The relay transmitter and receiver antennas are directive arrangements and are so positioned as to have an unobstructed transmission path.

The picture and sound transmitters are located on one of the top floors of the Empire State Building. Provision is made for supplying the *video* transmitter with signals from the cable and the radio relay. The transmitters have outputs of approximately 7.5 kilowatts, the picture transmitter operating at 49.75 megacycles and the sound transmitter at 52 megacycles. The two transmitter outputs feed through coupling filters to a single transmission line which runs to the top of the building. A single radiating structure is used having a power gain of approximately two through concentration in the vertical plane. This structure provides a circular pattern in the horizontal plane having horizontal polarization.

The receivers used in this field test are superheterodynes having a tuning range of 42 to 84 megacycles, capable of receiving both sound and picture simultaneously.

The head-end circuits are broad enough to accept both carriers and one picture side band. A single oscillator heterodynes both carriers. The intermediate frequencies thus produced are therefore separated in frequency by the same number of kilocycles as the transmitted carriers were separated, namely 2,250 kilocycles.

Separation of the sound and picture signals is accomplished in the intermediate amplifiers. The sound intermediate amplifier is relatively sharp and the picture intermediate amplifier relatively broad to pass the picture carrier and one sideband, and their pass bands are so spaced that when the sound is properly tuned the picture is also properly tuned.

The sound side of the receiver is more or less conventional. The intermediate amplifier is broader than is customary for a simple sound receiver. Following the sound intermediate amplifier are the audio detector, automatic volume control and audio amplifier, all designed to give high fidelity reproduction.

Following the picture intermediate amplifier are the detector and automatic volume control (which is independent of the sound AVC). From the detector the *video* signal is impressed on two amplifiers, one for the *video* signal to the "Kinescope" grid and the other to the synchronizing separating circuits for separating out the synchronizing impulses and impressing them on their respective scanning oscillators.

The *video* amplifier is designed to pass the *video* frequencies in the required range of approximately 60 to 1,500,000 cycles, with proper regard to amplitude, phase shift, transient response and signal polarity. This amplifier contains the contrast (or volume), detail and automatic background controls and circuits.

The synchronizing amplifier separates the synchronizing signals from the composite *video* signal by means of amplitude selection, separates horizontal and vertical synchronizing signals from each other by means of frequency selection, and delivers the impulses to the respective deflecting oscillators in proper amplitude and polarity for synchronization.

Each of the deflecting circuits consists of a blocking oscillator for generating synchronous impulses of large amplitude, a discharge tube circuit for generating the saw-tooth scanning voltage, and output amplifier tubes for supplying the saw-tooth current wave to the deflecting coils. Deflection, vertically and horizontally, is electromagnetic.

The television image is formed on the luminescent screen of a "Kinescope" 9″ in diameter, with an image size approximately 5½″ x 7¼″.

The receiver operates from the usual 110-volt 60-cycle line. One rectifier system supplies voltage to all tubes in the receiver except the "Kinescope," whose anode voltages are supplied by separate rectifiers. The receiver uses 33 tubes including the "Kinescope."

It is intended that these receivers will be used with an antenna which is a horizontal dipole.

MICRO-WAVES IN NBC REMOTE PICK-UPS

By

Robert M. Morris

Development Engineer, National Broadcasting Company

The National Broadcasting Company in its efforts to best serve the public interest has constantly endeavored to take its microphones to more and more remote points. To do this has required the use of radio to an increasing extent. In many cases wire lines have not been available in time to do the job. In other instances the very nature of the pick-up point (ship, airplane, balloon, etc.) has necessitated the use of radio circuits. Radio apparatus for these special events or spot news broadcasts has in general fallen into two classifications; first, portable units of from 10 to 100 watts and second, self-contained pack-sets of less than 1 watt, and light enough to be carried by one person. The extreme mobility of this latter type of equipment has made it of special interest for unusual or difficult broadcasts.

THE first example of a micro-wave portable transmitter was a pack-set designed and constructed by NBC in 1929 and used for the first time by Floyd Gibbons at Lakehurst, N. J. in describing the arrival of the Graf Zeppelin. This set operated on a rather low frequency and necessitated a long single wire antenna as shown in Figure 1.

The possibilities of units of this type sufficiently impressed the Navy officials and engineers of RCA Victor who witnessed the tests as to cause the development by RCA Victor of a transmitter of similar size and weight but designed to operate on approximately eight meters. This permitted a great reduction in size of antenna and provided the first entirely independent "walking transmitter". One of these pack-sets was obtained in 1930 by NBC and is shown in Figure 2 in use for broadcasting a golf match. This work marked the beginning of development in the ultra-high frequency region tending toward actual application of these wavelengths to commercial requirements.

In 1932, after the conduct of innumerable propagation tests under operating conditions, design of an improved "pack" transmitter was started by NBC. This unit incorporated in its design many lessons learned in the field tests. For example, it was of course desirable to reduce antenna size as much as possible and yet retain antenna efficiency. It was attempted therefore to operate on frequencies at the upper limit of tube efficiency at that time or approximately 60 to 70 megacycles. In preparation for the broadcast of arrival of certain flyers at Floyd Bennett airport a test was made quite successfully on these frequencies a day or so in advance. At this time the field was essentially clear of both planes and people. At the time of the flyers' arrival, however, a great crowd was present on the field. Signals from the pack-set which during the test had been 100 per cent were now so attenuated and so variable in intensity as to be practically un-

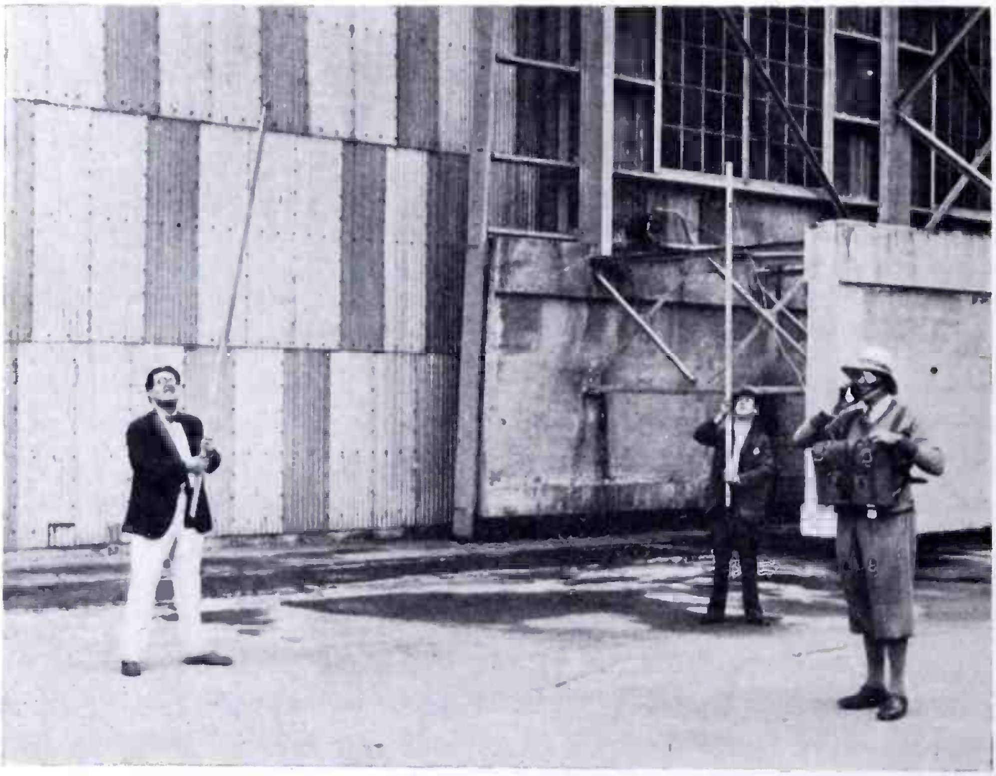


Fig. 1—Original NBC pack-set testing at Lakehurst, N. J. preliminary to arrival of Graf Zeppelin, August, 1929.

usable for the broadcast. It was found that this serious limitation in the utility of the pack-set could be overcome satisfactorily by a compromise between operating frequency, with its corresponding attenuation, and antenna efficiency. Frequencies in the order of 30 to 40 megacycles with antennas of slightly over one-eighth wavelength long proved to be the best combination from an operating standpoint. One of the improved pack-sets is shown in Figure 3. The range of these sets is nominally considered about one mile. Favorable conditions will however permit satisfactory transmission over greater distance. Pack-set transmission from the top of the City Bank-Farmers Trust Building in lower New York have been received with excellent signal strength and quality in Millburn, New Jersey, a distance of fifteen miles.

With the development by RCA Radiotron of the "acorn" tube, now the 955, previous limits were materially advanced. Where previous triodes were temperamental above about 75 megacycles, the new acorn tube would operate with good stability at 300 to 400 megacycles. This of course opened new horizons in the way of reduction of transmitter and antenna size although in view of our experience with variation in attenuation under working conditions it was unlikely that favorable results would be readily obtained.

Fig. 2—1930 model pack-set in use for broadcast of American Open Golf Championship Tournament. Note antenna, approximately quarter wave, bent in form of loop.

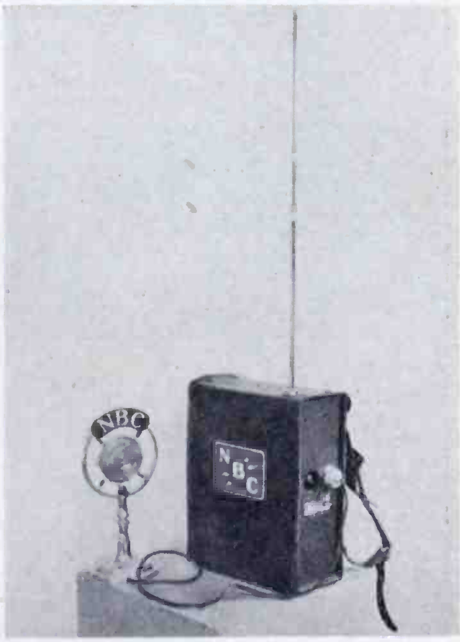


Fig. 3—Standard NBC ultra-high frequency pack-set.

In 1934 work was started on the miniature transmitter shown in Figure 4 designed for preliminary propagation tests on approximately 300 mc. The transmitter was encased in a 3 inch aluminum cube and incorporated a 955 tube in a tuned-plate tuned-grid circuit. An inductively coupled output circuit was arranged to feed either a dipole antenna or a transmission line to any desired antenna array. Modulation and power were externally supplied. During that summer extensive propagation tests were conducted with both non-directive antennas and directive arrays. In general, working between points on the ground, attenuation was found to be quite high and transmission to follow accepted line of sight theory. Interference phenomena were observed due apparently to multiple paths created by reflections from the ground and nearby buildings. Persons moving through the transmission field had a marked effect on received signals particularly when near either the transmitter or receiver.

More recently and as a result of cooperative development by the NBC and the National Carbon and Burgess Battery Companies, unusually light and efficient batteries have made possible some interesting advances in this field.

The hand transmitter shown in Figures 5 and 6 is a recent development in which are incorporated as an integral part of the unit the RF oscillator, modulator, microphone, and antenna. Power supply only, is external. The use of tuned lines in the grid and plate circuits

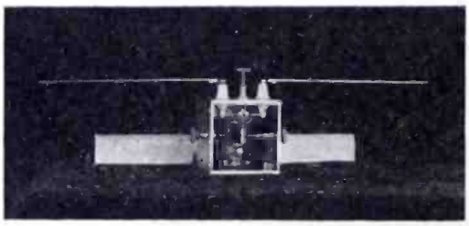


Fig. 4—300 megacycle oscillator for propagation measurements.

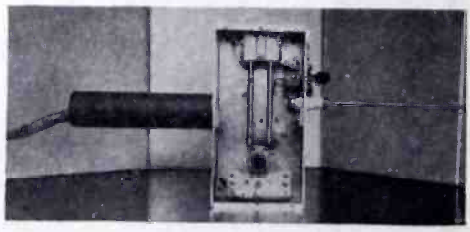


Fig. 5—Interior of handset type transmitter—320 megacycles.

provided the requisite degree of frequency stability and considerably improved efficiency at the operating frequency of 320 megacycles. This unit has been used for most of our more recent tests and has provided much interesting information from an operating standpoint. A schematic diagram is shown in Figure 7. At a plate potential of 135 volts, the RF oscillator plate current is approximately 4 milliamperes. The power in the antenna is approximately 0.2 watts.

A still more recent type of transmitter is shown in Figure 8. This unit is completely self-contained, including battery supply, microphone, modulator, oscillator and antenna, and weighs only six pounds. The physical size is about that of the conventional condenser microphone and amplifier widely used in broadcasting studios. It is believed that equipment of this type will prove valuable for transmission in large halls or enclosures where for any reason installation of wire circuits is not expedient.

Probably the most dramatic application of these miniature transmitters thus far is the "Top Hat" shown in Figure 9. This was used April 12 for a broadcast of the Easter Parade on Fifth Avenue, New York. The radio frequency portion of the transmitter is mounted inside the hat with the antenna projecting upward through the top. Battery supply and modulator are carried in a leather belt fastened around the announcer's waist. A pictorial layout is shown in Figure 10.

The problem of power supply for these very small transmitters is of course a very real one if weight and operating time are to be kept within practical limits. As previously mentioned, considerable aid has been received from the leading battery manufacturers in the solution of this difficulty. It is customary to build batteries to have a

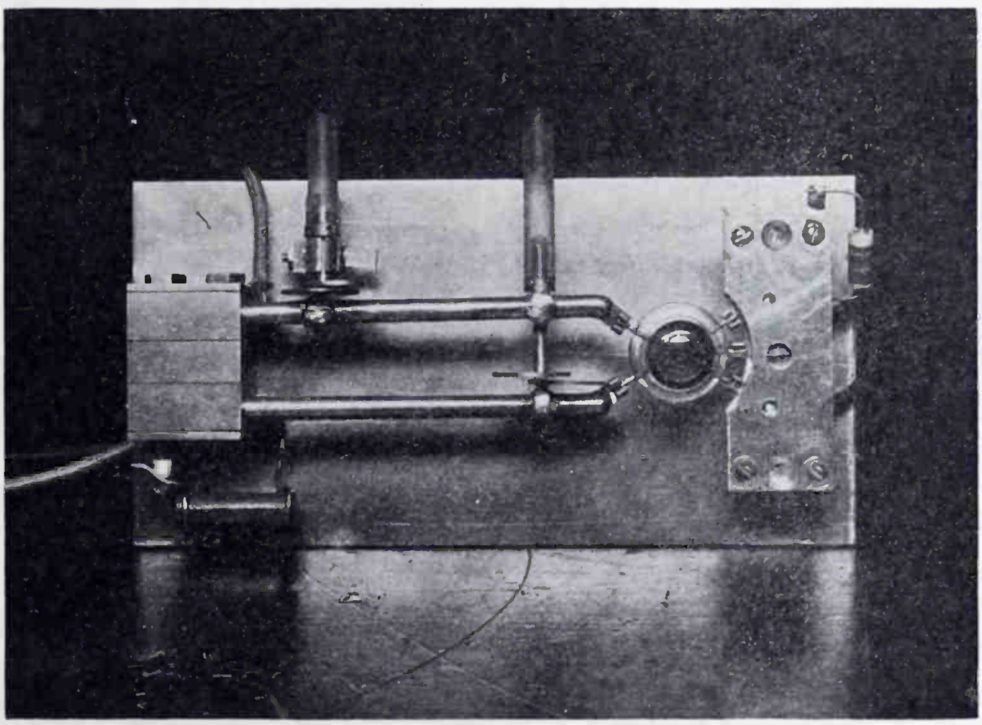


Fig. 6—Close-up of radio frequency unit.

shelf life of nine to twelve months. However, it is possible, by sacrificing shelf life, to increase operating time in a battery of given size and weight, as much as 300 per cent.

Forty-five volt battery units are now being made weighing a little over eight ounces and having dimensions of three and one-half inches in height, two and three-quarters inches in width, and one and one-eighth inches in thickness. On a constant load of ten milliamperes these units will give continuous service of nearly eight hours to a cut off voltage of forty volts.

Remarkable as this battery may be, it is interesting to note that a still smaller unit is in the process of development.

Reception of signals from the "Microwave" transmitters has been most readily accomplished using the super-regenerative type receiver. It has proved especially suitable because of its simplicity, high sensitivity and inherent automatic volume control action. One of the most serious problems encountered in reception of 300 megacycle signals was found to be extreme variations of signal strength due to interference effects. These variations, when using low power, were found

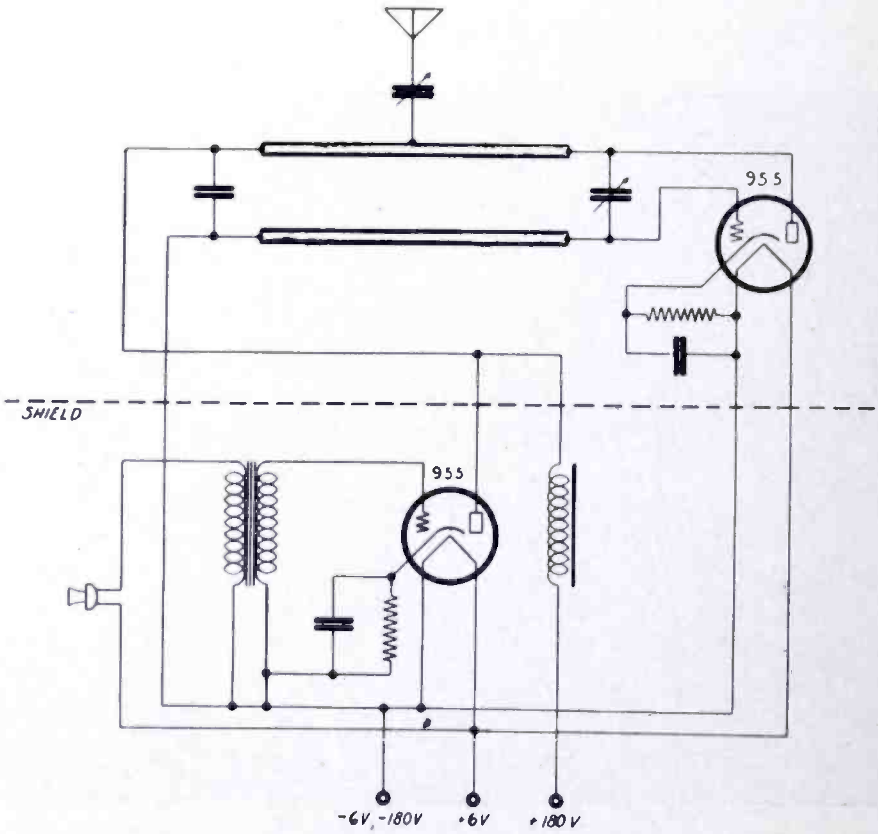
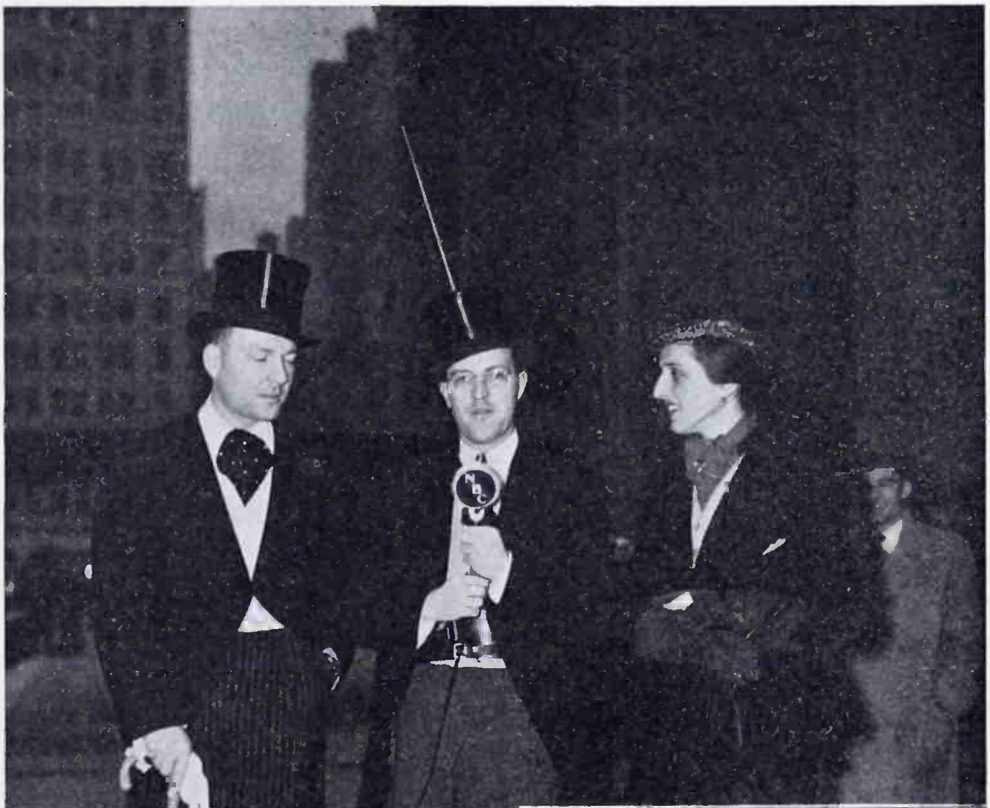
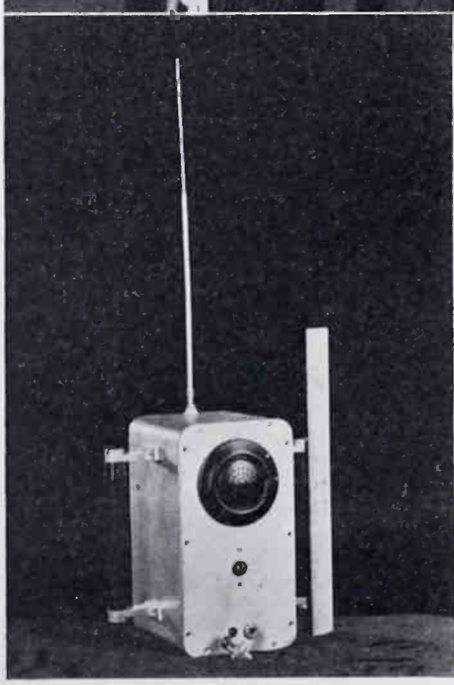


Fig. 7—Handset microwave transmitter schematic diagram.

to be beyond the range of control of the normal receiver at distances of more than a few hundred feet. This condition is particularly aggravating because moving the antenna only a few inches will bring in the signal again. As rapid physical movement of the antenna is obviously impractical, methods for effectively moving the antenna by electrical means are being investigated. Experimental work in progress along this line appears very promising.

