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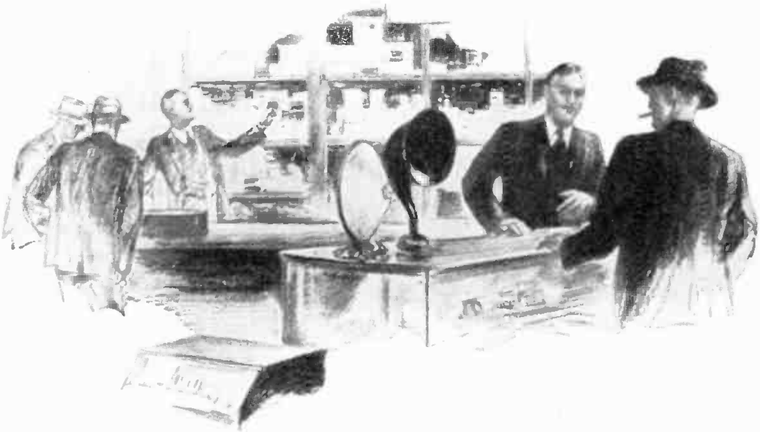

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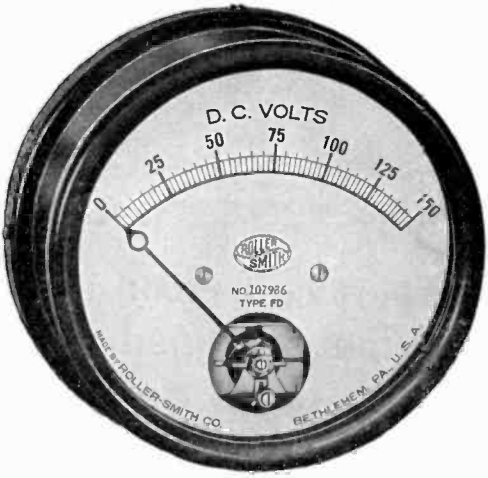

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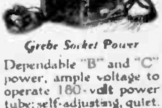

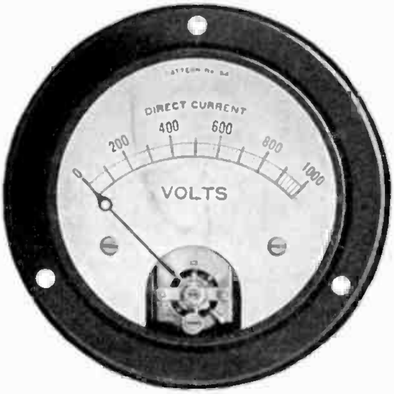
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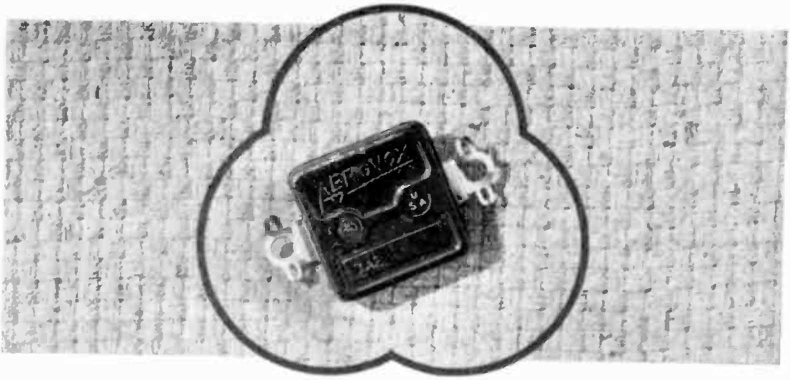

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PROCEEDINGS OF

The Institute of Radio Engineers

VOLUME 15 JUNE, 1927 NUMBER 6

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INSTITUTE ACTIVITIES

PRELIMINARY REPORTS OF I. R. E. STANDARDIZATION SUBCOMMITTEES

The preliminary drafts of reports of three of the Subcommittees of the Standardization Committee have been compiled and are now available in printed form for distribution to interested members and non-members of the Institute.

These reports have been submitted by the Subcommittee on Vacuum Tubes, Receiving Sets and Electro-Acoustic Devices.

It is desired that a copy of these reports be placed in the hands of every person interested in radio standardization in order that comments and criticisms may be made before the reports have been acted upon by the Standardization Committee.

A copy of the reports will be mailed promptly upon application to the headquarters of the Institute.

MAY MEETING OF BOARD OF DIRECTION

At the meeting of the Board of Direction of the Institute held on May 4, 1927 the following were present: Dr. Ralph Bown, President; Dr. A. N. Goldsmith, Secretary; W. F. Hubley, Treasurer; Donald McNicol, Junior Past President; Melville Eastham, L. A. Hazeltine, R. A. Heising, J. V. L. Hogan, R. H. Manson, R. H. Marriott, L. E. Whittemore and J. M. Clayton, Assistant Secretary.

The following Associate members were transferred to the grade of Member: F. Cheyney Beekley, Donald G. Little and J. A. J. Cooper.

Trinidad Matres was elected to the grade of Member.

One hundred and seventeen Associates and twenty-five Juniors were elected.

NEW YORK MEETING OF THE INSTITUTE

At the May meeting of the Institute held in the Engineering Societies Building, 33 West 39th Street, New York, on May 4, 1927 two papers were presented.

The first one, by Dr. Irving Wolff and A. Ringel, on "Loud Speaker Testing Methods" was presented by Dr. Wolff. This paper was illustrated by lantern slides. Copies were also available in preprint form.

The second paper was "On Quality of Speech and Music", presented by J. B. Kelly. Demonstrations to the effect of dropping frequencies from voice and music were given.

The papers were discussed by Messrs. Bown, Herbst, Frederick, Maloff, Fletcher, Vreeland, Furness, Minton, Cutting, Austin, Ringel, Wolff and others.

The attendance at this meeting was over three hundred and fifty.

NO JULY AND AUGUST INSTITUTE MEETINGS

There will be no meetings of the Institute during the months of July and August. The Institute offices will be open as usual, however, for the transaction of Institute business.

News of the Sections

PHILADELPHIA SECTION

The March meeting of the Philadelphia Section was held on the 25th of the month in the Bartol Laboratories, Philadelphia. J. C. Van Horn was the presiding officer.

A paper was presented by W. W. Knight on, "The Rejuvenation of Composite Radio Broadcasting Stations". This paper was discussed by many of the members.

The attendance at this meeting was over one hundred.

The April meeting of the Philadelphia Section was held in the Bartol Laboratories on April 22nd. J. C. Van Horn was the presiding officer.

Roger W. Barrington, Jr. read a paper, "Development of the Radio Receiver". This paper was discussed by R. S. Milne, R. L. Snyder and others.

The attendance was one hundred and twenty-five.

Following the meeting an inspection of the Bartol Laboratories was made by the members.

The next meeting of the Philadelphia Section will be held on May 27th in the Bartol Laboratories. Professor Charles Weyl of the University of Pennsylvania will deliver a paper entitled, "Reproduction of Sound".

CLEVELAND SECTION

The Cleveland Section held a meeting in the Case School of Applied Science on April 22nd. Ralph E. Farnham presided.

Two papers were presented. The first on, "Transmission of Pictures by Wire" was by R. S. Breese of the American Telephone & Telegraph Company.

The second by John A. Victoreen of the Victoreen Research Laboratories was on, "Photo Electric Cells".

The two papers were discussed by the members present. There were fifty-nine members in attendance.

The next meeting of the Cleveland Section will be held on May 26th in the Case School of Applied Science at which time W. C. Blackburn of the Western Electric Company will deliver a paper on "High Quality Reproduction".

CANADIAN SECTION

On May 4th a meeting of the Canadian Section was held in the Electrical Building of the University of Toronto. D. Hepburn presided.

A paper on "Electrolytic Condensers for 'A' Current Filters" was read by C. I. Soucy. This paper was presented by E. F. Andrews before the Chicago Section on February 25, 1927.

The result of the annual general meeting of the Section in the election of new officers of the Section is as follows: Honorary Chairman, Professor T. R. Rosebrugh; Chairman, A. M. Patience; Vice-Chairman, C. I. Soucy; Secretary-Treasurer, C. C. Meredith and Assistant Secretary, V. G. Smith.

Following this meeting ten manufacturers of radio equipment had arranged for a display of their new apparatus at the meeting place.

The Canadian Section will hold its next meeting on September 1st, 1927.

SEATTLE SECTION

A meeting of the Seattle Section was held in the Club Room of the Telephone Building, Seattle, on April 9th. W. A. Kleist presided.

Two papers were read. The first was entitled, "Copper Oxide Rectifiers" and was presented by J. A. Burleigh. The second paper was by J. J. Ritter on, "A New Type of Electrolytic Condenser".