An interesting fact which has been observed is that interference, both man-made and natural, is almost totally absent at wavelengths of one meter. Automobile ignition, which is so much in evidence on 30 to 40 megacycles is observed only in isolated cases on 300 mega-





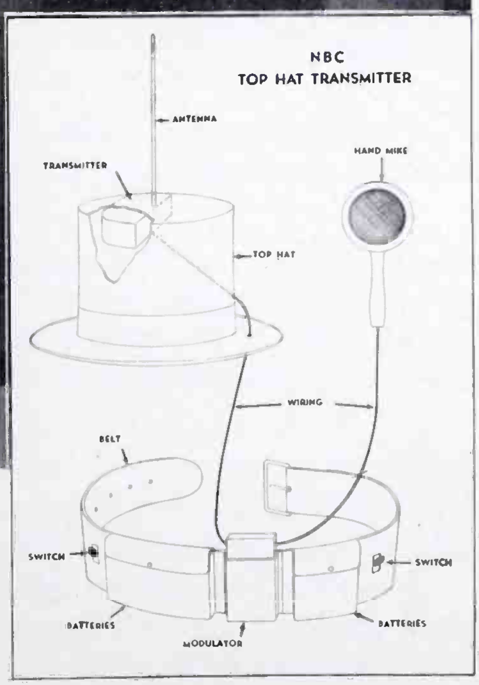


Fig. 8—Radio "Top Hat" being used for broadcast of Easter Parade.
Fig. 9—Completely self-contained 300 megacycle transmitter.
Fig. 10—Diagram of "Top Hat" transmitter.

cycles. Natural static seems to be entirely absent and even the so-called "shadow" or diathermy machine interference, so annoying on lower frequencies, has yet to be observed. Tests were made recently in New York, receiving at the Empire State Building, which indicated the possible importance of these favorable factors. Signals of good quality and low noise level were received from a transmitter having 0.7 watts plate input as far as 110th Street, a distance of about 3 miles. Signals have been received to a maximum distance of nine miles although the transmission was "spotty". Non-directive antennas for both transmitter and receiver were used for this work.

Whether transmitters of the type herein described will prove to be the predecessors of highly portable units applicable to personal point-to-point communication is, of course, impossible to tell. It is likely, however, that in the comparatively near future, many services will find wavelengths of 1 meter to be the answer to problems of interference or crowding on lower frequencies.

Acknowledgment

Much credit is due Messrs. C. P. Sweeny, R. A. Lynn, J. L. Hathaway, and W. C. Resides of the NBC Laboratory for work recorded in this paper.

SOUND REENFORCING SYSTEMS

BY

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INTRODUCTION

DURING the past few years the frequency and volume ranges of sound reproducing equipment have been improved to such an extent that sounds may now be augmented and reenforced with an increase in realism and artistic effects. A brief discussion will be given of the situations where sound reproducing systems are employed to augment original sounds.

The theatre which suffers mostly from insufficient speech loudness is, of course, the very large enclosed theatre and the open-air theatre. Further, in certain instances, the volume range of an orchestra is inadequate to render full artistic appeal, or to utilize the full capabilities of the hearing range. In these cases means are required for augmenting the intensity of the original sound. The systems for accomplishing this objective have been termed sound reenforcing systems.

For large outdoor gatherings, such as state occasions, athletic events in large stadiums and parks, sound reproducing systems are employed to amplify the speaker's voice.

In department stores, hotels, hospitals, schools, and factories, sound reproducing systems are employed to transmit sound from a central point to several independent rooms or stations. The systems for accomplishing this objective have been termed, general announce or call systems.

All of the above sound reproducing systems consist of the following components: microphones for colleting the original sound and transforming the impinging sound waves into the corresponding electrical waves; vacuum tube amplifiers for raising the electrical signal from the microphones to a level suitable for driving the loud speakers; and loud speakers for converting the electrical waves back into sound waves.

It is the purpose of this paper to describe sound reenforcing, public address, and general announce systems, together with the arrangement and characteristics of the components used in these systems.

Sound Reenforcing Systems

A large theatre equipped with a sound reenforcing system is shown in Figure 1. Microphones are concealed in the footlights for collecting the sound on the stage and others are placed in appropriate positions in the orchestra. The loud speakers are located above the

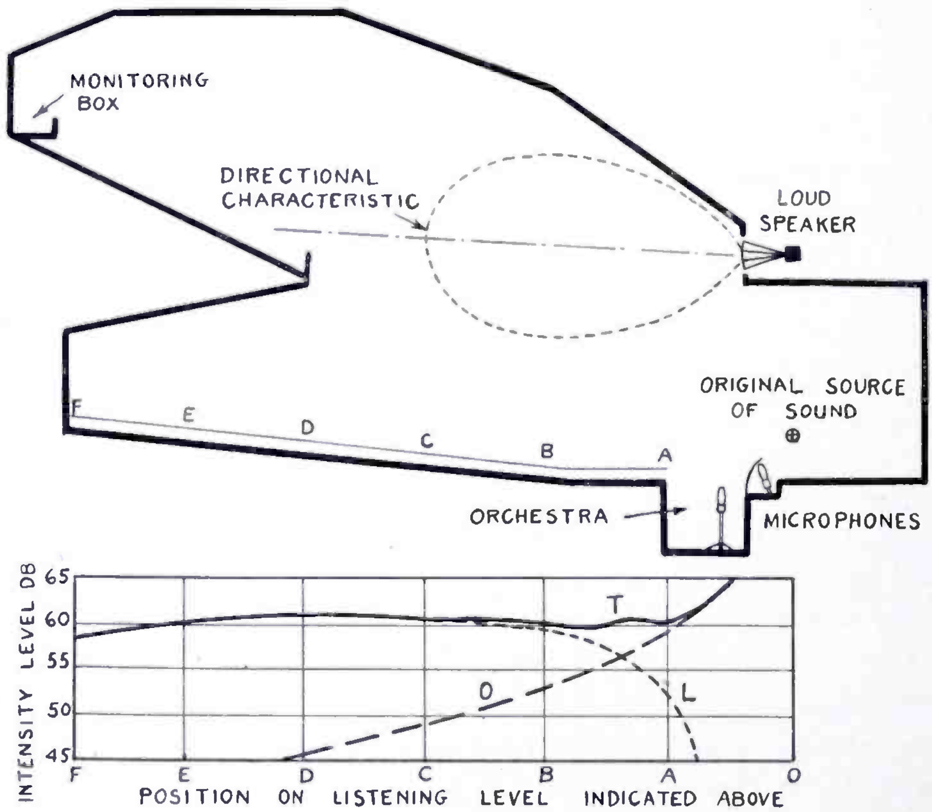

Figure 1
Arrangement of the components of a sound reenforcing system in a theatre. The graph shows the intensity level at the points indicated on the orchestra floor; Curve O, the intensity level due to the original source of sound; Curve L, the intensity level due to the loud speaker; Curve T, the resultant intensity level.

stage in the proscenium arch. The volume control and microphone mixing system is usually located in a box or booth in the balcony.

In this system there are two sources of direct sound, namely; the original sound and the augmented sound from the loud speakers. Usually the intensity of the original sound issuing from the stage will be quite satisfactory in the orchestra floor near the stage and as a consequence it is not necessary to augment the sound in this portion of the theatre. As the distance from the stage increases the original sound intensity decreases. To make up for this loss the sound energy from the loud speakers must progressively increase towards the rear of the theatre. This may be illustrated by the analysis which follows.

Consider the system shown in Figure 1. If the distance between the source of the original sound and the point of observation is D centimeters, the energy density, ergs per cubic centimeter, due to direct sound is

$$E_{D1} = \frac{P_{D1}}{4\pi D^2 c} \quad (1)$$

where P_{D1} = power output of the sound source, ergs per second, and c = velocity of sound, centimeters per second.

The sound intensity, or intensity, may be obtained from the energy density by multiplying it by the velocity of sound. The reference intensity for intensity level comparisons is 10^{-9} ergs per second or 10^{-16} watts per square centimeter. The intensity level of a sound is the number of decibels above the reference level.

The intensity level on the orchestra floor resulting from a sound source, as, for example, a speaker or singer on the stage, is given by the curve O of Figure 1. It will be seen that the intensity level in the rear of the house is inadequate for good hearing. Of course the generally reflected sound should be added to the direct sound. However, the added intensity is only a few decibels. The above considerations show that it is desirable to augment the original sound. The arrangement and characteristics of the sound reenforcing system should be chosen so that the resultant intensity level, due to direct sound from the combination of the original source and the loud speakers, is the same for all parts of the audience.

From the response frequency characteristic of the loud speaker, the pressure at any distance, r centimeters on the axis may be obtained from the following equation,

$$p = p_0 \frac{x_0}{r} \quad (2)$$

where p_0 = pressure, dynes per square centimeter obtained at a distance x_0, centimeters.

To obtain the pressure for a point not on the axis the above equation must be multiplied by a factor obtained from the directional characteristic at this frequency. The direct radiation from the loud speaker can then be obtained for any point in the space.

The energy density, ergs per cubic centimeter, due to direct radiation from the loud speaker is

$$E_{D2} = \frac{p_0^2 x_0^2 R^{\ \ 2}}{r^2 \rho c^2} \tag{3}$$

where R_θ = ratio of the sound pressure at angle θ to $\theta = O$.
ρ = density of air, grams per cubic centimeter.

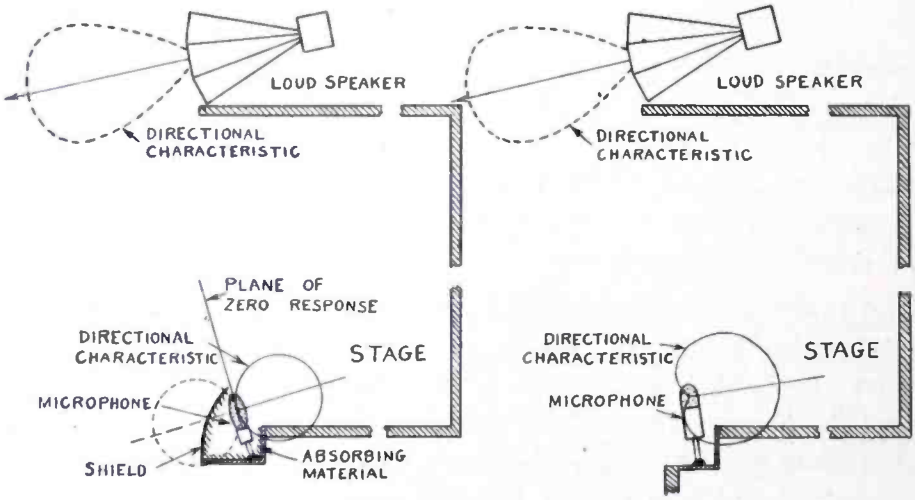

Figure 2

Arrangements depicting the use of directional loud speakers and directional microphones for reducing feedback between the loud speaker and microphone. The arrangement on the left employs a velocity microphone. A shield is used to reduce sound pickup from the orchestra and audience. The arrangement on the right employs a uni-directional microphone. The directional characteristics of this microphone are particularly adapted for collecting sounds on the stage and shutting out sounds coming from the orchestra and audience.

The problem is to select a loud speaker with suitable directional characteristics and then to adjust the power output and orientation so that the sum $E_{D1} + E_{D2}$ of equation 1 and 3 is a constant for all parts of the listening area of the theatre. The intensity level on the orchestra floor, in Figure 1, due to the direct sound from a loud speaker having directional characteristics as shown, is given by the curve *L*. The intensity level due to the combination of the original sound and augmented sound from the loud speaker is shown by curve *T* of Figure 1. The resultant intensity is quite uniform over the orchestra floor. A similar analysis will show that the intensity level in the balcony is also relatively uniform. Further consideration of the characteristic of Figure 1, shows that the total intensity level characteristic remains uniform when the output of the loud speakers, that is the gain in augmented sound, is varied over wide limits.

The energy density,[1] ergs per cubic centimeter, in the theatre due to generally reflected sound is,

$$E_R = \frac{4(P_{D1} + P_{D2})}{caS} \left[1 - \epsilon^{\frac{cS[\log_\epsilon(1-a)]t}{4V}} \right] (1 - a) \qquad (4)$$

where a = average absorption per unit area, absorption coefficient,

S = area of absorbing material, square centimeters,

V = volume of the theatre, cubic centimeters,

t = time, seconds,

P_{D1} = power output of the original sound, ergs per second,

and P_{D2} = power output of the loud speaker, ergs per second.

The aid obtained from reflected sound in a directional sound reenforcing system is relatively small, ranging from 2 to 6 decibels.

The microphones for collecting the sounds are usually concealed in the footlight trough. By employing directional loud speakers, as outlined above, the sound level at the microphones due to the loud speakers is low and thereby reduces the tendency of acoustic feedback or regeneration in the reproducing system. In large theatres, having an expansive stage, the pick-up distance will be very large. Consequently the sound which reaches the microphones from the original source will be small and will require considerable amplification which increases the tendency for feed-back. In cases where difficulties are experienced, due to acoustic feed-back, a further reduction in coupling can be obtained by employing directional microphones.[2] Furthermore, the stage collecting system should not be responsive to sound originating in the orchestra or audience. In case the microphones are located in the footlights the shielding effects of the apron together with a velocity microphone,[3] Figure 2, are in general, sufficient to accomplish this objective. Where it is impossible to shield the microphones in this manner the uni-directional microphone[4, 5] has been found to be very useful as will be seen from a consideration of the directional characteristics of this microphone shown in Figure 2.

In order to "cover" the action from any part of the stage, several microphones are employed, usually spaced at intervals of ten feet. The output of each microphone in the stage and orchestra is connected to a separate volume control on the mixer panel. This mixer and volume control system is located on the monitoring box. By means of this system the operator follows the action by selecting the microphone nearest the action on the stage. The operator also controls the ratio of the volume of the stage sound to that received from the orchestra, when there is orchestral accompaniment, as well as the overall intensity of the augmented sound. The monitoring box is usually located in the rear balcony, the position that is the most

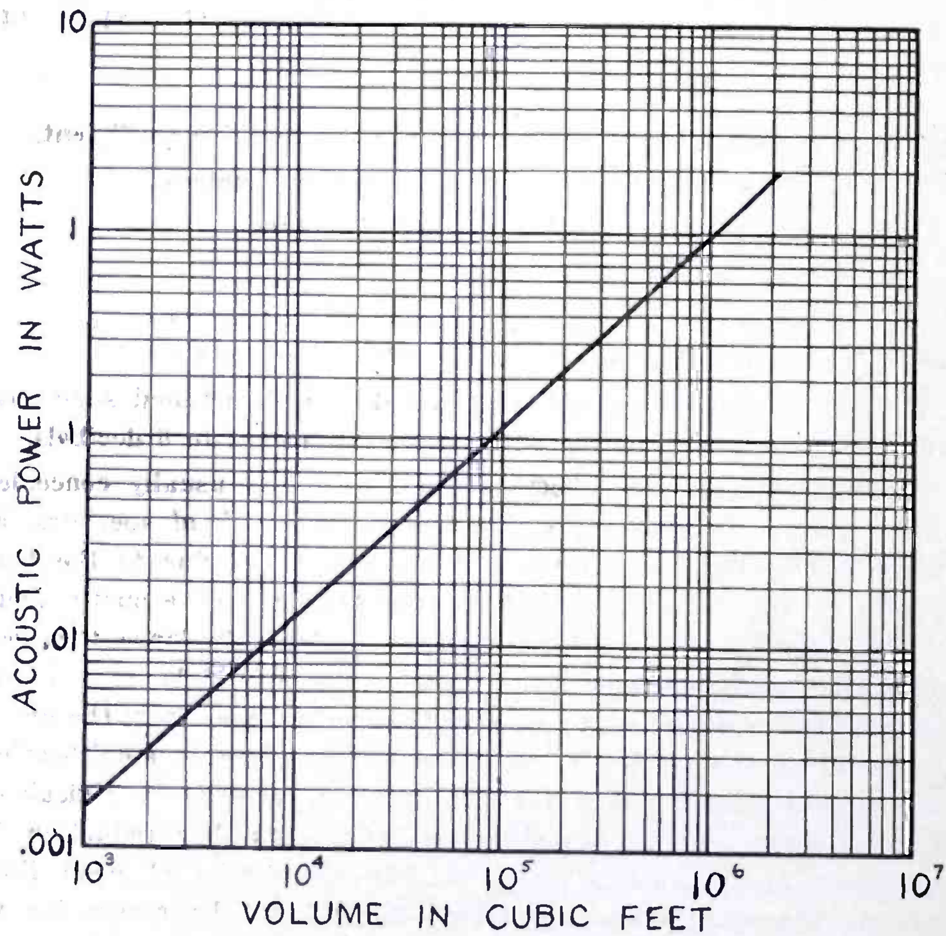

Figure 3
Acoustic power required for an intensity level of 80 decibels as a function of the volume of the auditorium.

susceptible to the augmented sound and one which also furnishes a good view of the action.

The power requirement is another factor in a sound reenforcing system. The minimum intensity which a theatre sound reenforced system should be capable of producing is 80 decibels. The graph of Figure 3 shows the acoustical power required, as a function of volume, in auditoriums to produce a level of 80 decibels. In larger auditoriums, where the orchestra is also reenforced, the power available should be greater. For example, to render full artistic appeal the system should be capable of producing a level of up to 100 decibels. Systems for producing this sound level, without distortion, usually require special amplifiers and loud speakers.

Public Address Systems

The term public address system ordinarily refers to a sound reproducing apparatus for use in addressing large assemblages. There are innumerable specific applications of sound reproducing apparatus for this purpose. The problems in all these situations are practically the same. It is the purpose of this section to consider some typical examples of the use of public address systems.

Regardless of the size of the athletic field or baseball park a public address system is useful for informing those in the stands of what is happening on the field. In general, the chief requirements are as follows: uniform distribution of sound intensity in all parts of the stand, adequate power to override any anticipated noise level of the maximum crowd, and facilities available for microphones at predetermined points.

A large stadium equipped with a public address system is illustrated by the left portion of Figure 4. Due to the size and configuration of the audience area it is practically impossible to obtain satisfactory sound level and coverage with a single loud speaker. Consequently the loud speakers are spaced at intervals, near the boundary of the field, sufficiently close together so that uniform response is obtained in the horizontal plane. The elevation view of Figure 4 shows how uniform sound distribution is obtained in the vertical plane by means of the directional characteristics. The microphones are usually located either on the field or in the press box.

A baseball field equipped with a public address system is illustrated by the right portion of Figure 4. As contrasted to the stadium, here a single loud speaker station is used to supply the entire audience area. The distance between the loud speakers and the auditors is very large. Therefore, the vertical coverage angle is very small, which means that practically any system will have a distribution angle sufficiently broad to supply the required vertical spread. However, for conservation of power the vertical spread of the loud speaker should correspond to the vertical angle subtended by the audience at the loud speaker. Since the distance of those nearest the loud speakers to those farthest removed (that is, considering the vertical angle only) is very nearly the same, the sound intensity from the loud speaker will be practically the same for all parts of the audience through any vertical plane and the use of compensation by means of the directional characteristics for change in distance in the vertical plane to obtain uniform response is not necessary. In the horizontal plane the spread of the loud speaker should correspond to the angle subtended by the stands at the loud speaker. Since the center line is farthest removed, a directional characteristic of the shape shown is necessary for obtaining the same sound level in all parts of the grand stand. To eliminate any difficulties due to feed-back a velocity microphone is used, and oriented so that the plane of zero reception passes through the loud speaker system.

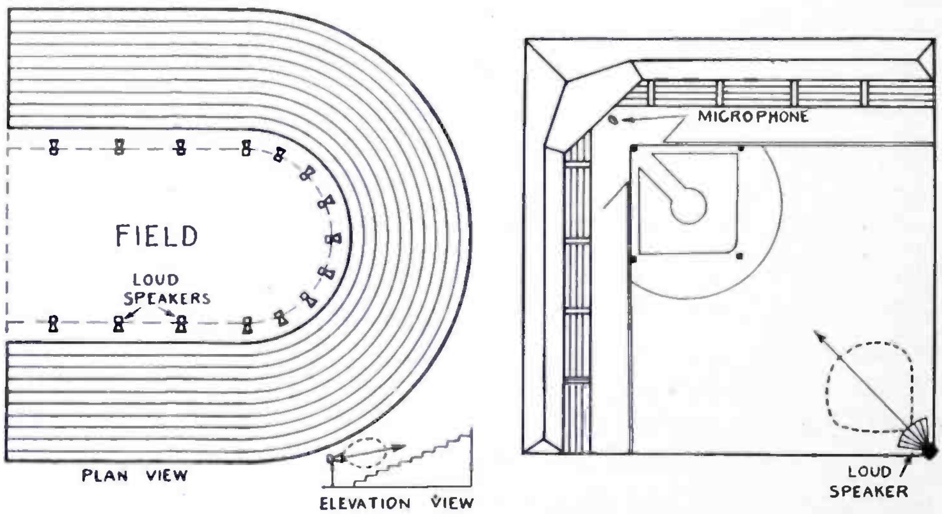

Figure 4

Two arrangements of sound systems for addressing assemblages in large grandstands. For the stadium on the left a large number of loud speakers are used, each loud speaker covering a small portion of the total area. For the ball park on the right a single loud speaker is used to supply the entire grandstand.

The sound level required for public address work of the type considered above will be determined by the noise level of the maximum crowd. In general it is not practical to employ a system with sufficient power to override the sound level during cheering, applause, etc. However, the power should be sufficient to override the general noise during relatively quiet intervals. The noise level may be determined by means of a noise meter. The power available should be sufficient to produce a minimum sound level of 80 decibels, or for very noisy conditions 20 to 30 decibels, above the noise during the relatively quiet intervals. In the two examples cited above, and in fact for all outdoor public address work, the only consideration is direct sound. The problem is to select amplifiers and loud speakers with characteristics which will deliver the required sound level over the distances and areas considered. The steps in the selection of a system may be as follows: First, the directional characteristics should be determined, as outlined in the preceding discussions, so that uniform response is obtained over the audience area. Second, either a single or a group of loud speakers having the desired directional characteristics should be selected. Third, the response characteristic of the system on the axis, at a specified input and distance, should be available to show the amplifier power required to supply the desired intensity level. Fourth, the power handling capacity of the loud speakers and amplifiers should be adequate to supply the required intensity level.

Two types of sound reenforcing installations for an outdoor theatre are illustrated in Figure 5. The system depicted on the left employs

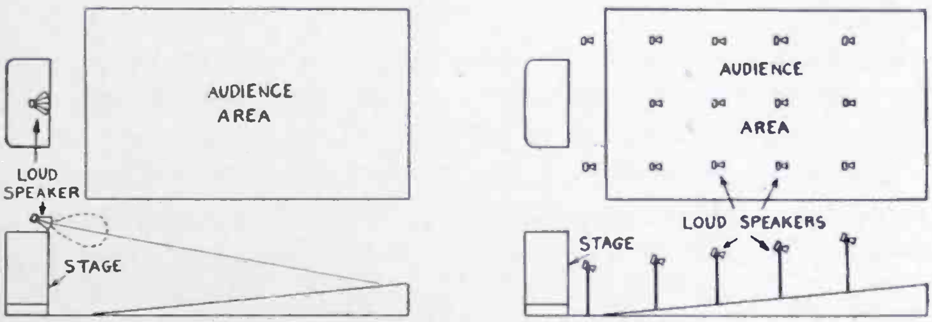

Figure 5

Two arrangements of sound reenforcing systems for an outdoor theatre. The arrangement on the left employs a single loud speaker having suitable directional characteristics to produce a uniform intensity level over the audience area. The arrangement on the right employs a number of loud speakers, each one covering a small portion of the audience.

a single loud speaker station. The same procedure for obtaining uniform sound coverage and adequate intensity level of the direct sound as used in the preceding considerations is applicable in this case. The system depicted on the right employs a large number of loud speakers each one supplying a small portion of the audience. The directional characteristics of the loud speakers should be selected so that each individual area is adequately supplied. Cognizance must be taken of the energy supplied from adjacent loud speakers.

There are certain advantages of each system. In the case of the single loud speaker system better illusion is obtained because the augmented sound appears to come from the stage. On the other hand, the intensity level outside the audience in a backward direction falls off very slowly. At a distance equal to the length of the audience area the level is only 6 decibels lower than that existing in the audience area. In certain locations the sound levels produced by such systems will cause considerable annoyance to those located in the vicinity of the theatre. By dividing the theatre area into small plots, each supplied by a loud speaker, and by directing the loud speakers downward, the sound intensity level outside the audience area will be considerably lower than in the case of the single loud speaker station and usually eliminates any annoyance difficulties. The short sound projection distance is another advantage of the multiple loud speaker system.

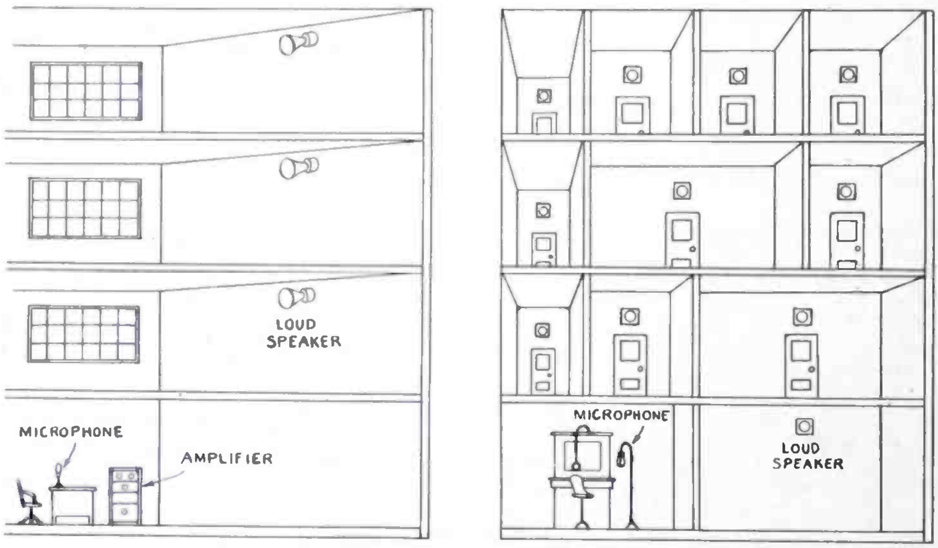

Figure 6

Two uses of call, general announce and sound distributing systems. On the left a high efficiency horn loud speaker is used to obtain a high sound level over a large floor area, as in a factory or a warehouse. On the right small direct radiator loud speakers are used to supply the small rooms at a relatively low level as in paging, announcing and centralized radio installations used in hospitals, hotels or schools.

The above typical examples of outdoor public address and sound reenforcing systems illustrate the principle factors involved in this field of sound reproduction.

General Announce and Paging Systems

General announce systems are useful in factories, warehouses, railroad stations, airport terminals, etc. A typical installation is depicted on the left portion of Figure 6. For this type of work intelligibility is more important than quality. The deleterious effect of reverberation upon articulation can be reduced, and a better control of sound distribution can be obtained, by reducing the low frequency response of the system. Furthermore, the cost of the amplifiers and loud speakers is also reduced by limiting the frequency range. To find the power required the sound intensity level under actual operating conditions should be determined. The system should be designed to produce an intensity level 20 to 40 decibels above the general noise level. Under no conditions should the system be designed to deliver an intensity level of less than 80 decibels. The loud speakers should be selected and arranged, following analysis similar to that outlined in the preceding sections, so that uniform sound distribution and adequate intensity levels are obtained.

For certain types of general announce, paging, and sound distributing installations, as is used in schools, hospitals, department stores, hotels, etc., the intensity level required is relatively low and the volume of the average room is usually small. For most installations of this type, save in noisy locations, an intensity level of 70 db. is more than adequate. Higher intensity levels tend to produce annoyance in adjacent rooms. From a consideration of the data of Figure 3 it will be seen that the power requirements for the loud speakers will be small. To blend with the furnishings of the room it is desirable to mount the loud speaker flush with the wall surface. Therefore for these applications a direct radiator loud speaker of the permanent magnet dynamic or magnetic type is most suitable. In this connection it should be mentioned that these loud speakers have a very low efficiency, being of the order of 1% as compared to 25% to 50% for horn loud speakers.

For large rooms requiring large acoustic outputs it is more economical to use a high efficiency loud speaker and effect a corresponding reduction in the power amplifier requirements. On the other hand, for an installation of the type depicted on the right side of Figure 6 and requiring a large number of units, it is more economical to use relatively inefficient low cost loud speakers and correspondingly larger amplifiers.

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ICONOSCOPES* AND KINESCOPES** IN TELEVISION

By

V. K. Zworykin

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TWO extremely important elements in any television system are the pickup device which converts the light image into electrical signals, and the viewing arrangement transforming the electrical signals back into visible images. In fact, the success or failure of a television system depends perhaps more on these two links than on any other part of the chain. In its present project RCA Manufacturing Company is using the Iconoscope and Kinescope for dissecting and resynthesizing images, and it is the purpose of this discussion to explain the operation of these instruments and point out the reasons for selecting them over other devices designed to serve as pickup and viewing equipment.

Historically, the development of any form of television had to await a means of converting a light signal into a corresponding electrical impulse. This step became possible through the discovery of the photoconductive properties of selenium in 1873. Within two years after this discovery, Carey proposed to make use of the properties of selenium in the solution of the problem of television. His suggestion was to construct a mosaic consisting of a great number of selenium cells, in a sense imitating the retina of the human eye. These cells were to be connected to shutters or lamps in corresponding positions on a viewing board. Although the suggestion was made in 1875, the device was not put into operation until 1906 when Rignoux and Fournier used this arrangement to transmit simple patterns and letters. Their mosaic consisted of a checker-board of sixty-four selenium cells. Each cell was connected to a shutter on a viewing screen which was also made up of sixty-four elements in positions corresponding to those in the pickup screen. When a picture was projected on the selenium cells the resistance of those illuminated decreased allowing an electric current to flow which opened corresponding shutters on the viewing screen. A light behind these shutters made the reproduced picture visible.

* From the Greek word "Icon" meaning an image, and "scope" signifying observation.

** From Greek word "Kineo" meaning movement.

The idea of dividing the picture into elements, converting the illumination on each element into electric current and sending the signal from each over individual wires is practical for a small number of divisions or picture elements and for transmission over short distances, but is useless as a means of producing pictures of the standard required of television today.

The next step was proposed by Nipkow in 1884. Instead of using individual wires connecting each picture element, he suggested sending the information from one element at a time over a single communication channel and then reassembling this information again at the viewing screen. This process was to be carried out at such a rate that the picture appeared continuous due to persistence of vision. The means proposed to accomplish this point-by-point transmission was the scanning disc. At the time of its invention the necessary technique of handling and amplifying small currents had not yet been developed so that it was a number of years before this scanning principle could be put to practical use. However, the principle was sound and the scanning principle has been the basis of all television systems since then.

While this development represents a great step forward, it was only attained at considerable expense of available picture signal. The loss is due to the fact that each element only contributes to the picture for a small fraction of the total time, whereas with the first system suggested each element operated continuously. To make this clear, consider again the simple sixty-four element mosaic used by Rignoux and Fournier. Each photoelectric element was connected to the viewing screen by a separate conductor and the picture to be transmitted projected continuously on all the elements, so that a signal current passed through every light sensitive element all the time. To reduce the scanning system to a comparable case, assume that we have the same mosaic of sixty-four photosensitive elements, but that they are all connected to a common communication channel. The elements are covered with shutters (i.e., the scanning disc) which allow only the light from one element of the picture at a time to reach its corresponding photocell. These shutters are opened one at a time in rotation covering the entire picture twenty or thirty times a second. Thus each light sensitive element is only operating for a fraction of the total time equal to one over the number of picture elements, in this case one-sixty-fourth of the time.

In order to regain this lost signal and yet retain the principle of scanning, the development of the Iconoscope was undertaken. To illustrate the method of attack, consider again the sixty-four element array of photocells. Instead of scanning the elements with shutters, assume that each element is connected to the contact points of a switch which connects them in rotation to the main communication channel. Thus the scanning is accomplished by means of a commutator switch.

So far, we have gained nothing over the previous method of scanning, but now if a condenser is placed across each of the photocells in such a way that it accumulates the entire charge released by the action of the light during the time the element is not connected to the communication channel, this charge can be used when the com-

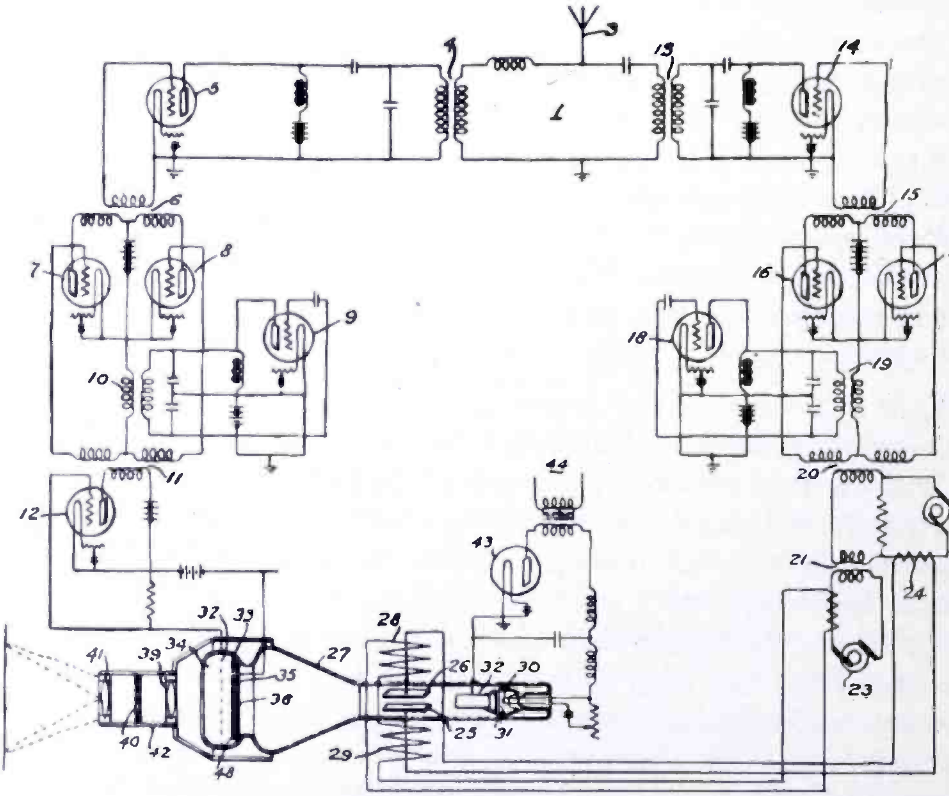

Figure 1

mutator switch again makes contact with this element. Therefore, photoelectric current is being released by every element continuously and this charge stored in the condenser belonging to that element until it is needed at the end of a scanning cycle.

The reduction of this principle to some practical form is obviously a difficult problem. The number of individual photocells and condensers required for a 360-line picture with a 4 to 3 aspect ratio will be of the order of 173,000 units, and it is quite apparent that a screen composed of that many conventional photocells and condensers is out of the question.

A solution devised by the author some years ago was to build up a mosaic screen which contained the equivalent of a vast number of photosensitive elements and condensers. This mosaic was mounted in a cathode-ray tube in such a way that an electron beam could be used to commutate the elements. Fig. 1 shows one of these tubes together with its associated circuits taken from one of the author's early patents.[1] Aside from the advantage gained through the application of the principle of storing the charge on each element for the entire picture time, this tube had the additional advantage that it involved no mechanical moving parts such as a scanning disc, mirror screw or drum, the scanning being done electrically.

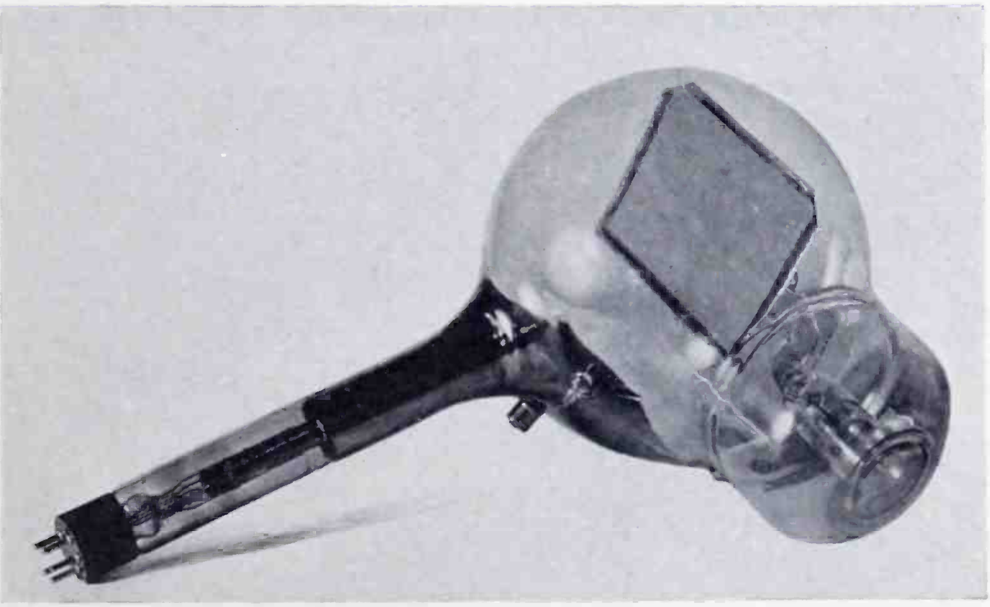

Figure 2

Although the first of this type of tube was built as far back as 1923, many years of research and development had to be undertaken before it was perfected sufficiently to meet the requirements of a satisfactory television system. The history of this development is interesting, but is somewhat outside the scope of this paper, which will be limited to a discussion of the tube as it is today.

The Iconoscope, as this type of tube has been named, is shown photographed in Fig. 2. It consists of an electron gun and photosensitive mosaic enclosed in a highly evacuated glass envelope. The arrangement of these elements is shown diagrammatically in Fig. 3.

The electron gun produces a narrow pencil of cathode rays which serves, as will be shown later, as a commutator to the tiny photocells on the mosaic. The gun is in reality a form of electron projector which

[1] V. K. Zworykin, Patent No. 1,691,324 "Television System."

concentrates the electrons from the cathode onto the mosaic in a very small spot. The electron optical system consists of two electron lenses which are formed by the cylindrically symmetrical electrostatic fields between the elements of the gun. Fig. 4 shows diagrammatically the arrangement of this gun, together with the equipotentials of the electrostatic fields making up the electron lenses. Below this diagram is the approximate optical analogue. Details of the gun construction are as follows: The cathode is indirectly heated with its emitting area at the tip of the cathode cylinder. It is mounted so that the emitting area is a few thousandths of an inch in front of an aperture in the control grid. A long cylinder with three defining apertures whose axis coincides with that of the cathode cylinder and control grid serves

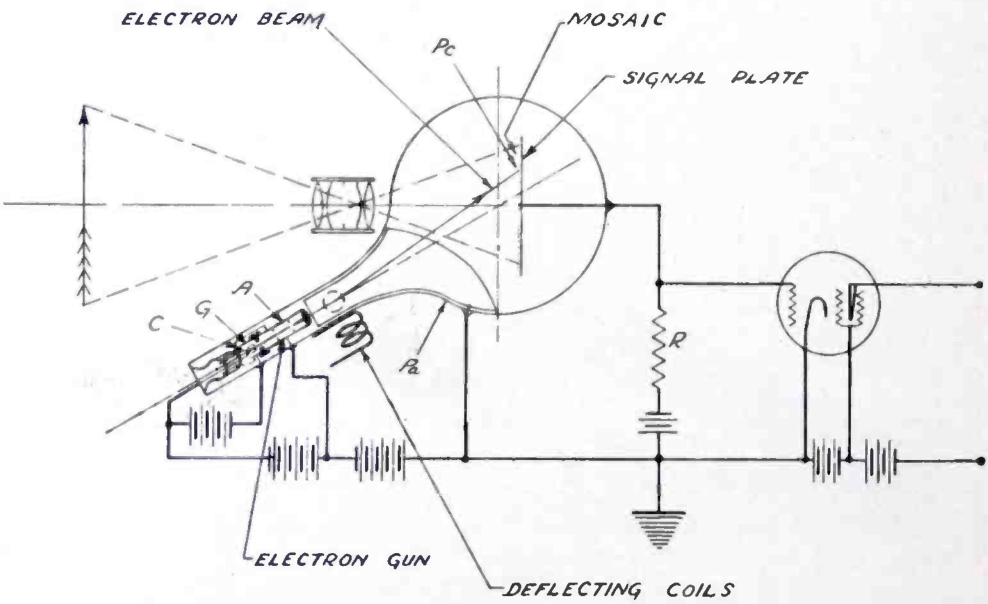

Figure 3

to give the electrons their initial acceleration and is known as the first anode. A second cylinder coaxial with the first anode and of somewhat greater diameter serves as second anode and gives the electrons their final velocity. The second anode is in general formed by metalizing the neck of the Iconoscope bulb, as shown in Fig. 3. The gun used in the Iconoscope is designed so that it will concentrate a beam current of from one-half to one microampere into a spot about five mils in diameter. Under ordinary operating conditions, a potential of about a thousand volts is applied between the cathode and second anode and the voltage of the first anode adjusted until minimum spot size is obtained. The exact value of the beam current to be used will, of course, depend upon the type of picture to be transmitted and the exact conditions of operation.

The beam from the gun is made to scan the mosaic in a series of parallel horizontal lines repeated at thirty cycles per second. This is accomplished by two sets of magnetic deflecting coils arranged in a suitable yoke and slipped over the neck of the Iconoscope. These sets of coils are driven by two special vacuum tube generators supplying a saw-toothed current wave, one operating at picture frequency supplying the vertical deflecting coils, the other at horizontal line frequency driving the second set of coils.