These papers were discussed by Messrs. Burleigh, Tolmie, Anderson, Syllvester, Libby and others.

The Chairman announced the appointment of the following Standing Committees of the Section: Meetings and Papers Committee—J. R. Tolmie (Chairman), H. E. Renfro, J. W. Greig and H. F. Mason. Membership Committee—C. E. Williams (Chairman), J. A. Burleigh and M. L. Wooley.

CONNECTICUT VALLEY SECTION

On May 6, 1927 a meeting of the Connecticut Valley Section was held in the auditorium of the Hartford Electric Light Company, Hartford, Conn. Dr. W. G. Cady was the presiding officer.

The meeting was addressed by D. G. Little of the Westinghouse Electric and Manufacturing Company on, "Some Experiences as a Radio Engineer" in which the speaker described the design of recent high power short wave radio equipment.

The discussion was participated in by Dr. Cady, Dr. Van Dyke and Messrs. Little, Hull, Kruse, Bourne, French, Brackett and others.

ROCHESTER SECTION

The Rochester Section held its April meeting on the 15th of the month in the Sagamore Hotel, Rochester. H. J. Klumb presided.

The meeting was addressed by Charles Bartlett who gave a talk on "Measuring Instruments Used in Radio".

Forty members attended the meeting.

The next meeting of the Rochester Section will be held on May 20th in the Sagamore Hotel. B. Olney will read a paper on "Acoustics".

LOS ANGELES SECTION

On April 18th the Los Angeles Section held a meeting in the Los Angeles Elks Club. Don Wallace presided.

Harry Fore of the Philadelphia Storage Battery Company presented a talk on "Socket Power Devices, Their Construction and Operation".

There were thirty-five members present.

WASHINGTON SECTION

The Washington Section held a meeting on April 13th in Harvey's Restaurant, 11th and Pennsylvania Avenue, N. W., Washington. Dr. J. H. Dellinger presided.

Dr. L. P. Wheeler of the Naval Research Laboratory delivered a talk on "The Establishment of Standard Radio Frequencies".

It was decided to hold future meetings of the Washington Section on the second Thursday of each month instead of the second Wednesday.

The next meeting of the Section will be held on May 12th at which time Commander S. C. Hooper, U. S. N. will deliver a paper on "The Mission and Scope of Naval Radio". This meeting will be held in Harvey's Restaurant.

PROPOSED NEW SECTIONS

Activity in the establishment of new Sections of the Institute continues. Correspondence looking to the formations of Sections in Milwaukee, Wisconsin; Atlanta, Georgia and Buffalo, New York is being held, in addition to the Section formation activities previously mentioned in the Proceedings.

In Milwaukee two organization meetings have been held. D. S. W. Kelly has been elected chairman of the temporary organization and S. Snead has been elected temporary Secretary.

In Atlanta, the preliminary organization work is being sponsored by The Atlanta Association of Radio Engineers, Major Walter Van Nostrand being the chairman of the Committee on Organization of an Institute Section. One organization meeting has been held, and it is contemplated that additional meetings will be held in the near future.

The Buffalo work has been initiated by C. J. Porter. The first organization meeting will be held in the near future.

Past Numbers of the PROCEEDINGS

Back copies of the PROCEEDINGS, except as listed below, are available from the Institute. From Vol 1 to Vol. 14, inclusive, these copies sell at $1.50 each. Copies of Vol. 15 can be supplied at $1.00 per number. In both of these cases members of the Institute are entitled to a discount of 25 per cent.

In the case of several of the numbers the stock of back issues is quite small. Additional copies will *not* be available when the present supply is exhausted.

As time goes on these back numbers of the PROCEEDINGS become increasingly valuable. Not only are the most important elements in the history of the engineering side of radio presented in these older issues, but practically no important phase of the radio arts or science can be named which has not been considered in the PROCEEDINGS at one time or another.

Members of the Institute who contemplate desiring to complete their files of the PROCEEDINGS should secure these copies before the stock is exhausted.

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Vol. 1, No. 2; Vol. 2, Nos. 3 & 4; Vol. 3, Nos. 1, 2 & 3; Vol. 4, Nos. 1 & 2; Vol. 5, No. 1; Vol. 6, No. 5; Vol. 7, Nos. 3 & 5; Vol. 9, No. 3; Vol. 11, No. 6; Vol. 12, Nos. 1, 2 & 3; Vol. 13, Nos. 1 & 4.

Bound volumes from Vol. 5 (1917) to volume No. 16 (1926) are available at $11.00 per volume, with the usual 25 per cent. discount to members.

Fourteen Year PROCEEDINGS Index

Work is practically completed on a very comprehensive Index of the PROCEEDINGS covering the past fourteen years. This Index includes not only a list of papers and authors, but also a cross-index by means of which papers on related subjects can be located quickly.

When available a copy of the Index will be sent free of charge to each member of the Institute. The price to non-members will be one dollar per copy.

Committee Work

SECTIONAL COMMITTEE ON RADIO, A. E. S. C.

The following is a report of the activities of the Technical Committees of the Sectional Committee on Radio, A. E. S. C., for March, 1927:

Committee on Transmitting and Receiving Sets and Installations

This Committee has no activities to report during the month.

Committee on Component Parts and Wiring

The Subcommittee of this Committee is active and will report to the main Committee at its next meeting in May.

Committee on Electro-Acoustic Devices

No March meeting was held by this Committee. A meeting will be held at an early date, however, at which time the electro-acoustic standards as proposed by the National Electrical Manufacturers Association in its Year Book, and by the Subcommittee of the Institute of Radio Engineers, will be available for consideration and study.

Committee on Vacuum Tubes

Material dealing with standardization of the dimensions of vacuum tube bases is available to this Committee and will be considered by the Committee at a forthcoming meeting.

Committee on Power Supply and Outside Plant

No activities of this Committee were reported for the month of March.

I. R. E. Subcommittee on Vacuum Tubes

At its meeting on May 6th, the Subcommittee on Vacuum Tubes completed its work, and has submitted its report to the Committee on Standardization of the Institute (this report will be found in the preliminary drafts of reports of the three Subcommittees which is available on request). The subject assigned to the Subcommittee was the recommendation of suitable methods for testing vacuum tubes. In addition to making selections from the various methods already in common use for measuring the characteristics of vacuum tubes, and specifying the conditions of test, two matters have been brought forward which had not been generally known in the art and which are especially interesting.

The *emission characteristic curve*, showing the relation of filament emission current to power which heats the filament, cannot usually be determined experimentally up to normal filament power without damaging the vacuum tube. A method of plotting experimental data, taken at reduced power, on a special "power-emission chart" results in a straight line which can be readily extended to normal power. The development of this chart is due to Dr. C. Davisson of the Bell Telephone Laboratories, who, together with M. J. Kelly of the Subcommittee, plans to present a paper on the subject in the fall.

The procedure heretofore commonly followed in measuring the *capacity between two electrodes of a vacuum tube* was to leave the third electrode on open circuit, or floating in potential. It was found that this procedure gave misleading results; it did not measure the direct capacity between the two electrodes (which is the important thing), but rather a combination of all three direct capacities present in a vacuum tube. Several methods of measuring direct capacity have been devised and studied under the direction of members of the Subcommittee. These have proven so satisfactory that it is recommended that all measurements of capacity with one electrode floating be abandoned in favor of direct capacity measurements. It is hoped to have several short papers on this subject prepared for presentation to the Institute.

The notation to be employed in connection with vacuum tubes has long been a bone of contention, as indicated, for example, by the recent presentation before the Institute of a paper on that subject by Professor Chaffee. The Subcommittee has studied the question and has prepared definite recommendations. The recommendations that received the most attention were current practice and convenience in printing and typing. It was found possible to recommend a system which satisfied both requirements and which, in particular, completely avoided special character signs.

I. R. E. Subcommittee on Receiving Sets

The Subcommittee on Receiving Sets held an all-day meeting on May 5th, in order that a tentative report on its work to date could be presented to the Institute for printing. The standardization of tests on radio receiving sets opened such a large field, that the subcommittee decided to restrict its scope for the present to broadcast receiving sets. Furthermore, detailed consideration has so far been given only to over-all tests; but it is planned to include in the final report tests on the parts which make up a complete receiving set, such as radio-frequency and audio-frequency amplifying transformers.

The essential technical properties of a broadcast receiving set are sensitivity, selectivity, and fidelity. The term "fidelity" has been recommended for adoption to take the place of the very general word "quality" and to signify the accuracy of reproduction at the output terminals of the modulation of the received wave. All three properties are to be determined by impressing a simple modulated radio-frequency voltage in the antenna circuit (using the self-contained antenna, if the set is so provided—otherwise a standardized artificial or real antenna circuit), and reading the output into a non-inductive resistor of proper resistance connected in place of a loud-speaker.

To determine *sensitivity* the input is adjusted to give a so-called "normal output" of 0.05 watt at a series of wave frequencies within the broadcast band. The input voltage is reduced to equivalent radio field intensity, and this is plotted on a graph against wave frequency. Values of modulation frequency (400 cycles) and percentage (30%) have been tentatively set.

To determine *selectivity*, the receiving set is tuned to a certain "standard test frequency" and the radio frequency input is varied simultaneously in voltage and in frequency so as to maintain a so-called "interference output" equal to one ten-thousandth of the "normal output" (that is equal to 0.00050 watt). Equivalent radio field intensity is plotted against carrier frequency. The test is then repeated for the other "standard test frequencies", these being tentatively set at 600, 800, 1000, 1200, 1400 kilocycles.

To determine *fidelity*, the receiving set and the input are both tuned to a standard test frequency and the modulation frequency is varied from 40 to 10,000 cycles, the input voltage being held constant at the value giving normal output at 4000 cycles modulation, and the modulation being 30% throughout. The relative voltage at the output terminals is measured and plotted against frequency. The test is then repeated for the other standard set frequencies.

SHORT-WAVE COMMERCIAL LONG-DISTANCE COMMUNICATION*

By

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I—HISTORY AND DEVELOPMENT

The engineers of the Radio Corporation of America followed with keen interest, the short wave experiments on this side of the Atlantic conducted during the winter of 1921-1922, as well as the contemporaneous European developments in this ultra high-frequency field. This interest was further stimulated during the early short wave re-broadcasting experiments of the General Electric and Westinghouse Companies. Many measurements were made during this period with the purpose of determining whether these short wave signals would be suitable for dependable long distances telegraph communication. The results of these early rebroadcast observations were, in general, not encouraging. They indicated wide signal variations with light and darkness, and extremely bad fading.

It is not surprising in view of these early observations that the first short wave telegraph transmitter constructed by the Radio Corporation should have been designed for experimental radio relay service. This transmitter was built early in 1923 at the Transoceanic Receiving Station at Belfast, Maine. It was hoped that this installation would provide the means for studying the effectiveness of short waves for the relaying of the incoming trans-Atlantic long wave signals supplementing the land lines from Belfast, Maine to New York City, a distance of about 400 miles. A general view of this experimental short wave radio relay transmitter is shown in Figure 1.

"2XAO" the Belfast relay transmitter proved more valuable in the study of propagation phenomena, and in pointing the way to many important transmitter developments

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than as a radio relay. The art was not sufficiently advanced at that time to bear the heavy responsibility of commercial trans-Atlantic relaying.

In the meantime, the Radio Corporation had contracted with its manufacturing companies for the construction of a number of experimental short wave telegraph transmitters. The first of these was installed in August 1923 at the high power trans-Atlantic Station at Tuckerton, New Jersey. It operated under the call letters "WGH" on a wavelength of 103 meters. Its first commercial use was on the evening of

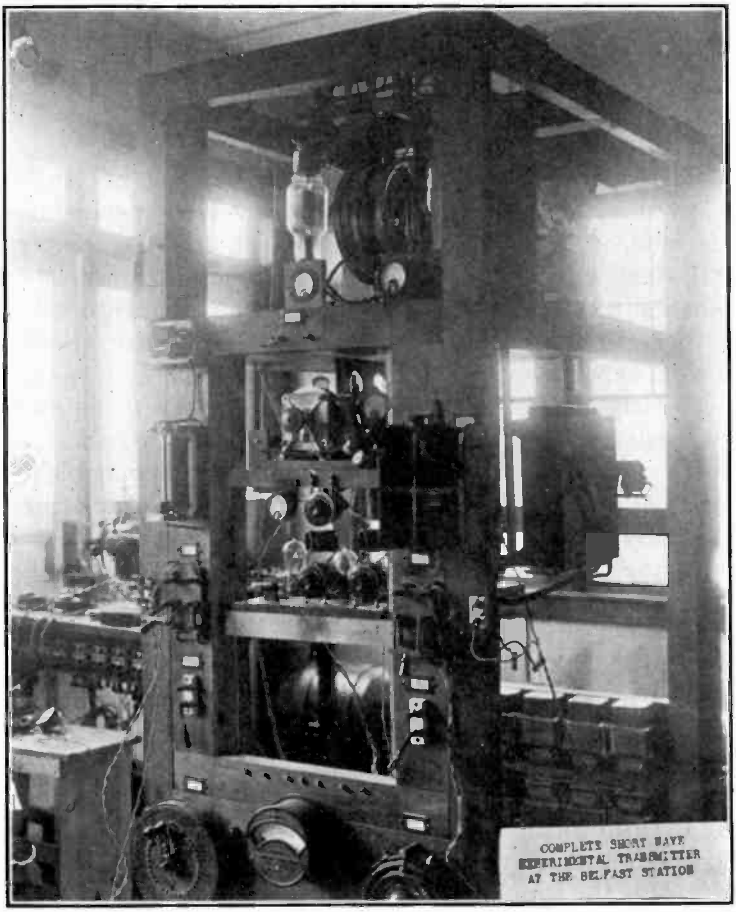

Figure 1—Experimental short wave radio relay transmitter 2XAO—Belfast, Maine.

September 11, 1923 when a ringside account of the Firpo-Wills fight was sent to Buenos Aires by this transmitter.

"WGH" represents the first serious attempt by the Radio Corporation at long distance communication via short wave channels. It was used as an auxiliary to the 200-kilowatt alternators, serving intermittently for communication to Berlin, Paris, and to Buenos Aires. It was operated regularly but at comparatively slow speeds for a period of several months during the hours of darkness.

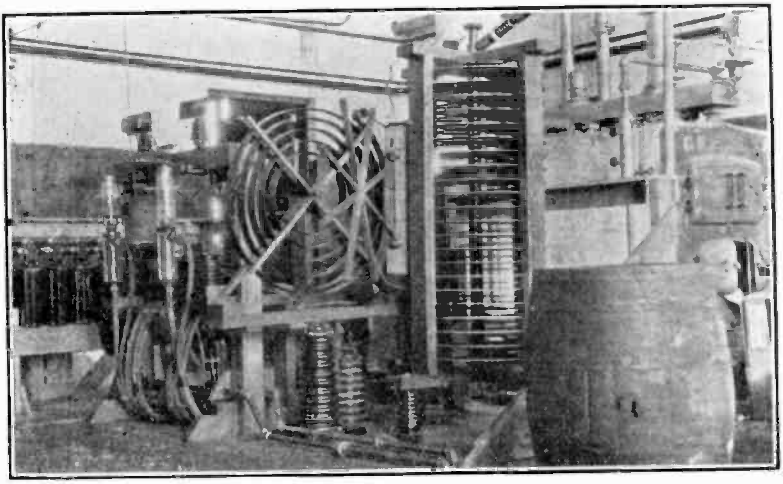

Figure 2—Experimental 103-meter short wave transmitter WGH, Tuckerton, N. J.

A view of the original "WGH" installation is shown in Figure 2. It was of the self-excited type using two water-cooled tubes in a Hartley circuit. The self-excited circuit, due to its susceptibility to frequency fluctuations, soon gave way to a master oscillator-power amplifier type of circuit. A push-pull amplification system was adopted throughout. The two water-cooled tubes functioned as a push-pull power amplifier. The addition of the master oscillator proved of considerable value in stabilising transmission and increasing traffic speeds.

During the spring of 1924 the "WGH" installation was followed by the distribution of 5 additional experimental short wave transmitters to the various high power stations of the Radio Corporation world network. These units were originally of the self-excited type similar to "WGH"; but were subsequently converted to master oscillator power amplifier types and eventually fitted with piezo-electric crystal control.

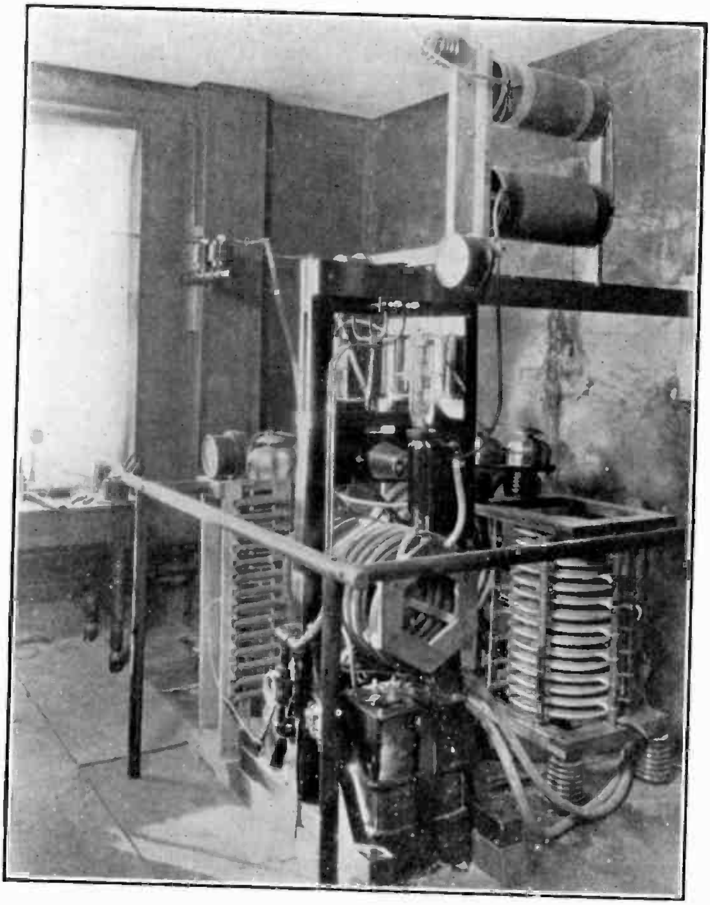

Figure 3—Experimental 95-meter short wave transmitter—KEL, Bolinas, California.