The element which characterizes the Iconoscope is the mosaic. It consists of a vast number of photosensitive globules mounted on a thin

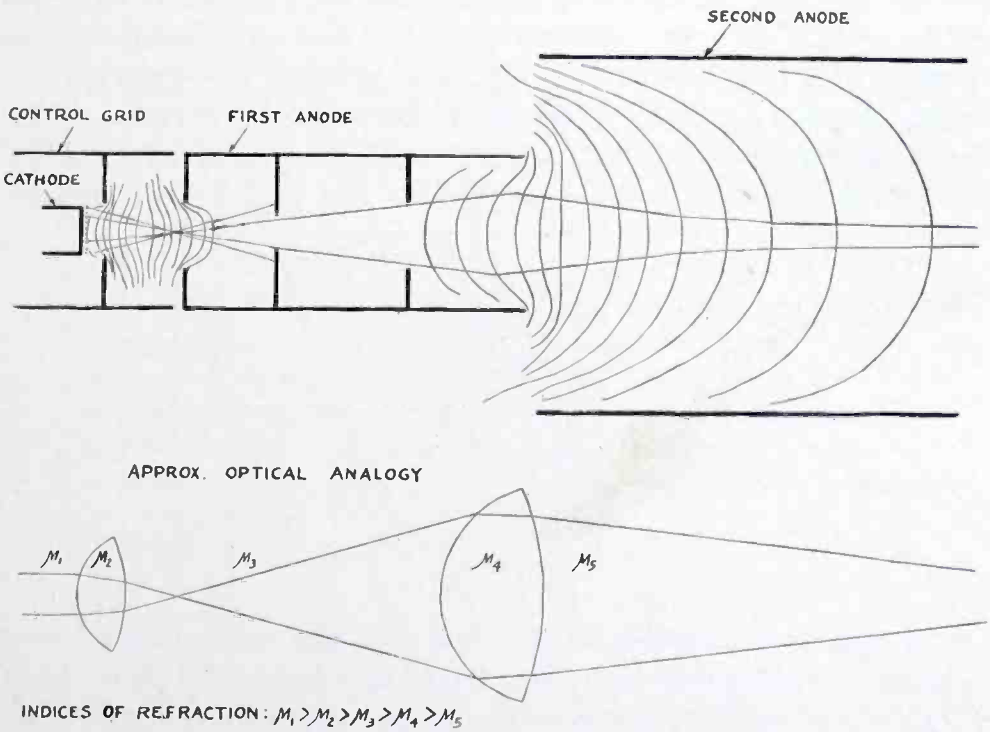

Figure 4

mica sheet in such a way that they are insulated from one another. The back of this sheet is coated with a conducting metallic film which serves as a signal plate and is connected to the input of the picture amplifier. The appearance of the mosaic is shown in Fig. 5. Such a mosaic may be formed in a variety of ways. For the standard type of mosaic the silver globules are formed by reducing particles of silver oxide dusted over the mica. Under proper heat treatment the silver globules reduced from the oxide will not coalesce but will form individual droplets. These droplets are sensitized after the mosaic has been mounted in the tube and the tube evacuated. The sensitization is similar to that used in the ordinary cesium photocell, that is, the silver is oxidized, exposed to cesium vapor, and then heat treated.

The result is that the photoelectric response of these globules is about the same as that of a high vacuum cesium photocell, both in sensitivity and spectral response. The spectral characteristic is shown in Fig. 6. The cut-off in the violet part of the spectrum is due to absorption of the glass walls. It is evident that the Iconoscope with a quartz window is sensitive from well into the infra-red, through the visible, and into the ultra-violet. Actual tests have produced images using radiation from 2000 Å down to more than 9000 Å.

The mica on which the silver droplets are mounted serves to insulate them from one another and further is made thin enough so that the capacity between each globule and the metallic signal plate will be reasonably large. The uniformity of cleavage sheets of mica, together with their excellent insulating properties, low dielectric hysteresis and low loss make them very suitable for this purpose. Other insulating materials, however, can be used; for example, a thin film of vitreous enamel on a metal signal plate has proven very satisfactory.

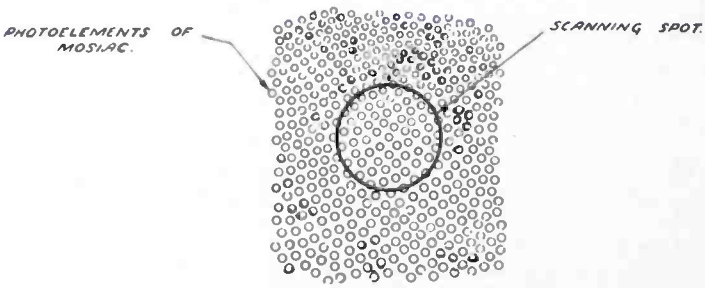

Figure 5

The mosaic is mounted in the tube with the silver beads facing the beam. In order that the optical image may be focused on its front surface, it is placed in the tube in such a way that a normal to its face makes an angle of 30° to the axis of the electron gun.

In essence, the Iconoscope may be thought of as a plain mosaic made up of a great number of individual photocells, all connected by capacity to the common signal plate and commutated by the scanning beam. The fundamental cycle of operation is as follows:

Every silver globule making up the mosaic is photosensitized so that when a light image is projected on the latter the light causes electrons of a number proportional to the light brilliance to be emitted from each illuminated minute size photosensitive area. The resulting loss of electrons leaves each photosensitive area at a positive potential without respect to its initial condition which potential is then proportional to the number of electrons which have been released and conducted away so that the mosaic tends to go positive at a rate proportional to the light falling on it. As the electron beam scans the mosaic, it passes over each element in turn, releasing the charge it has acquired and driving it to equilibrium. Due to the fact that each element is coupled by capacity to the signal plate, the sudden change of charge of the elements will induce a change in charge on the signal plate and result in a current pulse in the signal lead connected to the amplifier. The magnitude of these pulses will be proportional to the intensity of the light falling on the scanned element. Thus the signal output from the Iconoscope will consist of a chain of current pulses

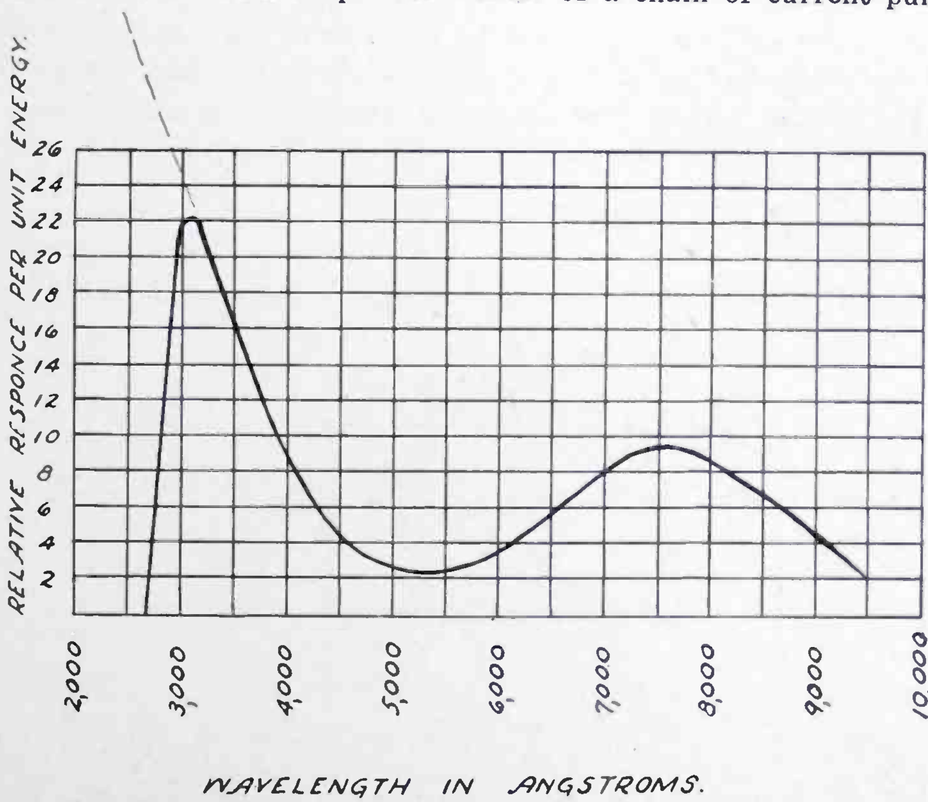

Figure 6

corresponding to the light distribution over the mosaic. This chain can be resynthesized at the receiver into a reproduction of the original image, as will be described later.

To clarify this cycle the equivalent circuit representation of a single element is shown in Fig. 7. The beam is represented by the switch and series resistance *R*. This switch may be considered as being open except at such times as the beam is actually on the element. When the scanning beam moves off the element, the photo-emission from it starts to charge the condenser *C*, the rate of accumulating charge being proportional to the illumination on the element. In the next scanning cycle, the beam again sweeps over the element, closing the switch and discharging the element. During this discharging cycle the entire charge accumulated during the time the beam was not on the element must now flow through the input resistor R_1 generating an e.m.f. which is applied to the input of the picture amplifier.

In designing the mosaic, it is evident that the time constant of the circuit discharging the condenser C must be small enough to allow it to fully discharge during the time the beam is on the element. This condition requires that $C \times (R_1 + R)$ be less than the time the beam is on the element. In practice, this condition is not difficult to fulfill.

At this point it is interesting to compare the e.m.f. supplied to the amplifier by this storage system with the equivalent voltage from a non-storage system. The equivalent circuit for the non-storage case is shown in Fig. 8. The current through the input resistor R_2 will be:

$$I_s = \frac{F.s}{n}$$

where F is the light flux in the picture, s the sensitivity of photo-

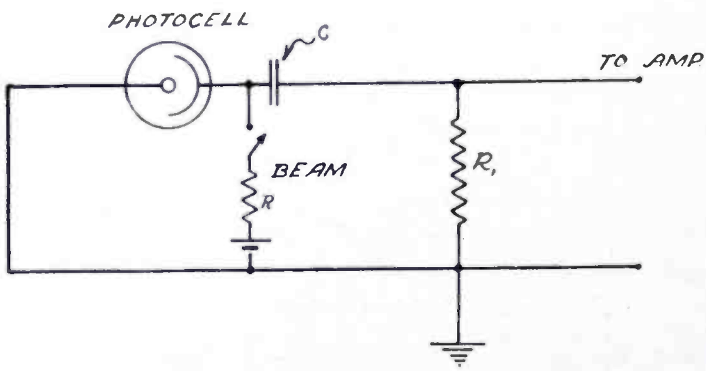

Figure 7

sensitive elements, and n the number of picture elements. The voltage to the input of the amplifier is:

$$V_2 = \frac{Fs\,R_2}{n}$$

In the storage case the charge accumulated by the element is:

$$Q = \frac{F.s}{n}\,t_p$$

where t_p is the picture time or $1/N$ for N pictures per second. When the beam strikes the element this charge leaves the condenser resulting in an average current of

$$i = \frac{Q}{t_e}$$

where t_e is the time the beam is on the element or $1/Nn$. This current is therefore:

$$i = \frac{F.s\,Nn}{n\ \ N}$$

and the voltage to the amplifier will be:

$$V_1 = FsR_1$$

Comparing the signal voltages generated in the two cases, we see that the ratio is:

$$\frac{V_1}{V_2} = \frac{FsR_1}{\frac{FsR_2}{n}} = n \qquad \text{where } R_1 = R_2$$

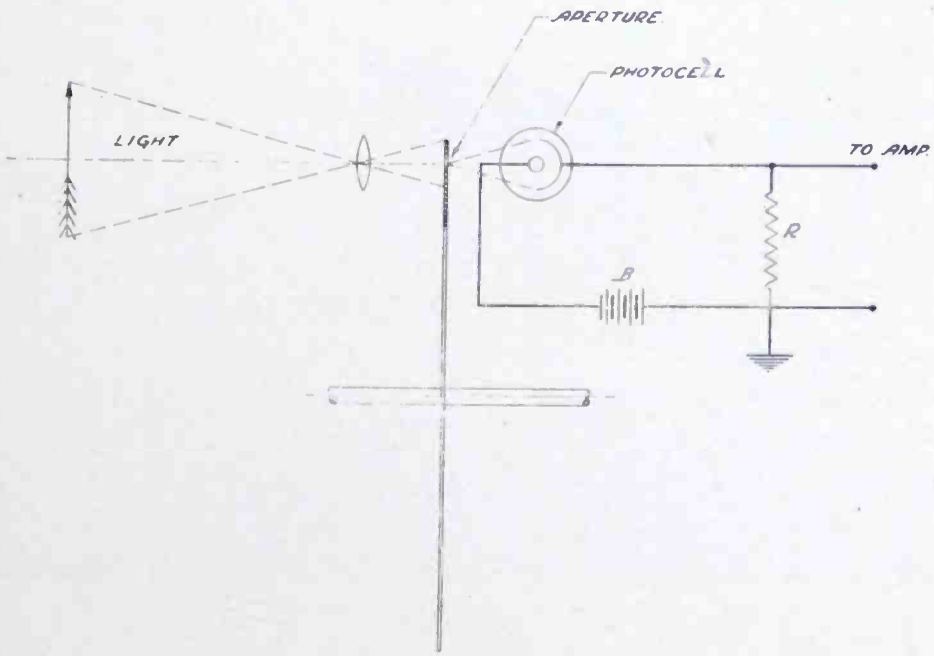

Figure 8

Where the number of picture elements is large as is the case in pictures with good definition, this gain in signal is extremely important. For example, the ratio in the case of a 360-line picture is 173,000 times the signal that could be obtained from the non-storage case.

In order to give a pictorial idea of the conditions on the surface of the mosaic, Fig. 9 is included. It represents the appearance of the charged image on the mosaic if it were visible to the eye. The region just behind the scanning beam is an equilibrium potential and therefore shows no visible image. As we examine the mosaic further away from the line just scanned, we find that the charged image gets more and more intense since the elements have been charging for a greater length of time. Just ahead of the scanning beam the image reaches its maximum intensity.

The picture just drawn of the operation of the Iconoscope is very much simplified. A number of factors complicate this seemingly straightforward cycle. Among the most important of these complicating factors are the potential distribution over the mosaic and the redistribution of secondary electrons emitted from the elements under bombardment. If the average potential of the mosaic is measured in

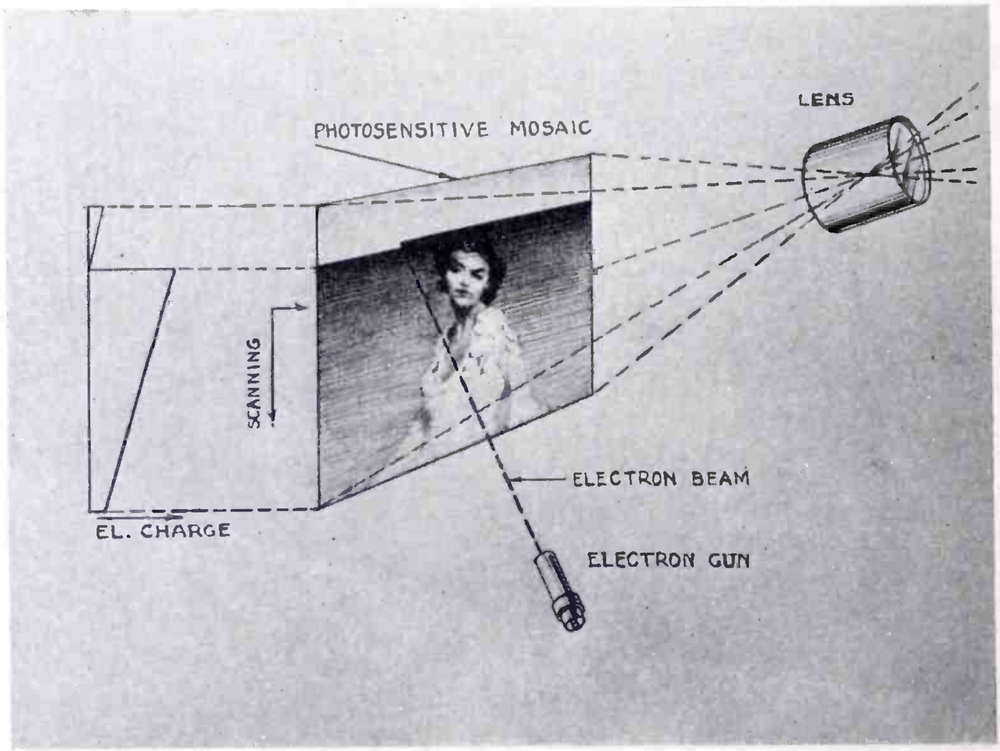

Figure 9

darkness while it is being scanned, it will be found to be between 0 and 1 volt negative with respect to the electrode which collects the electrons leaving the mosaic, that is, with respect to the second anode. However, the potential is not uniform over the surface of the mosaic. Elements directly under the beam are found to be in the neighborhood of 3 volts positive with respect to the second anode. As we investigate elements which have previously been bombarded, we find them less positive, until at a point one-quarter to one-third of the vertical distance along the mosaic from the point being bombarded, the potential has reached —1½ volts negative with respect to the collector. The rest of the mosaic is found to be at —1½ volts. Cathode-ray oscillograph measurements of the potential distribution over the mosaic shows that it can be mapped somewhat as shown in Fig. 10.

In order to account for the potential distribution over the surface of the mosaic, it is necessary to consider what takes place among the secondary electrons emitted from the cesiated silver elements under bombardment. It is well known that when a cesiated silver surface is bombarded by an electron beam of the order of 1000 volts velocity, a secondary emission of 7 or more times the primary bombarding current can be collected. However, since the mosaic elements are insulated they must assume, when in equilibrium, a potential such that the secondary emission current equals the bombarding current.

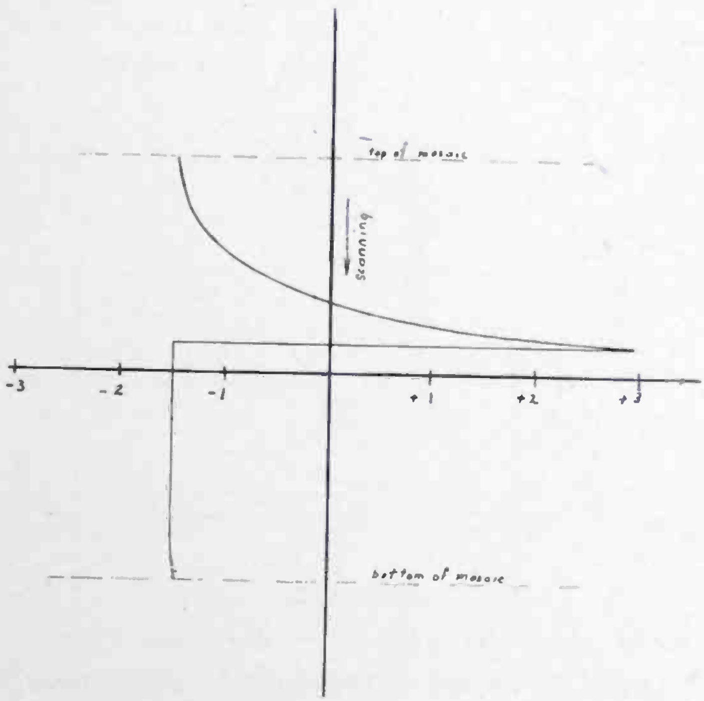

Figure 10

This potential is found to be about 3 volts positive with respect to the second anode. In the case of the mosaic in darkness it is obvious that the average secondary emission current leaving the mosaic must also be equal to the beam current since the mosaic is an insulator. Thus it must come to an equilibrium potential such that the average current escaping to the second anode equals the bombarding current.

Perhaps we should digress at this point and discuss more fully the mechanism by which an element acquires this positive equilibrium potential. Measurements of the velocity distribution of the secondary electrons from a bombarded surface show that they can be represented by a distribution curve such as shown in Fig. 11. In this figure the abscissa gives the velocity in electron volts of the emitted electrons, while the ordinates give the current per volt range in velocity composed of electrons having a given velocity. If the target is surrounded with an electrode to collect secondary electrons, the current it can collect will depend upon its potential relative to the target. When this collector is at zero potential the current reaching it will equal the total secondary emission as represented by the total area under the curve in Fig. 11. As the collector is made more negative, the current decreases since some of the electrons leaving will not have sufficient velocity to reach the electrode and will be driven back to the target. The current reaching the collector at some negative potential V_1 will be given by the area under the distribution curve from V_1 to the highest velocity; in other words

$$i_c = \int_{V_1}^{\infty} f(V)\ dV$$

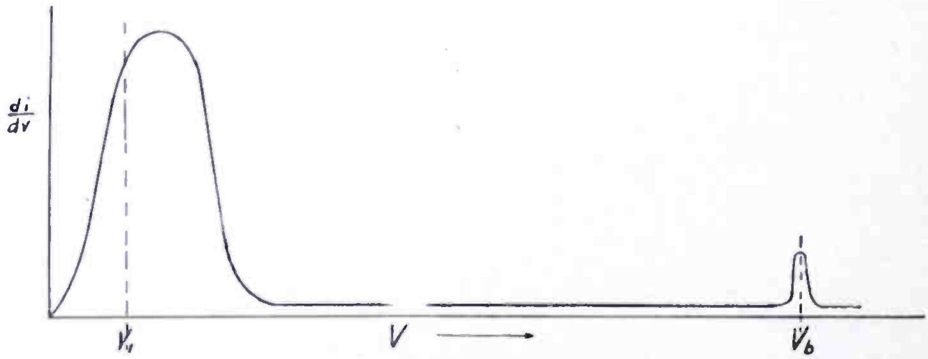

Figure 11

As the potential of the collector is decreased further eventually it will reach a point where the current collected just equals the current in the primary beam. At this point no current flows in the external lead to the target under bombardment. Experiment shows that for a cesiated surface such as is used to make up the globules on the Iconoscope mosaic, this potential is in the neighborhood of 3 volts. Hence, if an insulated target such as a mosaic element is bombarded more electrons will leave than arrive until the element reaches 3 volts positive, at which potential the element will be in equilibrium and the current arriving and leaving will be equal.

When the mosaic elements are scanned the secondary emission from them may be divided into three parts, one going to the second anode, another returning to the element itself, and a third being redistributed over the entire mosaic. This latter group which returns to the mosaic comes back as a more or less uniform rain of electrons having a maximum velocity of about 1½ volts.

This can be verified by removing a portion of the mosaic and substituting a metal sheet electrode in its place. If the mosaic, except for the substituted portion, is scanned and the current to the metal electrode measured, it will be found to decrease as the potential of the probe is decreased. At —1½ volts negative the current will be dropped to zero.