The call letters, distribution and operating wavelengths of these five transmitters were as follows:

KEL —95 meters—Bolinas, California,
KIO —90 meters—Kahuku, Hawaii,
WIR —74 meters—New Brunswick, New Jersey,
WQN—51.5 meters—Rocky Point, Long Island,
WIZ —43 meters—New Brunswick, New Jersey.

Figure 3 is a photograph of "KEL" the 95 meter installation at Bolinas, California, which may be considered typical of this group of experimental transmitters. The master oscillator and intermediate amplifier stages which were subsequently added as shown in Figure 4. In Figure

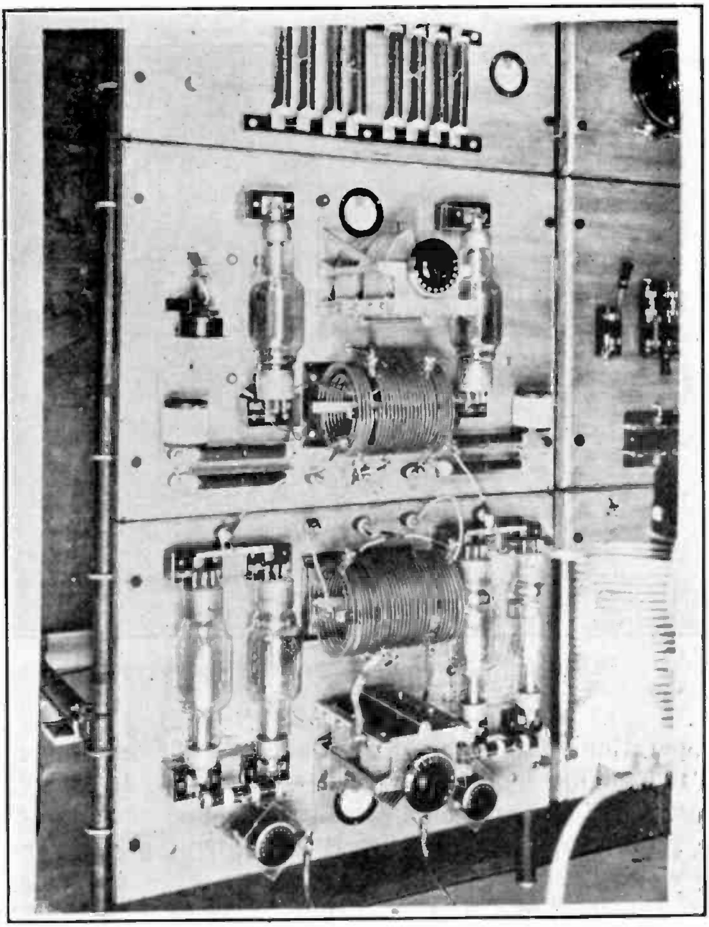

Figure 4—Experimental 95-meter master oscillator and intermediate amplifier units of short wave transmitter—KEL, Bolinas, California.

5 is shown the complete installation of the 90 meter transmitter "KIO" at Kahuku, Hawaii. This figure shows the power amplifier and intermediate amplifier panels the various control panels as well as the main rectifier for sup-

plying 10,000 volts d. c. and the intermediate rectifier which supplied 2,000 volts d. c.

In Figure 6, is shown the 95 meter vertical antenna at Bolinas, California. This antenna was energized by means of a transmission line 875 feet long.

It is of interest to observe that of the above group of five short wave experimental transmitters, only one is still in operation on its originally assigned wavelength namely—"WIZ" 43 meters at New Brunswick, New Jersey. This transmitter operates as a crystal-controlled master oscillator, power amplifier unit directly energizing a long vertical harmonic antenna without the medium of a transmission line. It is used as a supplementary means of communication during the hours of darkness to Berlin, Paris, and Buenos Aires. "WIZ" has been one of the most effective of the Radio Corporation's experimental short wave transmitters.

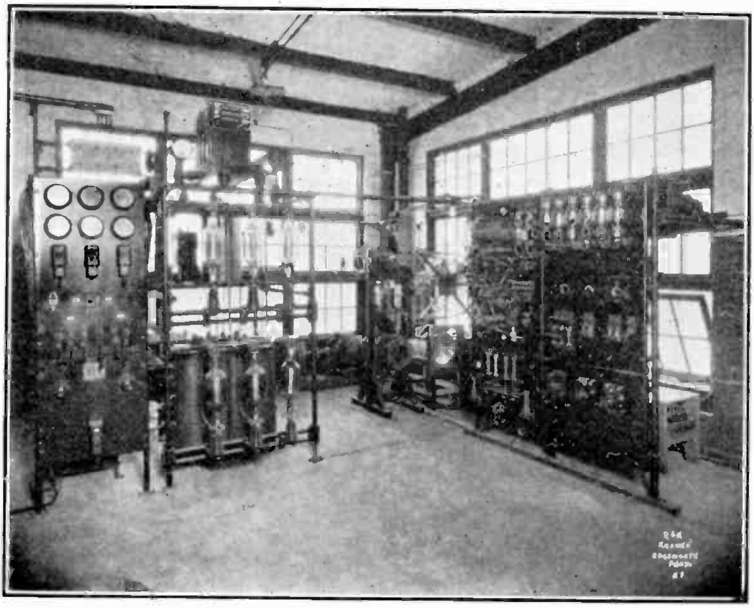

Figure 5—Complete 90-meter experimental short wave installation—KIO, Kahuku, Hawaii.

Early in 1925 the five original installations above described were followed by two others:

"WQO"—35 meters—Rocky Point, Long Island,
"WIK" —22 meters—New Brunswick, New Jersey.

"WQO" was subsequently reconverted in a reconstruction program undertaken at Rocky Point, Long Island. "WIK" was transferred from New Brunswick to Rocky Point. An intensive short wave experimental program with a view to centralizing short wave transmitter development at Rocky Point soon resulted in the installation of three additional short wave transmitters of still lower wavelengths. These units embody all the essential features of design dictated by experience with the earlier sets, such as adequate shielding, crystal control, elimination of losses in the cooling water of the power amplifier tubes, elimination

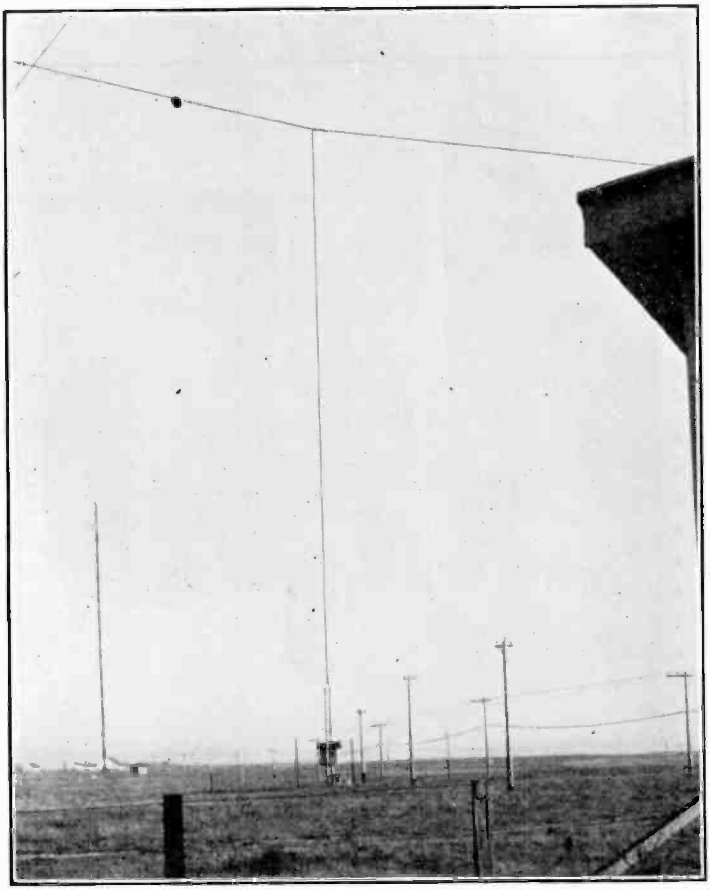

Figure 6—95-meter, third harmonic, vertical antenna and transmission line—Bolinas, California.

of interstage amplifier reactions, and improvement of tone quality.