Let us now consider the operation of the Iconoscope in the light of the phenomena just discussed. In the first place, due to the potential of the mosaic, there is very little electrostatic field aiding the escape of photo-electrons from the illuminated elements. This means that the charging of the globules is dependent in a large measure

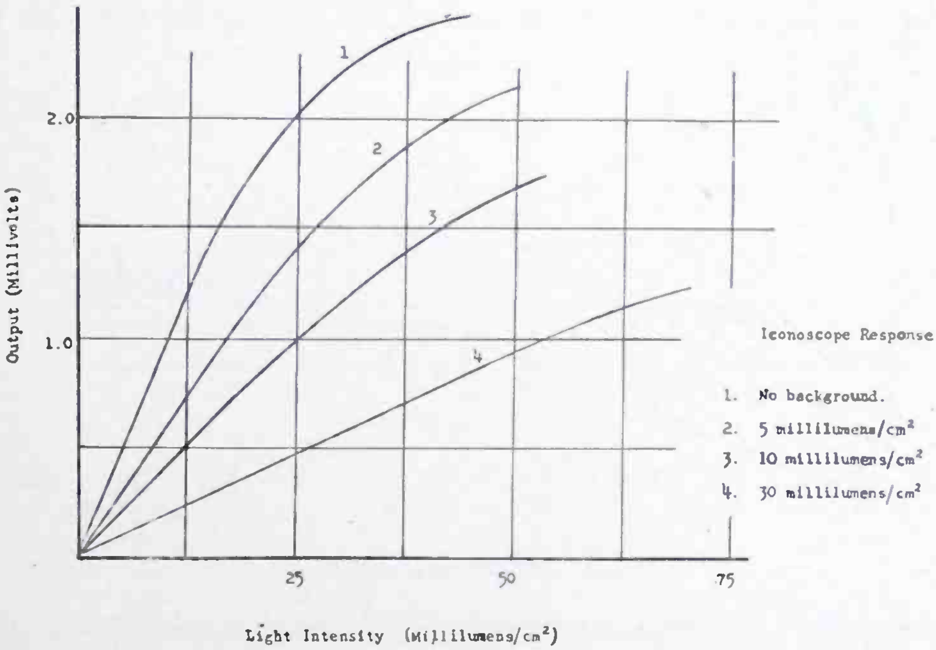

Figure 12

upon the initial velocities of the electrons. Therefore, the photoelectric emission is not very efficient and becomes less so as the illumination is increased. It should be remembered, however, that the photo-emission occurs during the entire picture time, the charge being accumulated on the condensers formed by the silver beads and the signal plate. In other systems, since photo-emission occurs only during the time a picture element is being scanned, there is a gain of the order of 10^5 to be had by using the storage system so that even if the above-mentioned photoelectric inefficiency were insurmountable there is still a very great advantage in favor of the Iconoscope system.

As was pointed out in the discussion of the potential distribution, there is a line across the mosaic directly behind the scanning beam which is 3 volts positive with respect to the second anode, while just ahead of the beam the potential is in the neighborhood of $1\frac{1}{2}$ volts negative. There is, therefore, just ahead of the scanning beam, a row of elements which have a strong field aiding the leaving photo-electrons. This field very much increases the photo-sensitivity along this line and gives rise to a phenomenon known as line sensitivity. This phenomenon can be demonstrated very strikingly in the following way:

The image from a continuously run moving picture film (i.e., by removing the intermittent and shutter from a moving picture projector) is projected onto the mosaic of the Iconoscope. The film is

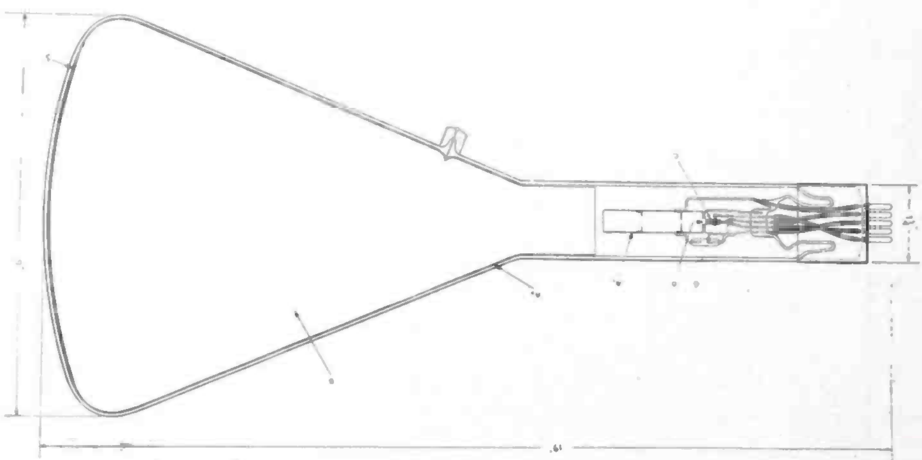

Figure 13

run at such a rate that the frame speed is equal to the picture frequency of the Iconoscope and in a direction such that the image moves opposite to the vertical direction of scanning. Under these conditions we find that the Iconoscope transmits a clear image of two frames of the moving picture film although, to the eye, there appears to be only a blur of light on the mosaic.

Thus we have two sources of signal, one the stored charge over the entire mosaic surface; the second from the sensitive line at the scanning beam. At low or normal light intensities by far the greater part of the signal comes from surface sensitivity, but under high illumination as much as 50% of the signal may come from line sensitivity.

As was pointed out above, due to the fact that the secondary emission is not saturated, some electrons from the point where the beam strikes the mosaic have not sufficient velocity to leave the mosaic entirely, but return to its surface as a shower of low-velocity electrons. The redistributed electrons act to some extent as a high resistance, short-circuiting the elements, since an element which is more positive than its neighbors tends to receive a greater share of these electrons. This resistance is, in effect, identical with that of the dynamic resistance of a triode tube and under normal operating conditions is high enough so that it does not produce a very serious loss in efficiency, but under high illumination where considerable difference in charge between nearby elements may be developed, this shunting resistance may become quite low with the result that there is a fairly large loss of signal.

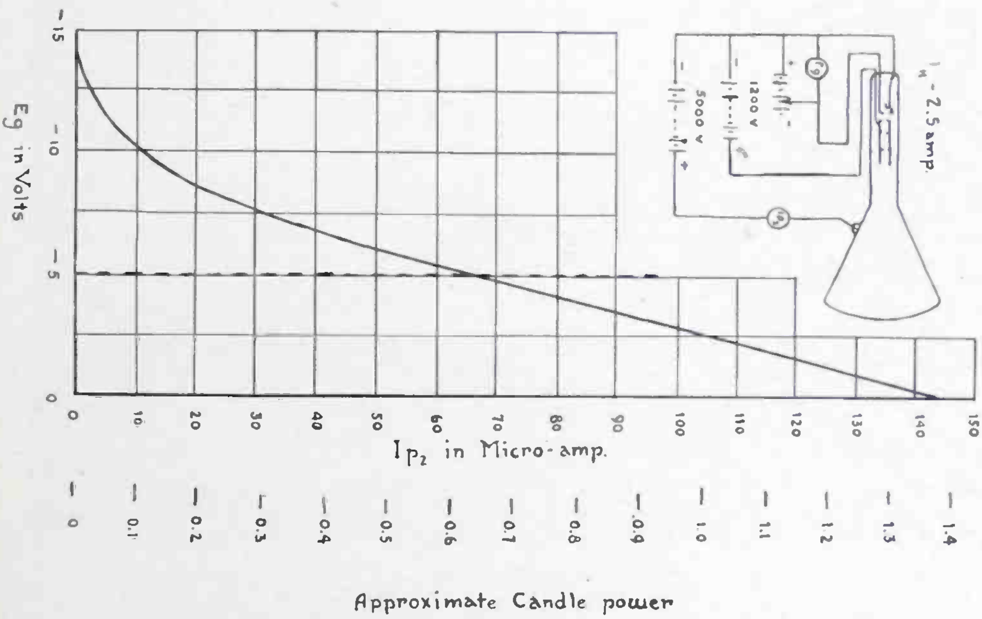

Figure 14

This redistribution of electrons is furthermore responsible for the generation of a spurious signal. It appears as an irregular shading over the picture even when the mosaic is not illuminated. The cause of this signal is the variation in instantaneous secondary emission current escaping from the mosaic to the second anode. As has been pointed out, the average secondary emission from the mosaic must be unity, but when we consider that a certain fraction of the secondary electrons from the point under bombardment returns to other parts of the mosaic, it is quite apparent that the instantaneous current leaving the mosaic may vary from point to point. This variation is produced by the lack of uniformity of potential and space charge over the mosaic.

It is interesting to note that if a clean sheet of metal is substituted for the mosaic, the spurious signal appears when it is scanned, provided the secondary emission is not saturated. The signal disappears, however, if the metal plate is made sufficiently positive or negative with respect to the second anode. Under these conditions, the secondary emission is either saturated or suppressed. In practice the effect of this signal can be eliminated by the introduction of a compensating signal. The spurious signal varies rapidly with beam current and under conditions of low beam intensity and moderately high illumination it is negligible compared with the picture signal.

So far, the scanning beam has been considered as some sort of commutating switch which sweeps over the mosaic. Actually, the beam does behave in just this way. The beam when falling on an

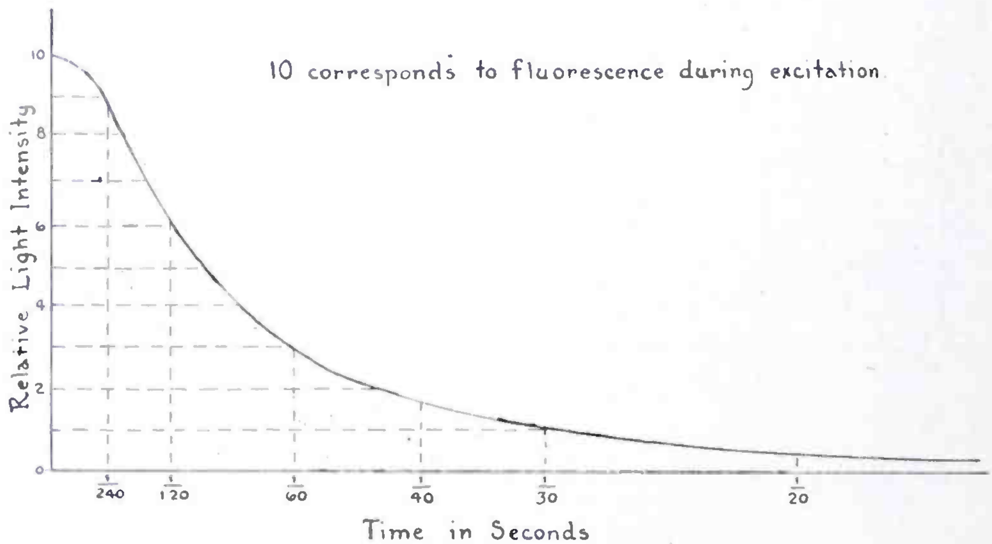

Figure 15

element connects it through a resistance (dynamic, of course) to the second anode. This is obvious when we consider the action of the beam. As has been pointed out, the ratio of secondary electrons to primary electrons from a cesiated silver surface is about 7 when saturated. However, if the bombarded surface is made positive this ratio decreases, reaching unity at +3 volts and one-half at about 10 volts. From curves giving the secondary emission ratio of an element for various collector potentials, together with a knowledge of the beam current, the effective resistance connecting the bombarded element with the second anode can easily be estimated. This resistance turns out to be of the order of 10^6 ohms. If the beam current is too weak, it will not fully restore the illuminated element to equilibrium. Considering a stationary picture, and neglecting the effect of the redistribution of scattered electrons, this would not reduce the signal obtained from a given amount of light. However, it would cause a lag and consequent blurring of the image of a moving object. In the actual Iconoscope because of the rôle the beam plays in establishing the potential of the mosaic and because of the shunting effect of redistributed electrons, there is an optimum beam current at which the signal is a maximum for a given condition of light.

Taking into account the various factors tending to reduce the output of the Iconoscope, it is found that the net efficiency of conversion is in the neighborhood of 5 to 10%. In other words, the signal output is about 1/20 that which would be expected on the basis of the

Figure 16

light flux reaching the mosaic, the saturated photo-emission of photoelectric elements, and the assumption that the entire photo-current is stored by the mosaic. The efficiency of conversion is not constant, but as explained above depends on the amount of light used. The efficiency is a maximum at low light and decreases as the light is increased. This point will be considered again under a discussion of the actual performance of the Iconoscope.

Up to this point we have based our consideration of the relative merits of the storage and non-storage types of systems on a comparison of signal output alone. The recent development of the secondary emission multiplier makes it necessary to introduce other considerations into this comparison. The electron multiplier provides a means of amplifying a photoelectric current to almost any desired extent without introducing any additional "noise" into the signal. It might seem, therefore, that we could amplify the minute photo-current obtained by the conventional scanning system to such an extent that the sensitivity of the two systems were equal. This, however, cannot be done because even with a perfect amplifying system the statistical fluctuations in the original photo-current are amplified just as much as the signal is amplified. Because of this there is a definite limit to the sensitivity of this type of system imposed by the original shot noise in the photo-current. In the case of the Iconoscope there is a similar limit, but because the charge representing each picture

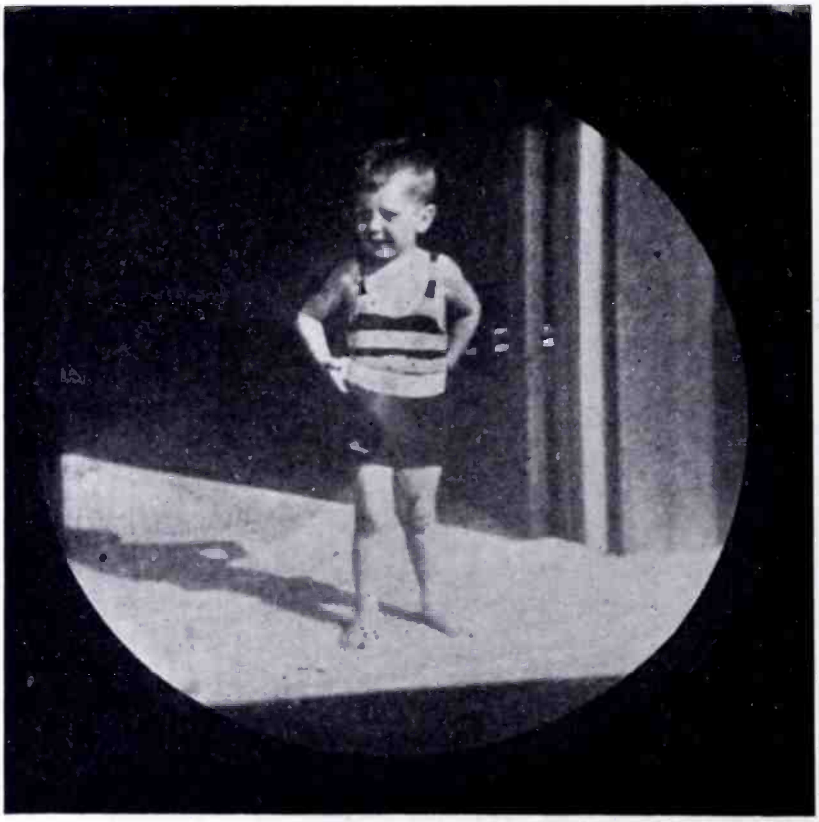

Figure 17

element is so much greater than in the non-storage case the ideal sensitivity is very much greater. Actually, in the type of Iconoscope described in this paper, the limit of the sensitivity is not set by the statistical fluctuations of the stored charge, but by the thermal noise in the coupling resistor to the amplifier. A quantitative comparison of the limiting sensitivity of the Iconoscope used at present, taking into account its inefficiency and imperfections, shows that it is able to operate at one-tenth the light required by a *perfect* non-storage system. This, of course, includes the use of an electron multiplier and applies to electrically scanned as well as mechanically scanned non-storage systems.

The resolution of an Iconoscope may be limited either by the size of the photoelectric elements or by the size of the scanning beam. The size of the silver globules in the Iconoscope described is many times smaller than a picture element so that many hundreds of them act together under the scanning spot. The resolution is limited, therefore, by the spot size. At present, the resolution adopted is about 360 lines, but when necessary the beam size can be reduced and the resolution made much higher.

Figure 18

The actual response of an Iconoscope under various conditions of illumination is shown in Fig. 12. The output is measured in millivolts across a 10,000-ohm coupling resistance and the light input measured in lumens per square centimeter on the mosaic. The curve showing the greatest response represents the signal output from a small illuminated area when the remainder of the mosaic is in darkness. The other curves of the family show the response from the same area when the mosaic is illuminated with a uniform background of light. The response is not linear but falls off as the illumination is increased until it reaches a saturation value. The saturation voltage output is nearly constant for tubes of a given design, but the

Figure 19

slope of the response curve may very from tube to tube depending upon treatment and is a measure of the sensitivity.

The decrease in sensitivity with illumination is not wholly disadvantageous in that it permits the transmission of a wider range of contrast over a given electrical system than would otherwise be possible. In a sense, this is similar to the compressor-expander systems used in sound recording.

In spite of the complicated manner of its operation and the factors mentioned reducing its efficiency, the Iconoscope is an extremely sensitive and stable device for obtaining television transmission. Excellent and consistent results are obtained under widely varying conditions of operation. The practical lower limit to light which can be used to transmit a picture is set by the "noise" in the picture amplifier. Measurements have been made to determine the illumination necessary for satisfactory operation. With an F/2.7 lens to focus the image on the mosaic, an average surface brilliancy of from 30 to 50 candles/sq. ft. on the object viewed gives completely satisfactory transmission. A recognizable image can be obtained from a good Iconoscope with 8 candles/sq. ft. using an F/16 lens, that is, with 1/150 the illumination mentioned above.

For comparison, the illumination of some scenes commonly met with is given in the following table:

Scene	*Location*	*Date*	*Time*	*Weather*	*Brightness*
Beach	Atlantic City	August	2:00 P.M.	Hazy	500
Boardwalk	Atlantic City	August	2:00 P.M.	Hazy	275
Street	Philadelphia	August	2:30 P.M.	Clear	200
Times Square	New York City	November	1:30 P.M.	Rain	40
Street Parade	East Orange	November	10:30 A.M.	Rain	40 to 60

It is evident that perfectly satisfactory outdoor pickup may be obtained under almost all average conditions of light.

The device used to reproduce the television picture is also electron operated. This tube, which has been named the "Kinescope," is similar to a cathode-ray oscilloscope in many respects. It consists of an electron gun for defining and controlling a cathode-ray beam and a fluorescent screen which becomes luminous under bombardment from the electron gun. A diagram of a typical Kinescope is shown in Fig. 13.

The cathode-ray beam is made to sweep across the fluorescent screen in synchronism with the scanning beam in the Iconoscope which is transmitting the picture. Furthermore, the current in the Kinescope cathode-ray beam is controlled by the signal impulses generated at the Iconoscope. This control acts in such a way that the impulse corresponding to a bright area on the Iconoscope causes an increase in

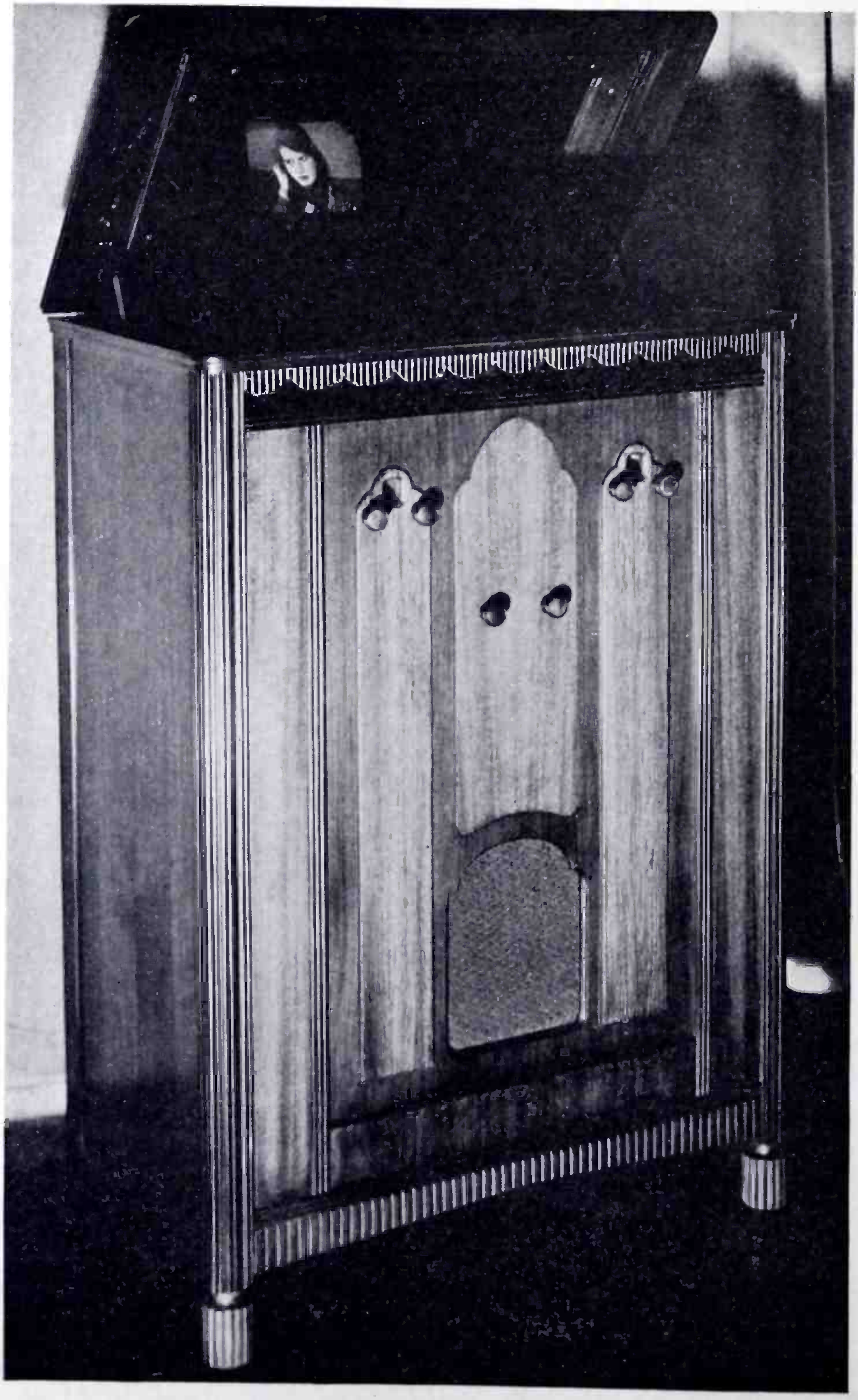

Figure 20

current, while a dark region causes a decrease. There will, therefore, be an exact correspondence both in position and intensity between the fluorescent illumination on the Kinescope screen and the light on the mosaic in the Iconoscope. A picture projected on the Iconoscope will therefore be reproduced by the Kinescope.