The call letters, location and operating wavelengths of these three transmitters are as follows:

"WLL"—16.6 meters—Rocky Point, Long Island,
"2XT" —16 meters—Rocky Point, Long Island,
"2XS" —14.9 meters—Rocky Point, Long Island.

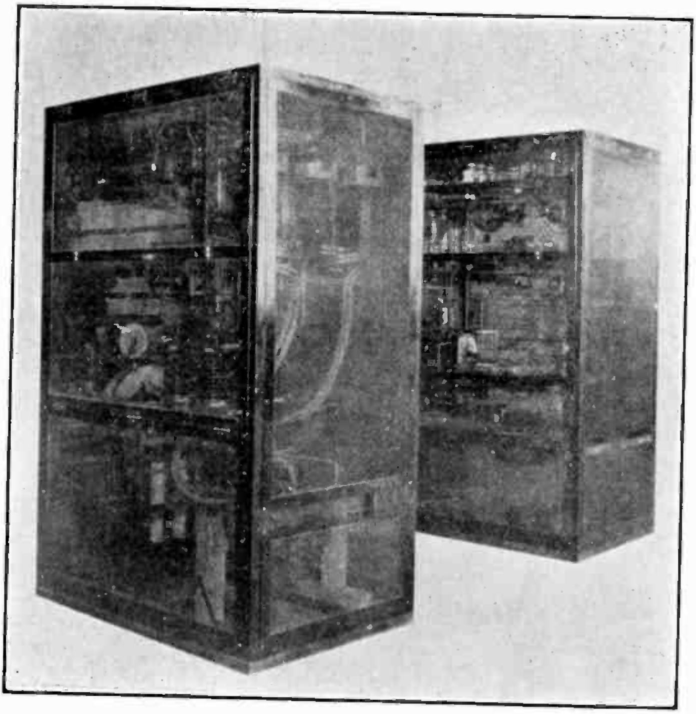

Figure 7—Short wave transmitter 2XT—16-meter, installed at Rocky Point, L. I.

This group of short wave transmitters is utilized in the Radio Corporation's South American service to Rio de Janeiro and Buenos Aires. Most interesting from a transmission viewpoint is that they are most effective during the hours of complete daylight, namely from about 6 A. M. to 6 P. M. This is shown more graphically in traffic charts in another portion of this paper.

In Figure 7, is shown a view of one of these transmitters installed for the above service at the Radio Corporation's Radio Central at Rocky Point, Long Island.

The Radio Corporation's short wave experimental transmitters with antenna inputs varying from 3-kw. to 20-kw. have in general been used as auxiliaries to the 200-kw. long wave alternators. A summary of these various short wave installations, their call letters, wavelengths, and the service to which each was assigned, is as follows:

2XAO—Belfast, Maine—60 to 110 meters—Relay Experimental
WGH—Tuckerton, New Jersey—103 meters—to Berlin, Paris & Buenos Aires
KEL —Bolinas, California—95 meters—to Honolulu & Japan
KIO —Kahuku, Tombouy of Hawaii—90 meters—to San Francisco & Japan
WIR —New Brunswick, New Jersey—74 meters—to London, Paris & Berlin
WQN—Rocky Point, L. I., 51.5 meters—to Berlin & Paris.
WIZ —New Brunswick, New Jersey—43 meters—to Buenos Aires, Berlin & Paris
WQO—Rocky Point, Long Island—35 meters—to Berlin & Paris
IXR —Manila, Philippine Islands—30 meters—to Honolulu & San Francisco
KEL —Bolinas, California—29.3 meters—to Honolulu & Java
HJG —Bogota, Colombia—22 meters—to Central America & New York
WIK —Rocky Point, Long Island—21.5 meters—to Buenos Aires, Berlin & Paris
WLL—Rocky Point, Long Island—16.6 meters—to Rio de Janeiro & Buenos Aires
2XT —Rocky Point, Long Island—16 meters—to Rio de Janeiro & Buenos Aires
2XS —Rocky Point, Long Island—14.9 meters—Rio de Janeiro & Buenos Aires
KEL —Bolinas, California—14.1 meters—to Manila & Java

A definite trend to shorter wavelengths is indicated in the above development.

A record of the performances of these experimental transmitters on commercial traffic is believed to be a topic of general interest. This phase of the subject is considered in Section II.

II—COMMERCIAL TRAFFIC OPERATIONS

It was realized very early in the development of short wave operation that the best test of effectiveness and comparative values of various wavelengths and types of transmitters was actual operation of the transmitter in the handling of commercial traffic. Consequently the RCA short wave transmitter instead of undergoing prolonged periods of test observation, were utilized immediately for commercial service as auxiliaries to the standard high power transmitters. The very high standards of reliability and accuracy required and maintained in the movement of commercial traffic provided a most severe test of short wave operations. Readability was judged not by mere audibility or even by intelligibility of signals over brief or irregular periods but by the exacting demands of comparison with established communication channels operating simultaneously with the short wave transmitters between the same two terminals.

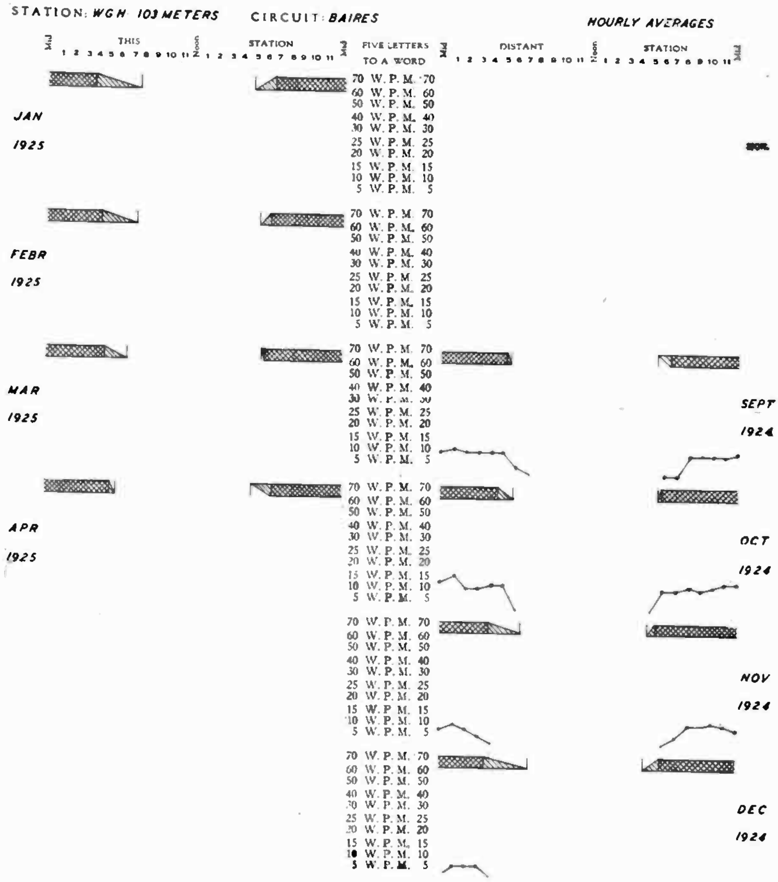

Figure 8—Commercial reception at Tuckerton—WGH, 103 meters, at Buenos Aires, September, 1924, to April, 1925.

Further improvements and refinements of the transmitters were guided by the results obtained during such service.

All the traffic data accumulated to date must be studied with the fact in mind that apparent results may have been affected to a greater or less degree by numerous alterations made in the transmitters from day to day. Nevertheless it seems well worth while to record the results which have been obtained and thereby furnish a basis for further and more reliable statistics in the future.

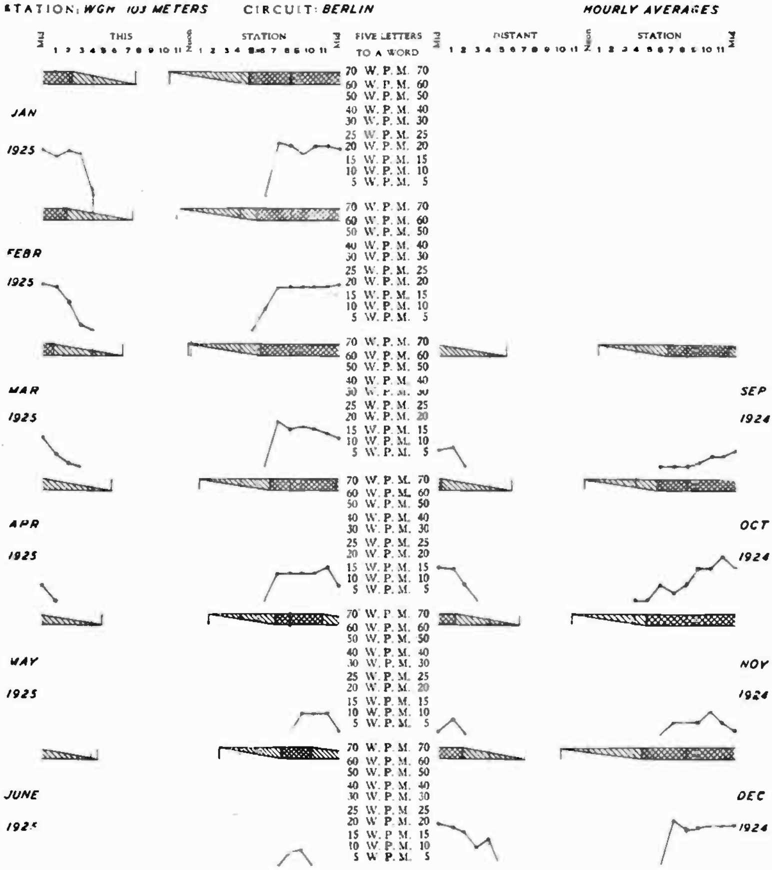

Figure 9—Commercial reception of Tuckerton—WGH, 103 meters at Berlin, September, 1924 to June, 1925.

The primary objective in all of the RCA Atlantic coast short wave activities has been to secure improved and reliable service between New York and South America. All the traffic handled and data obtained by operation between New York and Europe has been decidedly a secondary consideration. This is mentioned to explain the general trend of transmitter development and why certain transmitters and wavelengths with which seemingly excellent results to Europe were being obtained were abandoned in order to use available apparatus for further and more important developments in the South American services.

The first RCA short wave transmitter used for commercial traffic was WGH, on 103 meters, which went into service in September 1924. As shown in Fig. 8 it was found fairly effective for very slow transmission to Buenos Aires between the hours of 8 P. M. and 6 A. M. This period during October advanced with earlier sunset here, becoming 6 P. M. to 5:30 A. M. However the coming of winter at New York

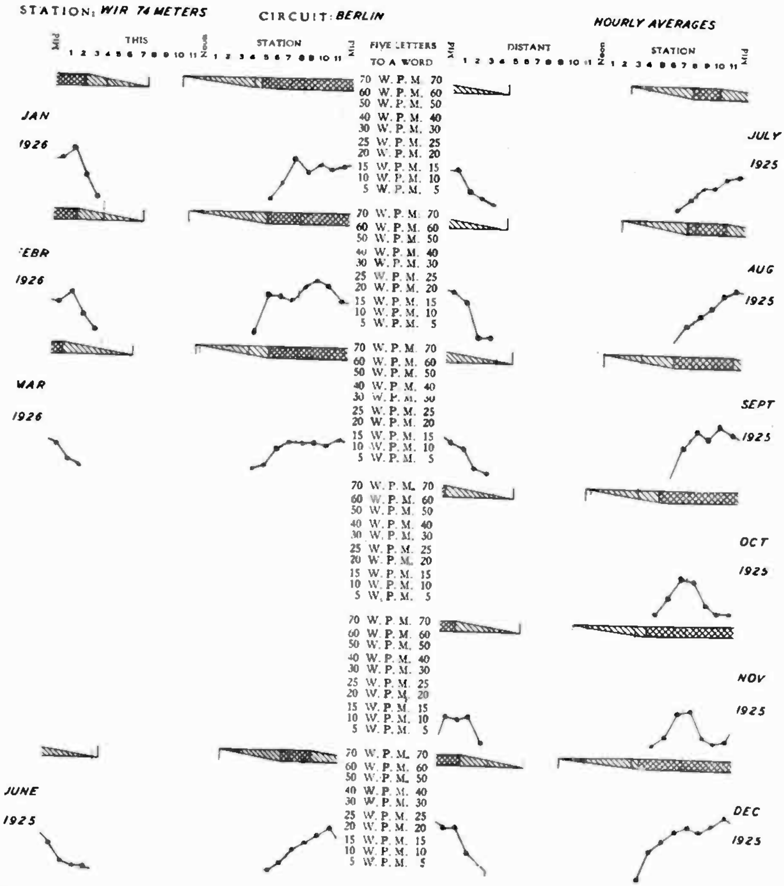

Figure 10—Commercial reception of New Brunswick—WIR, at Berlin, June, 1925 to March, 1926.

in November and December meant the approach of summer at Buenos Aires, with its heavy static season. Signals during November became less and less reliable until during December the usefulness of this transmitter to Buenos Aires had passed and thereafter it was hardly audible and never readable.

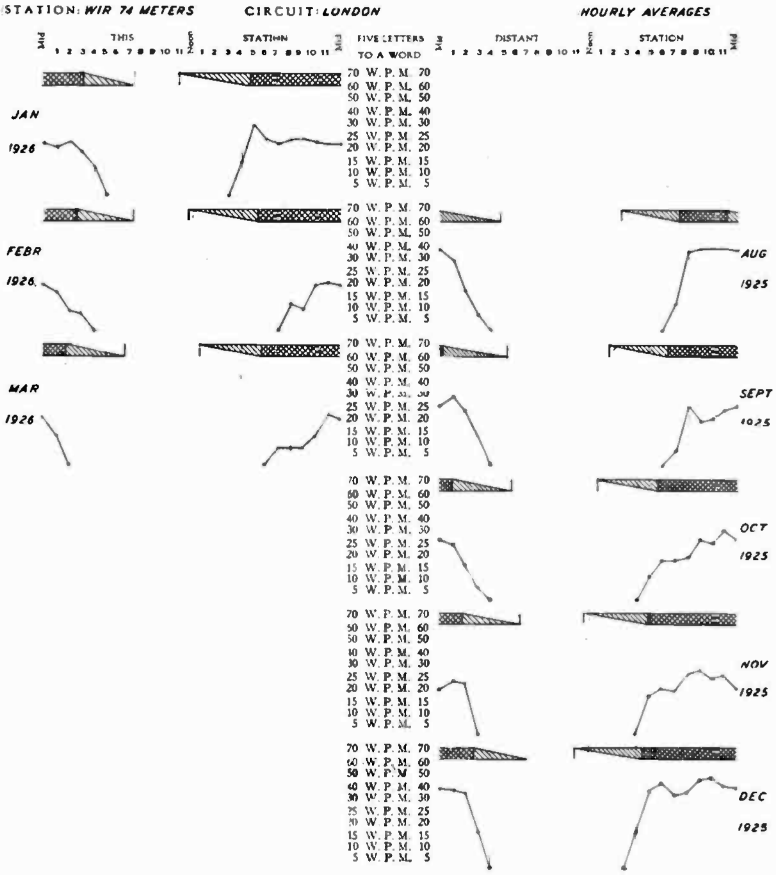

Figure 11—Commercial reception of New Brunskick—WIR, 74 meters, at London, August, 1925 to March, 1926.

In the meantime Berlin had become extremely interested in the use of short waves and was receiving traffic from WGH wherever that station could not be used to Buenos Aires. Fig. 9 shows the record of improved reception at Berlin during the winter months of 1924-5.

However, the approach of spring brought a sharp decline in reception speed and a shortening of the readable hours. By the end of May, Berlin was unable to accomplish much commercially and in June 1925, this pioneer transmitter, having served its purpose, was dismantled.