The electron gun in the receiving tube is similar in principle to that in the Iconoscope, but is made to handle larger currents and to operate at higher voltages. Furthermore, since the picture is reproduced by modulating the beam current, the control grid is a much more critical item. The control grid characteristic is determined by a number of factors such as the grid aperture, the spacing and geometry of the cathode, the first anode, etc. Fig. 14 shows a typical control characteristic for a Kinescope gun.

The fluorescent screen is made by coating the flat portion of the glass bulb with a synthetic zinc orthosilicate, very similar to natural Willemite. The synthetic material has high luminous efficiency, the light output at a given voltage being proportional to the current striking it. At 6000 volts the material gives nearly 3 candles per watt. The efficiency of light production varies somewhat with voltage used, but at higher beam velocities is nearly constant. This can be seen from the general relation between candlepower P, current intensity I, and applied voltage V, which is given by the equation:

$$P = AI\ (V\text{-}V_0)$$

A is a constant depending upon the phosphor and V_0 the extrapolated minimum exciting voltage, which proves to be in the neighborhood of 1000 volts.

In addition to its high luminous efficiency, this material does not burn or disintegrate under bombardment with electrons. The phosphorescent properties of a fluorescent material are an important consideration. An ideal substance for television work should emit a constant amount of light for one entire picture frame and drop to zero at the end of this period. If the phosphorescent time is too long, the moving portions of a picture will leave a "trail." For example, the path of a moving ball will be marked with a comet-like tail. On the other hand, if the decay time is too short, flicker becomes noticeable. The phosphorescent decay curve for zinc ortho-silicate is shown in Fig. 15.

Fig. 16 shows a photograph of a "Kinescope" with a 9-inch viewing screen. This is only one of a number of sizes, both larger and smaller, and designs possible for the "Kinescope."

Between the transmitting Iconoscope and the reproducing Kinescope there is a chain of electrical equipment involving the picture amplifier, transmitter, radio receiver and synchronizing system. This field is much too large to cover in this paper and has been treated in detail elsewhere.[1]

In closing, it might be well to illustrate the performance of the systems with some photographs of televised pictures as they appear on the screen of the Kinescope. These are shown in Figs. 17 and 18. The appearance of a typical studio pickup camera using the Iconoscope is shown in Fig. 19, while that of a console type television receiver can be seen in Fig. 20.

[1] Description of an Experimental Television Receiver, I.R.E. Proc., Vol. 21, No. 12, December, 1933.

An Experimental Television System, Part II—Transmitter, I.R.E. Proc., Vol. 22, No. 11, November, 1934.

An Experimental Television System, Part III—Receivers, I.R.E. Proc., Vol. 22, No. 11, November, 1934.

An Experimental Television System, Part IV—Radio Relay Link for Television Signals, I.R.E. Proc., Vol. 22, No. 11, November, 1934.

SAFETY OF LIFE AT SEA

By

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Executive Vice President, Comité International Radio-Maritime, Brussels.

Radio communication as an important factor in safety of life at sea has been well recognized since the early experiments of Marconi. In December, 1897, tests were conducted from a station at the Needles, England, and communication was established with a ship at sea over a distance of 18 miles. In 1898 a young engineer by the name of M. Travilleur of Belgium saw the possibilities of Wireless Telegraphy and predicted many of the radio services now used today. Travilleur at the time was engineer to the King of Belgium. Since 1897 a large number of scientists have been engaged in radio research work. At the present time there are over 15,000 ships throughout the world equipped with radio installations and ranges are measured in terms of hundreds or thousands of miles. Vessels under U. S. registry which carry radio installations number approximately 2300. It is the purpose of this paper to present a brief resumé of maritime radio applications in their relationship to safeguarding of life and property at sea.

THE application of radio communication to and from ships at sea is not limited to the rescue of passengers and crew from the perils of the sea. An illustration of this fact took place in early May of this year when the wife of the author of this article was taken suddenly ill with pneumonia on the *SS Bremen* after leaving Cherbourg for New York. It became apparent that a consultation between the ship's doctor, Dr. Joseph Von Geyr and Mrs. Pannill's physician, Dr. Touart in Bronxville, New York, was advisable and accordingly the radio telephone equipment on this vessel was brought into play with successful results whereby the two physicians were able to confer at frequent intervals during the entire voyage.

Regulations of the U. S. Department of Commerce, Bureau of Navigation and Steamboat Inspection, effective in January, 1936 called for installation of radio telegraph transmitting and receiving equipment on at least one motor lifeboat of passenger vessels over 2,500 gross tons, which navigate more than 200 miles off shore. This has led to the development of compact equipment in a weatherproof housing suitable for such application. The radio transmitter operates on the distress frequency of 500 K.C. and the radio receiver covers the band 350 to 550 K.C. Since space is limited in a motor lifeboat, the equipment is designed to work with a single wire antenna twenty feet high and approximately twenty feet long. A heavy duty storage battery is fitted in the lifeboat and has sufficient capacity to operate the radio equipment for a six hour period as well as supply power to an 80 watt searchlight. Provision is made to keep the storage battery on continuous trickle charge at all times while the lifeboat is on the davits.

This lifeboat equipment is designed to have a minimum range of 50 nautical miles. Tests have shown that ranges of 100 to 200 miles are obtained. The installation is so arranged that, in the absence of a radio operator, the transmitter may be placed in operation by a

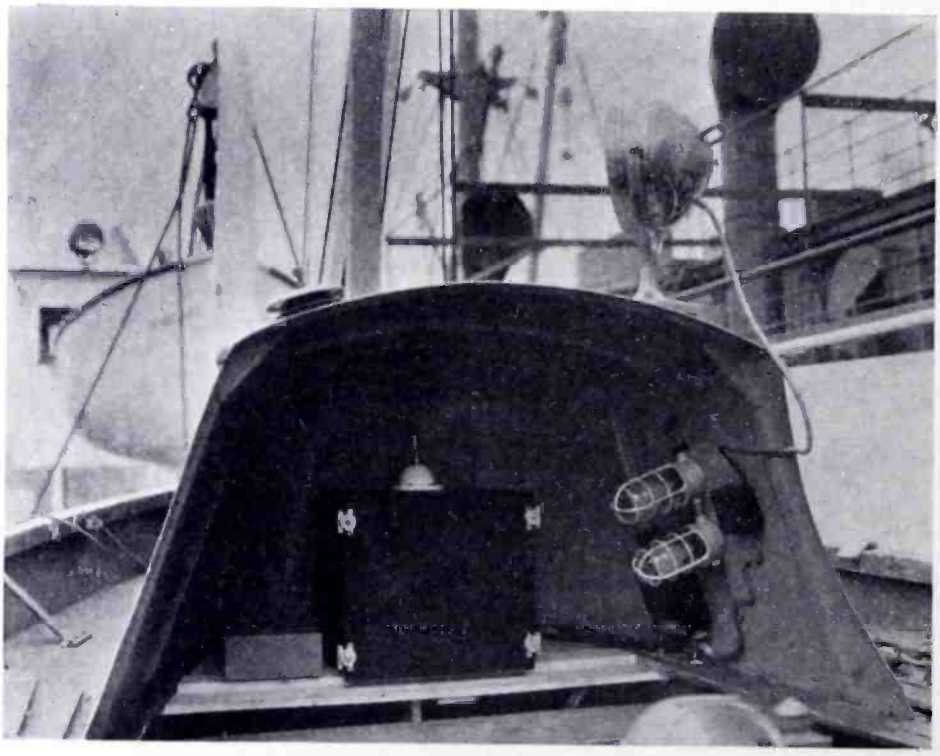

Fig. 1—Radio Equipped Lifeboat.

layman. In case of distress, after the motor lifeboat is launched, it may take in tow the other lifeboats from the vessel and by means of the radio equipment enable a rescuing ship to take bearings, using the direction finder to be described later. Views of a typical lifeboat installation are shown in Figures 1 and 2.

Coastal radio stations are an integral part of the radio service to ships at sea. In the United States, the Radiomarine Corporation operates a total of 17 coastal stations on the Atlantic, Pacific and Gulf Coasts and on the Great Lakes. Some of its main stations are located at Chatham, Mass., New York City, Tuckerton, N. J., Baltimore, Md., Savannah, Ga., Palm Beach, Florida, Galveston and Port Arthur, Texas, Los Angeles and San Francisco, Calif., and Portland, Oregon. On the Great Lakes stations are maintained at Buffalo, N. Y., Cleveland, Ohio, Chicago, Ill., and Duluth, Minn.

For long distance communciation from the East and Gulf Coasts of the United States, Radiomarine uses the Chatham and Tuckerton stations. These stations are equipped with powerful intermediate, long and short wave transmitters as well as suitable receivers for the various marine frequencies. Communication may be carried on with several ships simultaneously from these stations, since they are arranged for duplex operation. This is accomplished by locating the transmitting

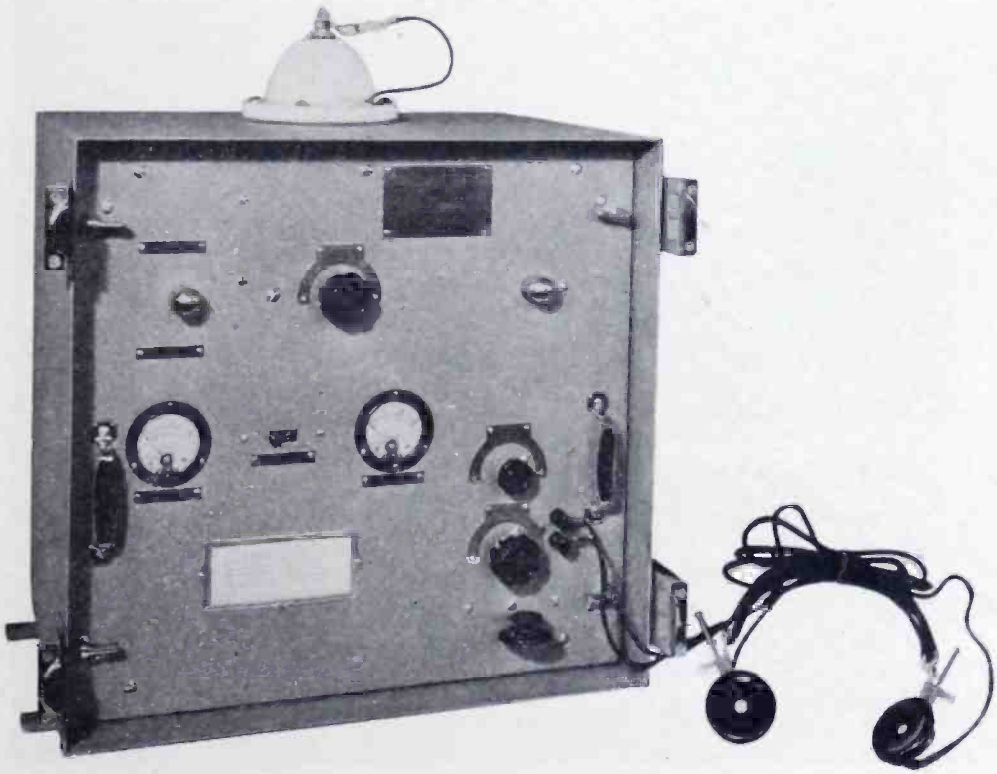

Fig. 2—Lifeboat Transmitter-Receiver.

antennas at some distance from the receiving point so that the receiving antennas are not in the direct field of the transmitters.

On the West Coast Radiomarine's long distance transmitting station is located at Bolinas, Calif., and the receiving station at Marshall, Calif. Its remaining coastal and Great Lakes stations are used primarily for communication with ships at various distances up to approximately 1,000 miles.

Radiomarine plans in the future to equip a number of vessels with marine telephone equipment in the event there is a demand for such equipment.

First in importance, and most extensive in use is the normal 500

K.C. (600 meter) shipboard telegraph installation. By international agreement a frequency of 500 K.C., with a 15 K.C. "guard band" on either side, has been assigned for distress and calling purposes. Ships at sea and coast stations in marine service maintain a watch on this frequency. In addition there are two periods during each hour, of three minutes duration each, when all transmission, other than distress calls, must cease on 500 K.C. To insure familiarity in the use of the equipment and reliability of operation, routine calling is permitted on 500 K.C. except during the three minute silent periods, while nearby

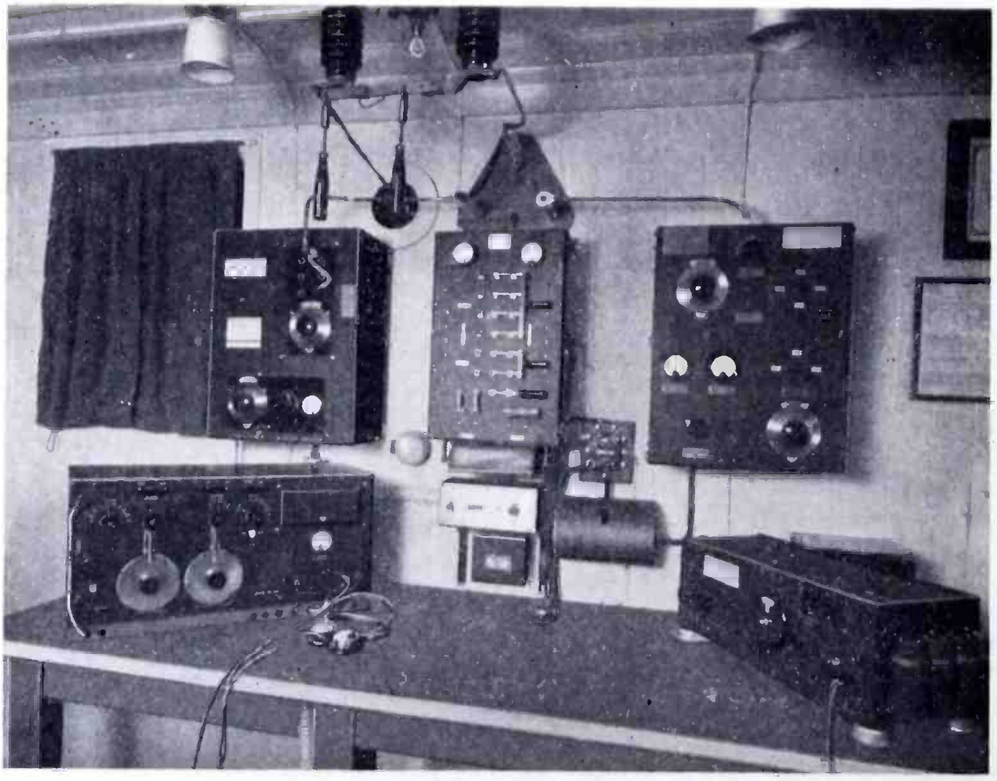

Fig. 3—Typical Radio Room Aboard Ship.

frequencies are employed for handling traffic in the band of 375 to 500 K.C. (800 to 600 meters). By international agreement the composition of three dots, three dashes and three dots (S O S) is used for calls of distress. These signals are followed by call letters or the name of the ship and its position in longitude and latitude.

The intermediate frequency radio installation used on small or medium class vessels comprises a radio transmitter with a power output ranging from 50 to 200 watts, and a radio receiver capable of receiving the various frequencies used in the maritime service. Larger vessels employ a radio transmitter of 500 to 1,000 watts output. Under present U. S. regulations a range of at least 100 miles is required, although the standard installations normally cover distances considerably greater than the legal minimum. As a further safeguard, first class ships (those licensed to carry 50 or more persons including crew) and many cargo vessels also have available an emergency power source, independent of the shipboard supply, for the radio transmitter.

While the intermediate frequency installation (375 to 500 K.C.) is considered satisfactory for distress and routine traffic over moderate distances use is made of short waves when ranges in excess of 1000 to 1500 miles are required. Various frequencies in the band of 5,500 to 17,100 K.C. (55 to 17 meters) are chiefly used for maritime short wave work. Weather reports transmitted by Government stations on short waves may be copied at great distances by the shipboard operator, and by employing the short wave transmitter, he may keep in touch with shore stations or other ships when in practically any ocean throughout the world. A typical radio room installation is shown in Figure 3.

The shipboard radio installation is also of value for other services not directly connected with distress applications. The U. S. Ice Patrol maintained off the Grand Banks of Newfoundland during the iceberg season, forms a valuable service in broadcasting positions of icebergs so that vessels in the North Atlantic may chart their course to avoid the iceberg zone. For ships which do not carry doctors, there is also available free emergency medical service and many cases are on record where a patient has been successfully treated through instructions sent by radio from shore.

The radio direction finder has been highly developed as an essential aid to navigation when fog, snow or other conditions make visibility at sea uncertain. The direction finder may be used to take bearings on a ship in distress so that the rescuing ship may chart its course to arrive at the disabled vessel in the shortest time. Another common application of the direction finder consists of determining the ship's position by taking bearings on special radio beacon stations which are operated by the various Governments. Approximately 290 of these radio beacon stations are in operation, of which 109 are maintained by the United States. A frequency band of 285 to 315 K.C., (1053 to 952 meters) has been allocated by international agreement for this service.

Since it is considered an aid to navigation, the direction finder on U. S. vessels is usually installed on the bridge or in the chart room so that it may be operated by the ship's officers. A sensitive and selective radio receiver is used in conjunction with a rotatable loop antenna. A handwheel and appropriate compass scale are attached to

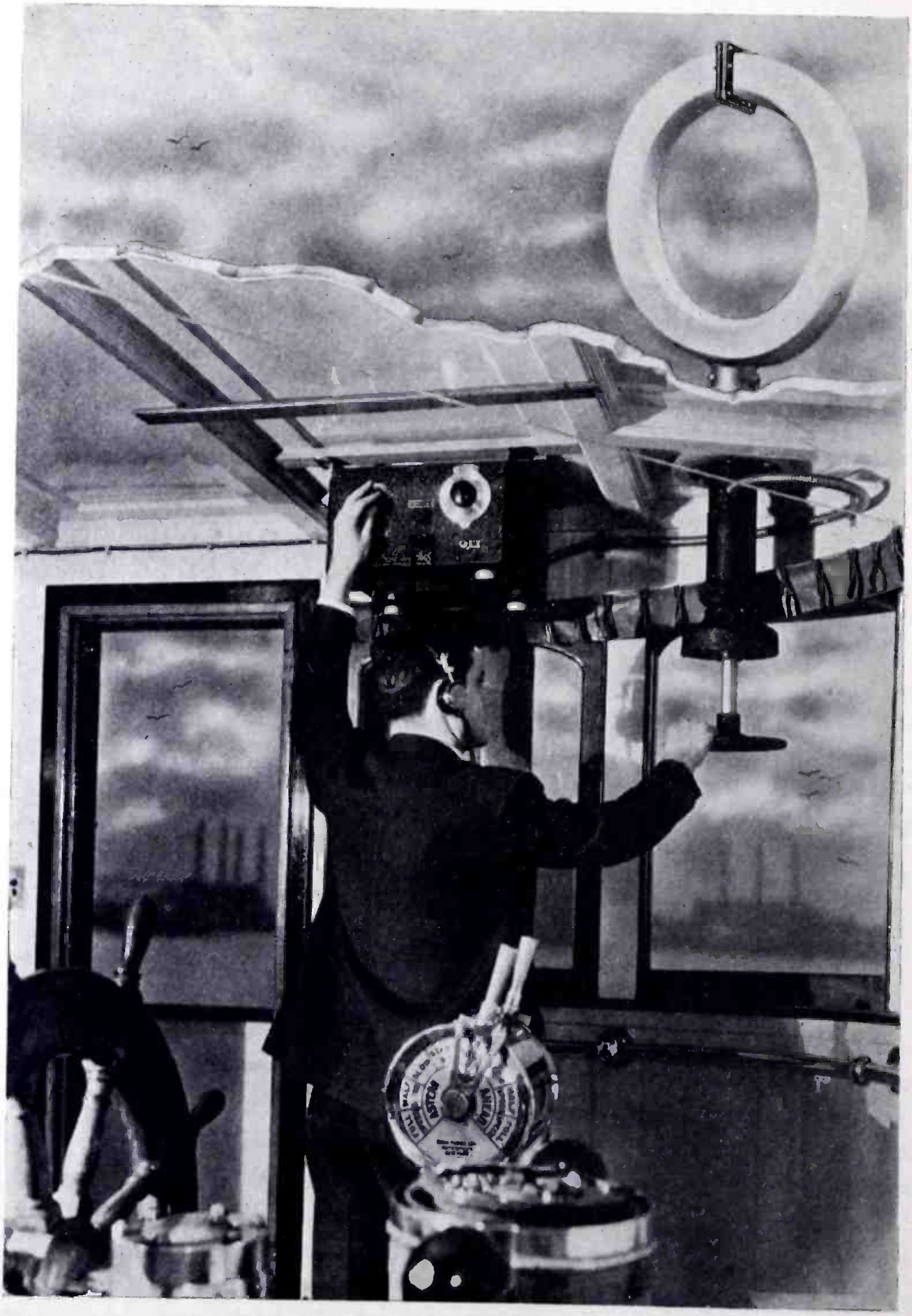

Fig. 4—Small Vessel Direction Finder.

the loop drive mechanism and in many installations the loop indicator is arranged over a Gyro compass repeater. The vessel's position is normally determined by taking bearings on a group of three beacon stations, each of which operates on the same frequency over successive time intervals. The officer tunes the receiver to the incoming beacon signal. He then rotates the loop until the signal is a minimum or at zero intensity and reads the compass scale or pointer attached to the shaft. This procedure is repeated on the other two beacon stations and the three bearings thus obtained are laid off on a chart which shows accurately the location of the three beacon stations. The intersection of the three bearing lines on the chart gives the position of the ship. Other uses of the direction finder may consist of taking several bearings on a single radio equipped lightship or lighthouse near a harbor entrance and then setting the ship's course so as to pass into the harbor safely. In addition to the larger more elaborate models of direction finders available for commercial vessels, there has also been developed a smaller simplified design suitable for use on yachts and other private craft. A view of one of these smaller direction finder installations is shown in Figure 4.

Weather conditions at sea are of prime importance to the navigator. It is not only desirable to observe weather changes in the vicinity of a ship, but also to be able to anticipate conditions ahead on the vessel's course. Radio facsimile weather map service has been under development by the Radiomarine Corporation during the past few years. In February of this year four Trans-Atlantic vessels were equipped with facsimile recording apparatus in order to obtain data under actual conditions at sea.

The new facsimile weather map service is being developed in cooperation with the U. S. Weather Bureau. For some years past arrangements have been made for weather observations to be taken at sea by numerous ships and forwarded by radio to the U. S. Weather Bureau. From this data Dr. James H. Kimball, in charge of the New York office, prepares a map which shows in detail weather conditions over the North Atlantic. With the advent of facsimile it became possible to then transmit to the ships a facsimile copy of the expert map prepared in New York.

As soon as the Weather Bureau completes the map each morning, it is rushed to the transmitting "scanner" at 66 Broad Street, New York City. This is a photo electric device which converts the light and dark sections of the map to appropriate pulses for controlling a powerful short wave transmitter at Rocky Point, Long Island. The method of scanning at the transmitting end is such that the machine

Fig. 5—Charles J. Pannill, president of Radiomarine Corporation of America examining a weather map just received by RCA's newly installed facsimile apparatus on the SS. Ile de France while in mid-ocean. Mr. Pannill has just returned from an executive session of the CIRM, association of marine radio interests of the world, of which he is executive vice-president.

analyses the weather map and converts it bit by bit into electrical impulses, the character and sequence of which correspond to the changes from black to white as the area of the map is explored. The scanning speed is precisely regulated by means of a precision tuning fork control.

The facsimile equipment aboard ship utilizes a similar tuning fork system so that the drum on the recording device rotates in exact synchronism with the machine at New York. A special short wave radio receiver is used on the ship, which is tuned to the incoming facsimile signal. After passing through the radio receiver the facsimile pulses are delivered to a printer amplifier, which in turn energizes an electromagnetic printing bar. A roll of carbon and a roll of white paper are caused to pass under the printing bar and over the rotating drum. Each signal impulse causes the printer bar to press the carbon paper against the white paper, with the result that the map is built up to become a facsimile of the original at the transmitting station.

The complete map as received aboard ship is 8″ x 10″ in size and requires approximately 20 minutes transmission time. No difficulty is experienced in receiving useful maps while the ship is in European waters and in fact maps have been recorded while vessels were in port at Oslo, Bremerhaven and Havre. A transmitting frequency in the 13,000 K.C. band is used for long distance work, while for vessels nearer New York a second transmission in the 6,000 K.C. band is employed. As an extension to the weather map application, news bulletins have also been transmitted over the facsimile system. The type of apparatus used aboard ship is shown in Figure 5.

In addition to the normal S O S signal used for distress at sea, there is also a special international signal to be used in conjunction with the auto alarm. This auto alarm signal consists of 12 dashes sent in one minute, each dash being four seconds long separated by a one second space. The auto alarm equipment consists of a radio receiver broadly tuned to 500 K.C. and a selector mechanism so arranged to recognize and record the four second auto alarm signal and to reject other signals. The selector mechanism is designed to actuate a bell or other warning device upon receipt of the auto alarm signal. Cargo vessels and other similar craft which carry one operator may be fitted with the auto alarm apparatus so that a continuous distress watch is kept even during the periods when the radio operator is not on duty. In the United States the Federal Communications Commission has recently issued specifications for auto alarm equipment which will lead to approved apparatus for installation on American vessels.

On June 20, 1936, the Senate ratified the Safety of Life at Sea Convention with some reservations. Upon the acceptance of these reservations by the nations that have already ratified the Convention and the issuance by the President of the United States of the necessary proclamation putting the regulations of the Convention with the reservations into effect, a large number of American vessels not now so required will be compelled to carry direction finders and emergency apparatus in addition to the usual equipment for radio communication purposes. And a large number of American vessels not now required to carry radio communication equipment will be required either to carry such equipment or to install automatic alarm sets.

A REVIEW OF RADIO COMMUNICATION IN THE FIXED SERVICES FOR THE YEAR 1935

By
C. H. Taylor
R. C. A. Communications, Inc., New York City

Summary—*International communication has been bettered by the opening of eight radiotelegraph and of nine radiotelephone direct circuits. The first around-the-world two-way telephone conversation took place this year in New York over wire to San Francisco, by radio to Java, by radio to Amsterdam, by wire to London and by radio to New York, a total distance of 23,000 miles. Many nations improved their national point-to-point radio communications. In the United States five cities were added to the national networks. The Pan American Airways completed a network of eleven stations in Alaska and built a chain of stations across the Pacific Ocean. To make their installations at Midway and Wake, particularly the latter, an uninhabited island, many difficulties were overcome; for commercial circuits of relatively short length, ultra-short waves were used. The value of these wavelengths for emergency installations was illustrated by their use in the bridging of a forty-mile gap created by the hurricane of September 2, 1935 in the wire-telephone-line circuit between Miami and Key West. General advantage was taken of the technical advances in the art to install improved equipment. The study of the ionosphere continued. John H. Dellinger of the National Bureau of Standards was able recently to associate a fading phenomena which recurs in fifty-four days with the rotation of the sun.*

Introduction

THIS review briefly covers the developments in point-to-point communications for commercial purposes during the year 1935. The importance of radio communications in the fixed service field has not been lessened. Commercial centers scattered over the surface of the globe are pressing for improved intercommunication and in most instances these expansions to existing facilities are being made by new radio circuits.

New International Circuits

The continued demand from the international business for direct service is shown by the following new radiotelegraph circuits opened to the public during the year 1935 between Rome and Shanghai, Tokyo and Rio de Janeiro, Tokyo and Amsterdam, Warsaw and Rio de Janeiro, Warsaw and Buenos Aires, Prague and Buenos Aires, London and Addis Ababa, Ethiopia, and the United States and Tahiti.

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A similar demand is evidenced in the international telephone field by the opening of the following direct radiotelephone circuits between Paris and Moscow, London and Tokyo, Berlin and Tokyo, Tokyo and Siam, Malaya and the Philippine Islands, London and Reykjavik, Copenhagen and Reykjavik, the United States and Santo Domingo, and the United States and Honduras.

The Paris-Moscow radiotelephone circuit was set up to relieve the congestion on wire lines—a notable addition to the use of radio circuits to supplement wire line circuits.

The attainment of long-distance telephony to truly world-wide proportions is well illustrated by the fact that there was carried out during April, 1935, the first around-the-world two-way telephone conversation. The circuit extended from New York City completely around the world, by wire to San Francisco, by radio to Java, by radio to Holland, by wire to London, and by radio back to New York City, a total distance of some 23,000 miles. The conversations took place between officials of the American Telephone and Telegraph Company located in separate rooms in the long-distance telephone building in New York City. This world-circling connection was made possible through the fact that there exist at the several points noted, effective transoceanic short-wave telephone stations which could be interconnected. The success of this linked circuit test naturally entailed the very close co-operation of the several communication agencies involved.

New National Radio Circuits

In the national areas, the expansion of radio communication facilities continued unchecked in all parts of the world. Within the United States, Detroit, Seattle, Los Angeles, Philadelphia, and Camden have been added to the domestic direct radiotelegraph networks.

This year has seen the opening of new circuits, the extension of existing facilities, and the authorization of new construction for radiotelegraph purposes particularly in China, New Zealand, Afghanistan, Russia, Chile, and the French Colonies. Similarly for radiotelephone purposes in Colombia, in China, in Chile, between Italy and the Italian Colonies and between England and South Africa.

The number of wire-telephone systems of cities and towns connected to existing radiotelephone circuits has increased in Brazil, in Colombia, in Argentina, in Paraguay (through Argentine) and in the Philippine Islands. Mention must also be made of the new networks set up for specific services such as that for police work in the States of São Paulo, Brazil, and for aviation in Alaska and over the Pacific Ocean from California to Manila.

In addition to the above listed expansions in the short-wave field, the year 1935 is conspicuous for the steadily increased use of ultra-short waves for fixed services. The most important of these new circuits are between Barcelona, Spain, and the Balearic Islands, the Islands of Molokai and Oahu of the Hawaiian Group, England and the Channel Islands, the mainland and coastal islands of Norway, England and Ireland, and the islands of Japan.

A hurricane in Florida on September 2 provided opportunity for radio to serve in an emergency rôle. The storm washed out a forty-mile section of pole line carrying wire-telephone circuits between Miami and Key West isolating Key West and Havana. Since it was evident that months would elapse before the wire circuits would be replaced upon a permanent basis, some small aviation radio transmitters, together with suitable receivers all battery operated, were hurried to the scene. This equipment, operating on frequencies between four and five megacycles, with transmitter powers of about five watts, proved to be quite satisfactory for temporarily bridging the forty-mile gap. Two emergency circuits were established and the radio transmitters and receivers were arranged for remote control from the Miami and Key West telephone offices.

New Stations and Equipment

Early in the year the Mackay Radio and Telegraph Company opened its new central transmitting station at Brentwood near New York City, N. Y. This company also rebuilt its central receiving station at Southampton, N. Y., and opened a new receiving station at Honolulu. New stations were opened by R.C.A. Communications, Inc., at Detroit, Seattle, and Los Angeles. The Mutual Telephone Company built and opened an ultra-short-wave radiotelephone circuit between Molokai and Maui, Territory of Hawaii. The Pan American Airways built and put into service, a complete chain of radio stations across the Pacific Ocean; these stations are located at Alameda and Los Angeles, California, Hawaii, Midway, Wake, Guam, Manila and Macau. The stations at Midway and Wake, particularly the latter point, required lengthy and careful planning because of the inaccessibility of these stations by regular or normal transportation facilities. This company also extended its facilities in the Territory of Alaska by the addition of eleven stations. At many stations obsolescent transmitters have been replaced by new units of larger output and power. Greater use has been made of directive and directional types of antennas and more highly selective receivers are being installed to enable circuits to be worked with greater freedom from interference.

Automatic Operation of Installations

The trend to design of installations, the equipment of which can be operated without attendance, continues to increase in the short-wave radiotelegraph field. The new installations built by R.C.A. Communications, Inc., for their domestic service have their transmitting units designed and installed for operation unattended. Similarly, the new receiving station of the Mackay Radio and Telegraph Company at Honolulu runs without attendance. At each of the above installations all servicing of the remotely controlled equipment is directed from the associated terminal. The American Telephone and Telegraph Company has operated successfully during this year totally unattended ultra-high-frequency radiotelephone terminals at Green Harbor and Provincetown. Similar installations have been made by the British Post Office at Stranraer, England, and Belfast, Ireland.

The Mackay Radio and Telegraph Company during several months of 1935, keyed one of its commercial high power telegraph transmitters by means of a three-meter control circuit between New York City and Brentwood, N. Y., a distance of approximately forty miles. This ultra-high-frequency circuit, using unattended transmitters and receivers, gave satisfactory service twenty-four hours per day and was used for telegraph speeds on commercial traffic up to 200 words per minute.

A new domestic circuit between New York and Philadelphia, Pa., which R.C.A. Communications, Inc., brought into service in December operates with unattended ultra-high-frequency relay stations at New Brunswick, N. J., and at Arney's Mount, near Trenton, N. J.

Automatic Operation of Equipment

The operation of printers on radiotelegraph circuits received a real impetus from the success of the two-channel multiplex printer equipment used by R.C.A. Communications, Inc., on their New York-London circuit. This Higgett System had been developed by the cables and radio group in London and used successfully on the British Imperial radio circuits to South Africa, India, and Australia. The R.C.A. Communications, Inc., multiplex system has been in commercial use between New York and San Francisco throughout the year 1935. Traffic has been carried on two channels during this period and in November three-channel operation was started. The use of facsimile equipment was not materially expanded during the year. Photoradio service in the national and international fields continued to have commercial value. A photoradio transmission direct from San Francisco to London was made in connection with this year's automobile speed record run of Sir Malcolm Campbell's "*Blue Bird.*" The new ultra-high-frequency R.C.A. Communications, Inc., circuit between New York and Philadelphia introduces a service based on the use of facsimile type of equipment.

TECHNICAL ADVANCES

The trend toward higher power transmitters continued although this is to some extent disguised by the greater use now being made of directive types of antennas. The increased use of crystals with zero temperature coefficient is contributing to the higher order of frequency stability obtained on the more modern transmitters. Fortunately there has also been a reduction in the number of transmitters using modulated emissions for telegraph purposes and a general improvement in frequency stability. This has been materially helped by the improved equipment used for frequency measurements by the Tropical Radio Company, R.C.A. Communications, Inc., and the American Telephone and Telegraph Company at their monitoring stations.

The National Bureau of Standards in the United States extended the range and usefulness of its standard frequency transmissions by adding the frequencies of ten and fifteen megacycles to the former transmission frequency of five megacycles. It is now possible to compare local frequency control apparatus at practically any point in the world with standard frequency transmissions of one or the other of the National laboratories.

The fixed services have taken advantage of the improvements made in vacuum tubes and their associated circuits throughout their newer equipment. These have been of considerable assistance in the exploitation of the field below ten meters. The special tubes now available have made it possible, during this year, to build greatly improved equipment for use in this band. Considerable progress has been made in the study of wave propagation on these frequencies, but exact information on the effects of atmospheric diffraction on fairly long-distance communication is still rather meager. In the field below one meter, the developments during the year were generally limited to improvements in apparatus.

The trend to increased use by medical science and industry of apparatus employing high-frequency currents has changed appreciably the magnitude of our interference problems. Use of such apparatus is becoming widespread throughout the United States, and widely separated receiving installations have complained of interference which has been traced to operation of this type of apparatus.

The studies of the ionosphere by a large number of laboratories initiated in previous years have continued during 1935. Short-wave radiotelephone signal variations over transatlantic and transpacific paths have been investigated in an effort to gain a better understanding of the transmission medium, particularly as affected by magnetic disturbances. Extensive studies of transmission angles and wave paths have been carried on using pulse signals transmitted across the Atlantic. Data published during the year were of principal importance in further correlating conditions of ionization with the position of the sun. The information now available permits communication companies to select frequencies and to design directive antennas on a somewhat more logical basis than has been the case heretofore.

John H. Dellinger of the National Bureau of Standards reported, during the year, the observation of a sudden disturbance of high-frequency transmission lasting about fifteen minutes and recurring at intervals of approximately fifty-four days which corresponds to twice the rotational period of the sun. These fadings occur only on the illuminated side of the globe.

Acknowledgment

The writer desires to acknowledge the valuable contribution of material for this review by officials of Mackay Radio and Telegraph Company, Tropical Radio Company, American Telephone and Telegraph Company, and the Pan American Airways, Inc.

NEW DEVELOPMENTS IN AUDIO POWER TUBES

By

R. S. BURNAP

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SOME attribute common to engineers keeps them perpetually dissatisfied with their own achievements. To this axiom, radio engineers are no exception. After the first enthusiasm over an accomplishment, the true radio engineer seeks to better his results. His search may lead him toward improved performance, lower cost, greater efficiency, or a new method of attack. The direction, however, in which he searches is usually relatively unimportant; the important thing is that he searches. Although it is true that positive results sometimes come slowly, progress is inevitable, especially in a business as dynamic as radio.

For example, consider the field of audio power-tube design. The first audio power tubes were triodes, designed to have low plate resistance and high mutual conductance. These requirements automatically stipulate a low amplification factor and, therefore, a low power sensitivity. Such tubes were (and still are) employed, either singly or push-pull, in Class A_1 Service, i.e., under conditions where the direct plate current does not vary appreciably with signal strength and where the most positive signal swing does not drive the grid or grids positive. Triodes of this type operated in this way produce very little audio distortion. Such distortion as is produced with a single-ended stage is chiefly second harmonic, the least objectionable of the harmonics. In push-pull amplifiers, second-harmonic distortion is eliminated through cancellation. Therefore, from the criterion of distortion, Class A_1 triodes are practically ideal. However, as every engineer knows, it is rare that several ideals can be achieved at the same time. In this respect, Class A_1 triodes are no exception; the triode system requires large signal inputs and delivers audio power with rather poor power efficiency (about 25% as a maximum). The reason for poor efficiency is that the maximum plate-current swing is limited by the fact that maximum plate-current requirements occur at low plate voltage where tube conductance is low.

Regardless of these drawbacks, Class A_1 triodes served very well where low efficiency was not a serious obstacle and as long as power requirements were moderate. The trend some six years ago to higher audio power, partly for greater emphasis of bass notes and partly to offset the lower efficiency of commercial dynamic speakers made it imperative to provide greater tube efficiency. The solution was power pentodes. These tubes employed a screen grid to obtain high amplification and a suppressor to permit the plate voltage to swing with audio signal well toward the zero value. This design made possible tubes, for Class A_1 operation, capable of nearly twice the plate efficiency of a triode and requiring less than one-third the signal input. However, again as with triodes, everything was not ideal. Inherently,

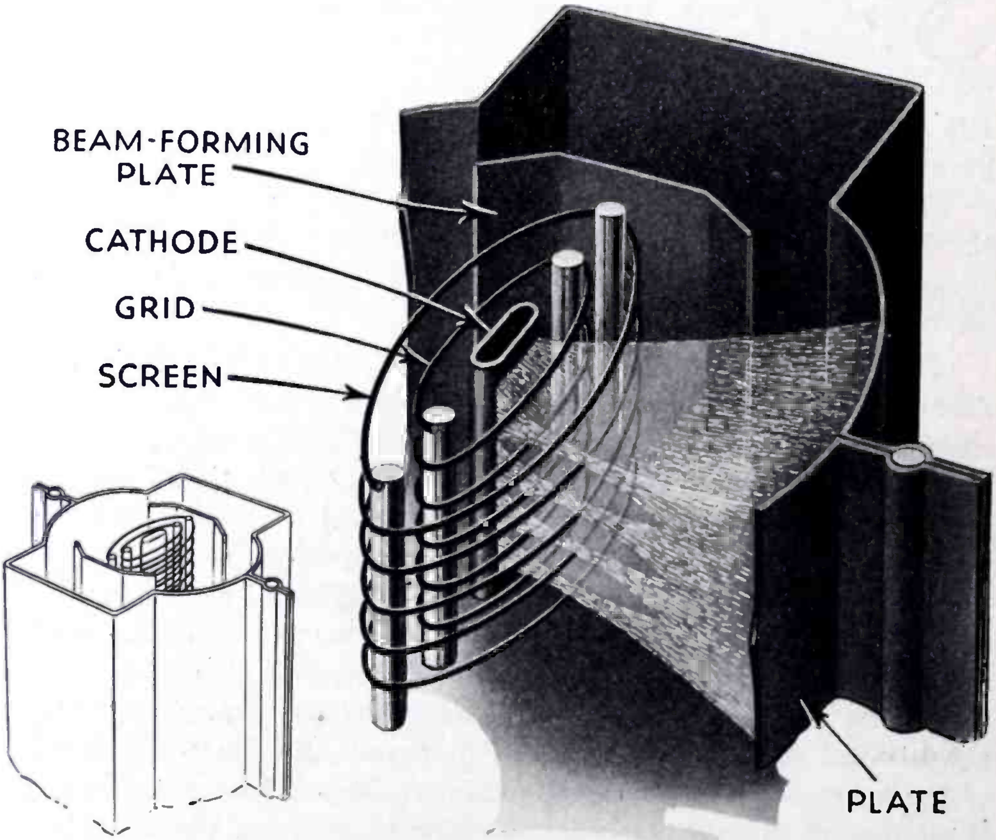

Fig. 1—Structure of Beam Power Tube and Formation by Grid Wires of Beam Sheets.

pentodes were troubled with rather large third-harmonic distortion which unfortunately did not cancel out in push-pull operation.

Regardless of this limitation, power pentodes solved the immediate problem quite acceptably and superseded power triodes in most commercial receivers. But pentodes even with their higher efficiency and power-handling ability did not prove adequate to meet the higher power required to supply the greater realism expected of modern receivers. This requirement was met by departing from conventional Class A_1 operating conditions and permitting the input signal to swing the grid positive. Conventional power triodes and pentodes, as well as specially constructed triodes having high amplification factors, usually operated overbiased to keep down the zero-signal plate current, were employed. By operating these tubes overbiased and driving them so as to draw grid current, it was possible to obtain high efficiency. Furthermore, current drains demanded of the rectifier system were large only at maximum signal inputs. These power amplifiers, however, have certain shortcomings peculiar to all amplifiers drawing grid current; that is, higher-order harmonics, which as a group are particularly disturbing to the ear, are generated whenever the grid

Fig. 2—The Beam Power Tube

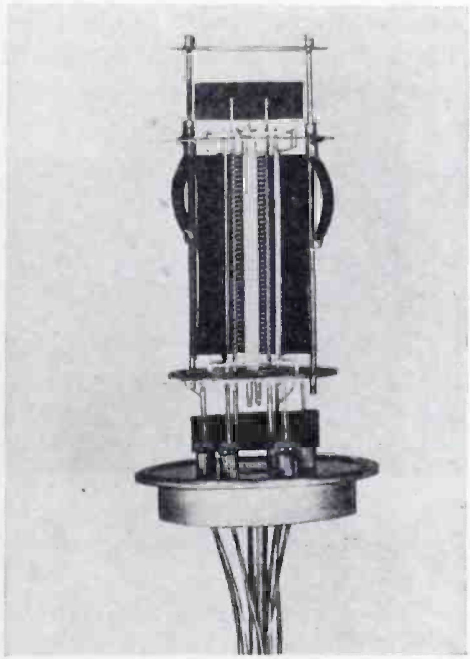

Fig. 3—Mount Section of Beam Power Tube

enters the positive voltage region. Another difficulty is that power is required from the preamplifier stage to drive the output stage. Frequently, the power-handling ability of the driver stage is exceeded and thus excessive preamplifier distortion is added to the output. These shortcomings can be met by suitable design, but the cost rises rapidly for optimum compensation.