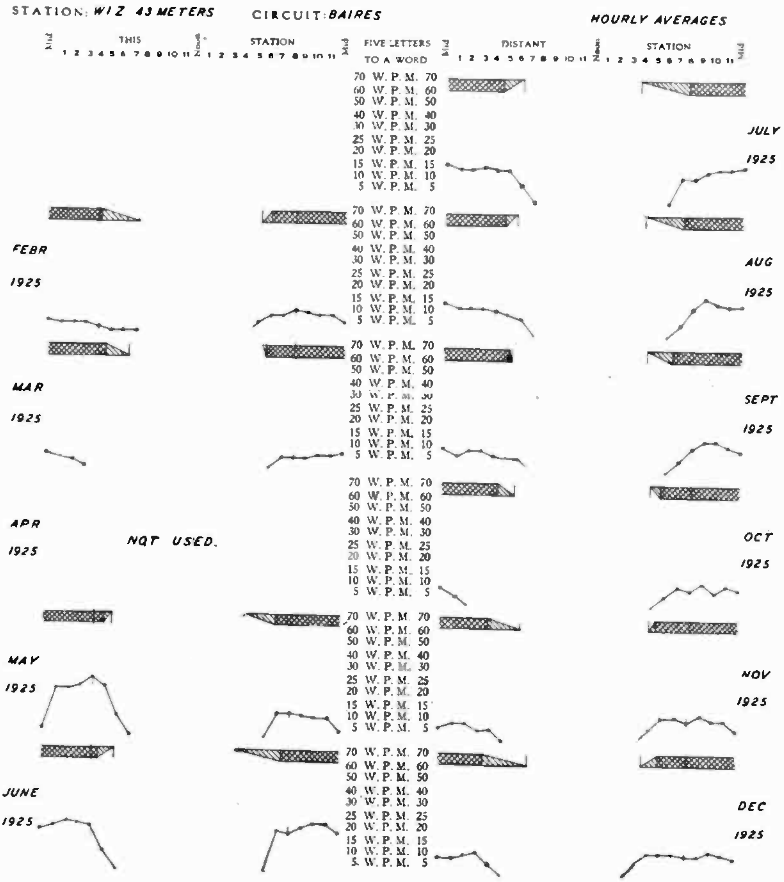

Figure 12—Commercial reception of New Brunswick—WIZ, 43 meters, at Buenos Aires, February to December, 1925.

Next in order of wavelength came WIR, 74 meters, located at New Brunswick, New Jersey and beginning operation in June, 1925. This transmitter was not used to Buenos Aires, because in May, 1925, a 43-meter transmitter, WIZ, had gone into service and was proving far superior for

South American service to the 103-and 74-meter wavelengths.

WIR did however operate successfully to Berlin and to London during almost a year. In hours of usefulness and speed of operation to Berlin, it proved to be comparable to WGH, perhaps becoming readable some one-half to one hour earlier in the day and being slightly less subject to daily and seasonal static conditions.

London did some very good work in reception of this transmitter, copying at high speed for hours at a time and receiving over a somewhat longer period each day than did Berlin. Shorter distance and somewhat longer hours of darkness probably account for this difference. Results of WIR transmission to Berlin and to London are given in Figures 10 and 11.

This station, although very useful in the movement of traffic to Europe, was discontinued after March, 1926 in order to furnish apparatus for shorter wave-length transmitters for South American service.

Station WIZ, 43 meters, at New Brunswick, went into operation in February, 1925. It has become perhaps the best known short wave transmitter in the world, being used by amateurs, commercial administrations, and military services, as a standard of comparison for reliability and wavelength. It is heard over the entire earth at some hours of each day.

During 1925 it was subject to innumerable changes in design. Traffic data for that year are therefore subject to much question and explanation. Results for 1926 are more reliable, the design and operation of the transmitter having become more stable and well standardized. This is the only transmitter for which two years data is available and the natural tendency is to compare 1925 with 1926. Much of the discrepancy between the two years is thus explained.

The 43-meter wavelength proved much less subject to seasonal effects for use to Buenos Aires than had the previous longer waves, and therefore was more reliable. Speed of transmission to Buenos Aires is normally quite low. To Berlin very good high-speed operation is obtained and at least a fair commercial speed is to be depended upon practically every night of the entire year.

Periods of weak signals and strong signals of several days or weeks duration which affect reception heavily are reported by Berlin. These periods have been studied in relation to sun spots, magnetic disturbances, barometric pressures, and other natural phenomena, but no definite

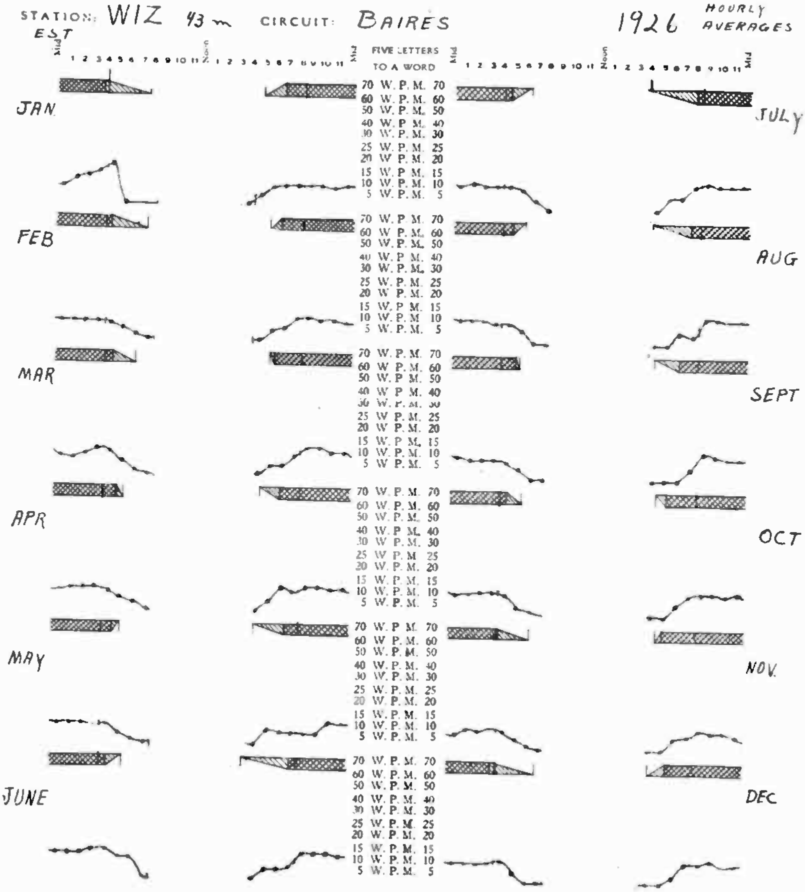

Figure 13—Commercial reception of New Brunswick—WIZ, 43 meters, at Buenos Aires for year 1926.

connection is yet established with anything. A more or less regular cycle of about 35 days is becoming noticeable and is being checked up at present.

Hours of readability during 1925 and 1926 to Buenos Aires and Berlin are shown in Figs. 12, 13, 14 and 15. Although 43 meters is a "darkness" wavelength for all transoceanic operation, the readable period does not follow seasonal variations of sunrise and sunset as closely as might be expected.

Stations WQN, 51.5 meters, and WQO, 35 meters, both located at Rocky Point, New York, were operated commercially for several months during the fall of 1925. The results

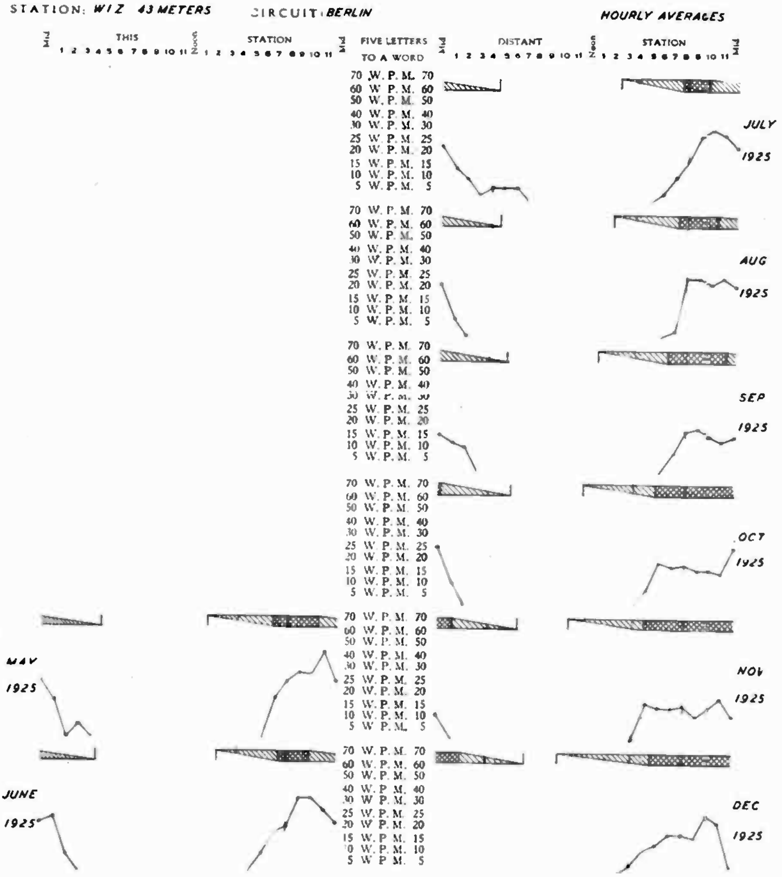

Figure 14—Commercial reception of New Brunswick—WIZ, 43 meters, at Berlin, May to December, 1925.

obtained were so nearly identical with those on 43 meters that operation of the Rocky Point transmitters was discontinued and efforts concentrated on an attempt to utilize much shorter wavelengths which were expected to provide daylight operation to supplement the darkness operation on 43 and 74 meters.