While these developments were going on, Mr. Otto Schade of the Research and Development Laboratory of the RCA Radiotron Division had been making a comprehensive analysis of power-tube requirements and design possibilities. Aided by a special cathode-ray oscillograph of his own design which permitted obtaining within a few minutes complete and accurately scaled characteristic curves of any developmental tube, he has produced a new design of power tube combining the low-distortion characteristics of a triode with power sensitivity and power efficiency better than that of the conventional pentode. Power-handling ability is ample. Next to the results obtained, the most interesting feature of Mr. Schade's work is the manner in which the theory of electron behavior in a tube was tested and extended by critical analysis of developmental types. This work is described in detail in Mr. Schade's paper*; here only a brief description of the more striking features can be given.

Early in his investigation, Mr. Schade concluded that a triode design did not offer possibilities of meeting his ideal specifications. In fact, later on he calculated that an ideal triode design comparable to his final tube design would have to have a mutual conductance of

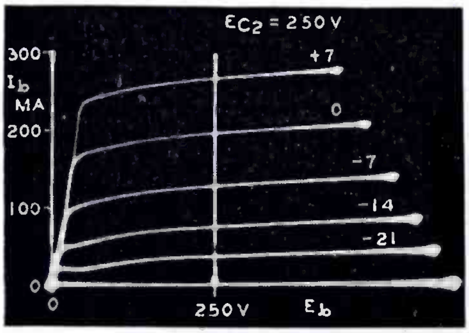

Fig. 4—a. Plate Characteristics for Beam Power Tube.

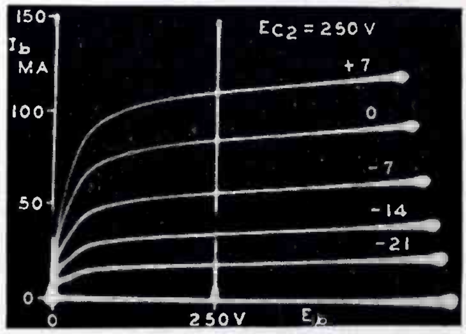

Fig. 4—b. Plate Characteristics for Conventional Pentode.

These curves also illustrate the use of the special cathode-ray oscillograph. By means of a switching mechanism, all curves and lines shown in the photograph appear on the cathode-ray tube screen at the same time. Abscissa and ordinate values can be read conveniently and accurately by adjusting an abscissa reference line to intersect any curve at the desired point. The voltage and the current readings for the point under consideration can then be read on meters in the circuit producing the reference line. This equipment is useful not only for the speed and accuracy with which results can be obtained, but also for the fact that observations can be made of conditions which, due to heating effects, cannot be observed with static methods of measurement.

56,000 micromhos, a value approximately 10 times higher than that of the best commercial triode design. Improvement of the pentode seemed to offer the most profitable field of attack. But what to do? It was known that third-harmonic distortion could be reduced by operating conventional pentodes at lower loads; such operation, however, was not practical because it entailed too much sacrifice in power

* Presented at New York Meeting of the Institute of Radio Engineers on April 1, 1936. Will undoubtedly be published at later date in Proceedings of the I.R.E.

	SINGLE-TUBE OPERATION									PUSH-PULL OPERATION							
Condition	No.1		No.2		No.3		No.4		No.5	No.6		No.7		No.8		No.9	No.10
Class of Operation*	A_1		A_1		A_1		A_1		A_1	A_1		AB_1		AB_1		AB_2	AB_2
Kind of Bias	*Fixed*	*Self*	*Fixed*	*Self*	*Fixed*	*Self*	*Fixed*	*Self*	*Fixed*	*Fixed*	*Self*	*Fixed*	*Self*	*Fixed*	*Self*	*Fixed*	*Fixed*
Heater Volts[1]	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Plate Volts	375	375	200	200	300	300	250	250	375	250	250	400	400	400	400	400	400
Screen Volts	125	125	200	200	200	200	250	250	250	250	250	250	250	300	300	250	300
D-C Grid Volts[2]	−9	−9[3]	−11.5	−11[3]	−12.5	−11.8[3]	−14	−13.5[3]	−17.5	−16	−16[3]	−20	−19[3]	−25	−23.5[3]	−20	−25
Peak A-F Grid Volts	8	8.5	11.5	11.5	12.5	12.5	14	14	17.5	32[4]	35.6[4]	40[4]	43.8[4]	50[4]	57[4]	57[4]	80[4]
Zero-Sig. D-C Plate Current (Ma.)	24	24	52	55	48	51	72	75	57	120	120	88	96	102	112	88	102
Max.-Sig. D-C Plate Current (Ma.)	26	24.3	57	56	55	54.5	79	78	67	140	130	124	110	152	128	168	230
Zero-Sig. D-C Screen Current (Ma.)	0.7	0.7	3.5	4.2	2.5	3	5	5.4	2.5	10	10	4	4.6	6	7	4	6
Max.-Sig. D-C Screen Current (Ma.)	2	1.8	5.7	5.6	4.7	4.6	7.3	7.2	6	16	15	12	10.8	17	16	13	20
Load Resistance (Ohms)	14000	14000	3000	3000	4500	4500	2500	2500	4000	5000[5]	5000[5]	8500[5]	8500[5]	6600[5]	6600[5]	6000[5]	3800[5]
Distortion − Total %	9	9	9	9	11	11	10	10	14.5	2	2	2	2	2	2	**	**
− 2nd Har. %	8	8	8.7	8.7	10.7	10.7	9.7	9.7	11.5	−	−	−	−	−	−	−	−
− 3rd Har. %	4	4	2.5	2.5	2.5	2.5	2.5	2.5	4.2	2	2	2	2	2	2	**	**
Max.-Signal Power Output (Watts)	4.2	4	4	4	6.5	6.5	6.5	6.5	11.5	14.5	13.8	26.5	24	34	32	40 #	60 ##
Power Sensitivity (Milliwatts/volt²)	131	111	60.6	60.6	83.3	83.3	66	66	75.1	28.4	21.8	33.1	25	27.2	19.7	24.6	18.8
Efficiency (%)	42	42.8	32	32.5	37.3	37.7	30	30.6	43.2	37.2	38.3	50	52	51.6	58	56.8	61.2
Peak Grid-Input Power (Mw.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180[6]	350[6]
Bias Resistor (Ohms)	−	365	−	185	−	220	−	170	−	−	125	−	190	−	200	−	−

* Subscript (1) indicates that grid current does not flow during any part of input-voltage cycle. Subscript (2) indicates that grid current flows during some part of input-voltage cycle.

** With zero-impedance driver and perfect regulation, plate-circuit distortion does not exceed 2%. In practice, plate-voltage regulation, screen-voltage regulation, and grid-bias regulation should be not greater than 5%, 5%, and 3%, respectively.

\# An output of 20 watts can be obtained at the grid-current point of Condition 9.

\## An output of 23 watts can be obtained at the grid-current point of Condition 10.

[1] When the 6L6 is operated at maximum ratings, the heater voltage should not exceed 7 volts.

[2] Maximum resistance in the grid circuit should not exceed 0.1 megohm for fixed-bias operation nor 0.5 megohm for self-bias operation.

[3] No signal.

[4] Grid to grid.

[5] Plate to plate.

[6] Driver stage should be capable of supplying this power to the grids of the 6L6's at low distortion. The effective resistance per grid circuit of the Class AB stage should be kept below 500 ohms and the effective impedance at the highest desired frequency should not exceed 700 ohms.

Fig. 5—Summary of Operating Conditions for Beam Power Tube.

output. Third-harmonic distortion appeared when the load line intersected the curving portions of the plate characteristics. Obviously, the desirable thing to do was to straighten out the plate characteristics. The accomplishment of this required careful investigation and analysis to determine the cause of the curvature. Mr. Schade's conclusion was that the suppressor in the conventional tube was the chief offender. While it was true that the suppressor was effective in suppressing secondary emission from the plate, this effectiveness was too great at the grid wires which are at zero potential. As a result, with low plate voltages an increasing number of primary electrons were driven back to the screen and caused a rapid drop in plate current. It was apparent that no practical change in the structure of the suppressor grid could eliminate this curvature. An ideal barrier which would permit unrestricted flow of current to the plate but would completely block current flow in the reverse direction was required. A difficult requirement; nevertheless, one capable of fulfilment. Why not take advantage of the fact that electrons proceeding from a high-potential screen to a low-potential plate slow up and thus build up a zero-gradient space charge at low potential to oppose the relatively low velocity with which secondary electrons start back toward the screen?* To make this solution really successful required unusual attention to design details. The zero-gradient space-charge region must be homogeneous in electron density, must be of adequate density, and must be positioned at the right distance between screen and plate to accomplish the desired results. The attainment of these characteristics was complicated by the fact that the distance between screen and plate must be kept reasonably close so that the tube envelope would be of practical manufacturing dimensions. Mr. Schade achieved the required electron density by confining the electrons to beams; homogeneity of the space-charge region by suitably designing the contours of cathode, grids, and plate; and the positioning of the space charge at low potential by properly adjusting the screen-plate spacing and the beam angle. A further and important innovation was to use screen and control grids of constant pitch so assembled that the screen grid is hidden from the cathode by the control grid. This feature has many desirable virtues: it makes possible the uniform formation of electron-beam sheets between successive turns of the grid wires; it reduces the current intercepted by the screen; it reduces the number of electrons which return to the screen because of their tangential velocity; and it makes possible higher overall efficiency as well as higher power output.

* Some developmental work had been done in Europe, especially by the Electric and Musical Industries Limited in England, along this line.

Fig. 1 shows an artist's drawing of the structure of the new tube and illustrates how the electrons are confined to beams. The beam condition illustrated is that for plate potential considerably less than screen potential; the high space-charge region is indicated by the heavily dashed portion of the beam. The confinement of the electrons is produced by the two beam-confining plates which are at cathode potential. Note that the edges of these plates coincide with the dashed portion of the beam and thus extend the zero-potential region beyond the beam boundaries to prevent stray secondary electrons from returning to the screen outside the beam.

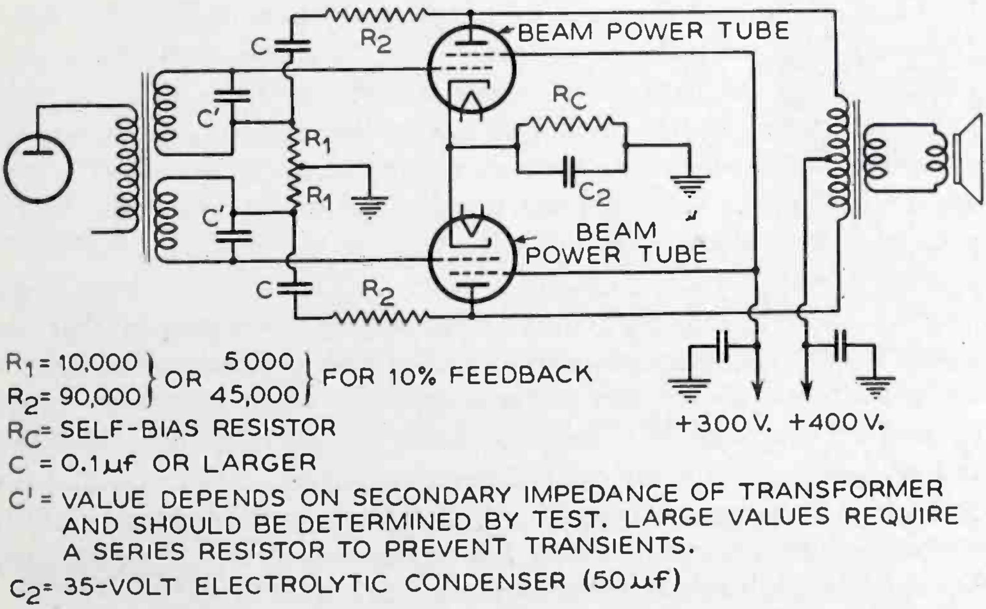

Fig. 6—Inverse Feed-Back Circuit.

Fig. 2 shows a view of the finished tube. Fig. 3 shows a sectional photograph of the mount structure; the control grid is completely hidden by the screen, so that the tube apparently has but one grid. Fig. 4 gives the plate characteristics of the new tube compared to those of a conventional pentode. Note the flatness of the plate characteristics of the Beam Power Tube, the sharpness of the knee, and the extension of the straight portions toward the left. The latter is an important point because it indicates increased power-handling ability and improved efficiency. The efficiency of this new tube is remarkable. Two of these tubes in a push-pull Class A_1 amplifier, operated self-biased at a plate voltage of 400 volts and a screen voltage of 300 volts, can produce 32 watts of audio power at an overall efficiency of 45% including losses due to screens, plates, self-bias resistor, and heaters. Under these same conditions, the peak signal input per tube is only 28.5 volts; the total harmonic distortion is the very low value of 2 per cent consisting almost entirely of the third harmonic. The higher-order harmonics are negligible. Fig. 5 tabulates in detail the performance capabilities of this new tube, now identified as the RCA-6L6.

In the introductory paragraphs, no mention was made of an undesirable performance characteristic of loud speakers supplied from high-impedance tubes. At the resonant frequency of the speaker, speaker efficiency rises to a high value and produces an unpleasant booming unless the tube has sufficiently low resistance to damp the action. To a satisfactory degree, the plate resistance of power triodes is low enough to provide suitable damping. With pentodes, this is not the case. Like pentodes, the Beam Power Tube also has a high plate resistance, but due to the high power sensitivity of the 6L6 it is practical to use a circuit, previously of rather academic interest for receivers, which causes the tube to provide damping action. The procedure is simple. Voltage from the plate circuit is fed back to the grid in inverse phase. By suitably adjusting the feed-back ratio, any desired damping can be obtained. Fig. 6 illustrates the circuit elements. The only adverse effect on circuit performance is that the power sensitivity decreases. Power output and efficiency remain essentially the same as for conventional circuits, while distortion is decreased by approximately the same factor as the required grid signal is increased to obtain the desired damping action. Thus, the 6L6 can be used to obtain power sensitivity, distortion, and damping, equal to or better than that of the best power triode and, at the same time, maintain its high efficiency and power-output capability.

Truly, this latest audio power-tube development represents progress.

OUR CONTRIBUTORS

HAROLD H. BEVERAGE is an alumnus of the University of Maine, from where he received a B.S. degree in Electrical Engineering. Following his graduation he spent five years with the General Electric Company, the latter four years in Dr. Alexanderson's radio laboratory. In that period the Alexanderson Alternator was being developed. When the U. S. Navy took over the high-powered transmitting station at New Brunswick, Mr. Beverage assisted in the installation there of an Alexanderson Alternator and special receiving equipment for the Navy's program of using that station for transoceanic communication. During the early tests the receivers were under Mr. Beverage's care. In 1920 he became Research Engineer on Communication Receivers for the Radio Corporation of America and in 1929 transferred to R.C.A. Communications, Inc., for which company he now is Chief Research Engineer. In 1923 Mr. Beverage was awarded the Morris Liebmann Memorial Prize for outstanding contributions in radio antenna development.

LEWIS M. CLEMENT, Vice-President in Charge of Engineering and Research of the Victor Division of RCA Manufacturing Company, Inc., started his radio career in 1914 as assistant chief engineer in the California-Hawaii radio communications service. Two years later he joined the Bell Telephone Laboratories from which he supervised the establishment of the first radio-telephone link between Catalina Island and Los Angeles. During the war he was in charge of design and development of all electric-radio apparatus for use by U. S. Government services. In 1925, Mr. Clement became Chief Engineer of the Fada Radio Company, and three years later Vice-President and Chief Engineer of the Kolster Radio Company. Following this, he was for a year Assistant Manager of the Radio Department of the Westinghouse Electric and Manufacturing Company, when he became Chief Engineer of radio receiver design for the International Standard Electric Company. His duties in this capacity, which he maintained until his present RCA appointment, consisted of engineering the radio receivers for eight foreign factories located in South America, Australia, Budapest, Antwerp, London, Paris and Berlin.

E. W. ENGSTROM is the man responsible for the development and design of apparatus used in the present RCA television field test. He is Director of General Research for the Victor Division of the RCA Manufacturing Company, Inc. Since joining that company in 1930 he has been associated with engineering on Photophone apparatus, broadcast receivers and research. Prior to that he devoted seven years to radio transmitters and receivers while in the engineering organization of the General Electric Company. Mr. Engstrom graduated from the University of Minnesota in 1923.

ROBERT M. MORRIS attended the Western Reserve University and the Case School of Applied Science, following which he joined the Western Electric Company. He became a member of the original staff of Broadcasting Station WEAF when that station was inaugurated by the American Telephone and Telegraph Co., in 1924, and has since been closely associated with it. In 1927, following WEAF's acquisition by the newly-organized National Broadcasting Company, he became a member of NBC's technical organization. He is now Development Engineer of NBC. Mr. Morris is a member of the Acoustical Society of America and an Associate Member of the Institute of Radio Engineers.

DR. HARRY F. OLSON received his B.E. degree in 1924, M.S. in 1925, Ph.D. in 1928, and E.E. in 1932, from the University of Iowa. Eight years ago he became an RCA engineer and in that time spent two years in Photophone development work. He is now Research Engineer in the Victor Division of the RCA Manufacturing Company, Inc. Dr. Olson is a member of Sigma Xi, and of the American Physicial Society, and is a Fellow of the Acoustical Society of America.

DR. VLADIMIR K. ZWORYKIN received his degree in Electrical Engineering from the Petrograd Institute of Technology in 1912, where he also started his experiments in Television. Later he studied in Paris and with the coming of the war, served as an officer in the Signal Corps of the Russian Army. Dr. Zworykin came to the United States in 1919 and joined the Westinghouse Company. He received his Ph.D. from the University of Pittsburgh and in 1929 joined RCA. He is at present Director of the Electronic Research Laboratory of the RCA Manufacturing Company, Inc.

IN EVERY era of American radio CHARLES JACKSON PANNILL has been an outstanding figure. He pioneered in radio as did his Virginia ancestors in railroad building. His first interest in telegraphy dates back some 38 years ago when he was a telegrapher in the "Coast Signal Service" of the United States Navy. In 1902 he assisted Professor Reginald A. Fessenden in Fessenden's famed early experiments and, later, he took part in the historic tests from Brant Rock, Massachusetts, in which, among other achievements, communication was established with Scotland. Mr. Pannill installed the first radio equipment on a U. S. battleship; he inaugurated the first communication by radio between New York and Philadelphia (a real achievement at that time in 1903); he received the first U. S. radio operator's license and, during the world war period, compiled the first comprehensive naval radio regulations in the form still in use, while acting as expert radio aide and later Assistant to the Director of Naval Communications. He joined the U. S. Naval forces in November 1914 and remained until January 1919. Following the war he became Director of Mallory Industries, Inc., Vice President and Director of Liberty Electric Corporation, and Vice President and General Manager and Director of the Independent Wireless Telegraph Company, of which he later became President. He is now President and Director of Radiomarine Corporation of America; President and Director of RCA Institutes Inc., Executive Vice President of the Comite International Radio-Maritime, Brussels, Belgium, and Chairman of the Board of Editors of RCA REVIEW. While in Washington he was a member of the Cosmos Club and Washington Society of Engineers. He is a Fellow, Institute of Radio Engineers, Member of the Society of Naval Architects and Marine Engineers, Member New York Maritime Exchange, as well as several city and country clubs.

CHARLES HENRY TAYLOR, vice-president in charge of engineering for RCA Communications, has seen radio advance from a tiny spark-coil set capable of working ten miles, to a giant tube transmitter communicating with the Antipodes. As the new communication grew, he grew with it, and today he controls the engineering destinies of the largest communication system in the world. He took the course in electrical engineering at Heriot-Watt College, in Edinburgh following which he joined the Wireless Telegraph and Signal Co.—later Marconi's Wireless Telegraph Co. His early activities included work on the development of the jigger, in connection with Marconi's famous patent on tuned circuits; service in South Africa with Marconi apparatus in the Boer War, and experimental work in the Marconi factory at Chelmsford. He came to America in 1902 to complete station CC at South Wellfleet, and to erect two Alaskan stations. In 1919 he became a member of the Communications Engineering Department of RCA after 20 years of service as an engineer for the English and the American Marconi Companies. Mr. Taylor is a Fellow of the Institute of Radio Engineers.

ROBERT S. BURNAP is an M.I.T. man with a B.S. degree in Electrical Engineering, which he received in 1916. Following that he spent a year as Research Assistant in Illumination, Massachusetts Institute of Technology, and then went to the Edison Lamp Works of the General Electric Company, where he engaged in research, factory and commercial engineering activities for 13 years, with the exception of the war period, which he spent in service with the U. S. Army Signal Corps. In 1930 he became Engineer in Charge of Commercial Engineering Section, RCA Radiotron Division, and is still occupying that post. Mr. Burnap is a Fellow of the Society of Motion Picture Engineers, Associate Member of the Institute of Radio Engineers, and a Member of the American Institute of Electrical Engineers.

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