One of the most important uses made of WQO was a run of three weeks using a wavelength of 44 meters and output of about 12 kw. for comparison with WIZ on 43 meters and output of about 6 kw. It was determined without doubt that the traffic capacity of the two transmitters, wavelengths being nearly alike, was in direct proportion to their power. This disposed of a theory which had gained much credence that in short wave working the effectiveness of a transmitter was determined entirely by its wavelength and that power increase would be of negligible effect.

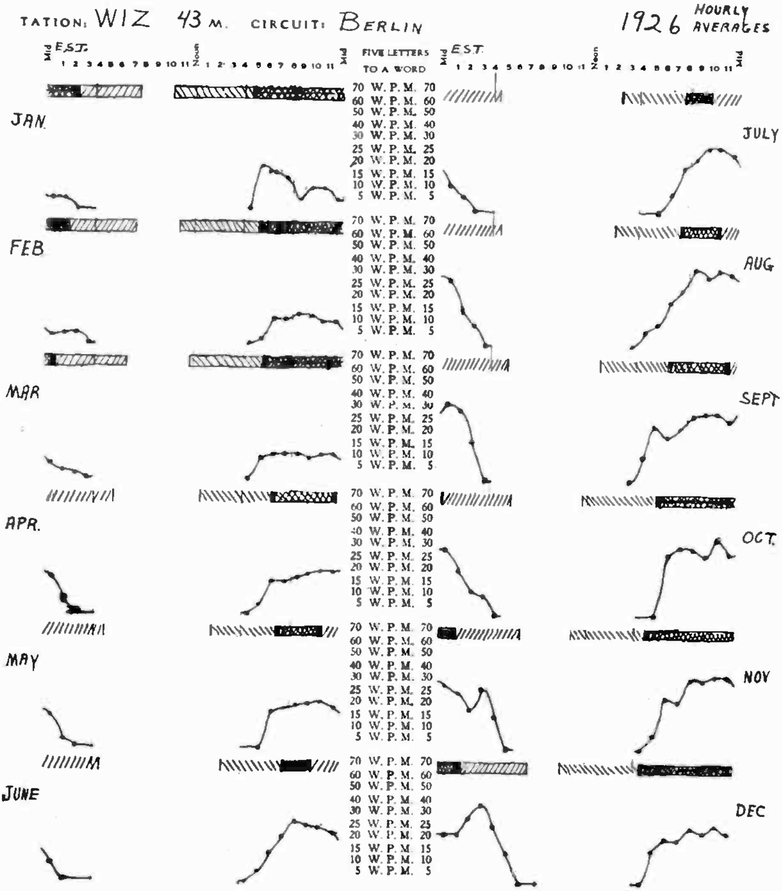

Figure 15—Commercial Reception at New Brunswick—WIZ, 43 meters, at Berlin, for year of 1926.

2XS, 14.9 meters, at Rocky Point, went into service in

January, 1926 and during the entire year was operated successfully and very regularly to Buenos Aires and Rio de Janeiro during daylight. Fig. 16 gives readability records of 2XS, 14.9 meters, to Buenos Aires. The beginning of readability each day coincides quite sharply with sunrise at New York but continues after sunset at both New York and Buenos Aires and varies greatly in its "fading" time according to season of the year. Hours of readability at Rio de Janeiro very closely agree with those shown for Buenos Aires.

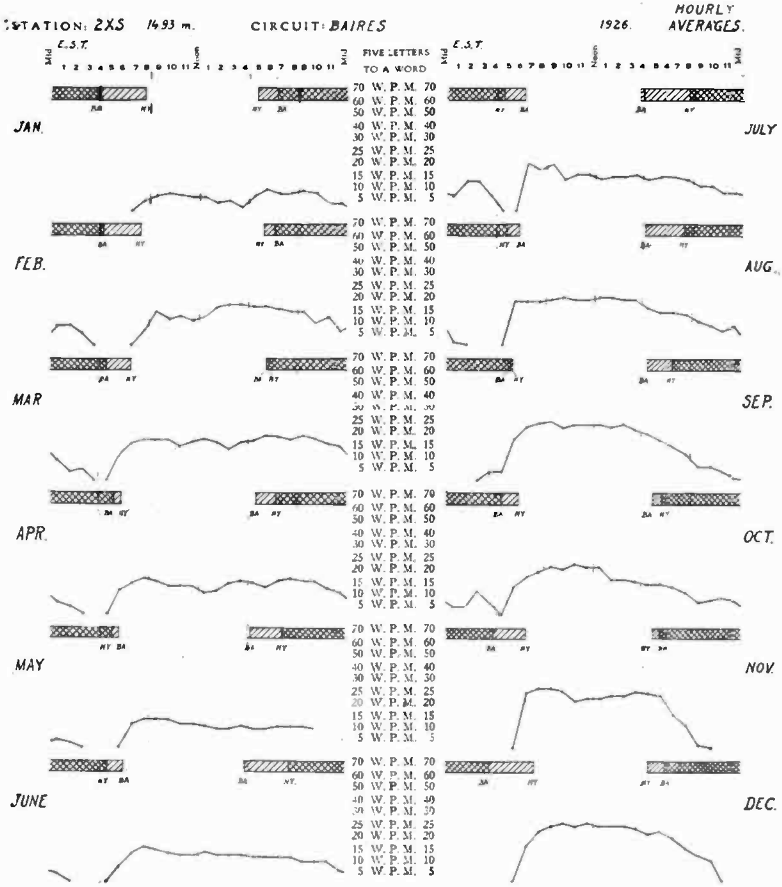

Figure 16—Commercial reception of Rocky Point—2XS, 14.93 meters, at Buenos Aires, for year of 1926.

European reception of 14.9 meters is confined to a very brief period each day. Due to constant operation of the 2XS transmitter for South American service no regular use of it has been made to any European point and but little operating data secured on this wavelength for such use.

Other transmissions have been conducted using trans-

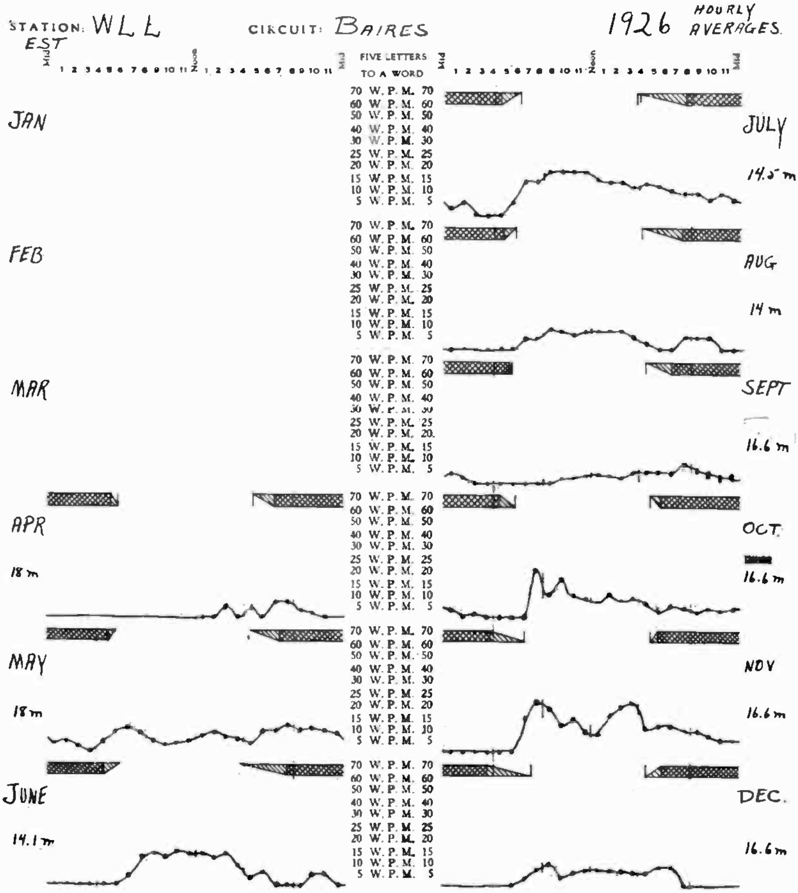

Figure 17—Commercial reception of Rocky Point—WLL, 18 to 14.1 meters, at Buenos Aires for year 1926.

mitter WLL at Rocky Point, at first on 18 meters during April and May 1926. Readability to Buenos Aires covered practically the full 24 hours but signals were weaker and less reliable than 2XS. This may be attributed to the more experimental nature of the transmitter installation rather than to difference in wavelength. Record of WLL operation to Buenos Aires is given in Fig. 17.

Any account of short wave operation to date must include the 22-meter station WIK at Rocky Point although its operating data include only two months, November and December 1926.

This wavelength is peculiar in being useful to South America as a "darkness" transmitter and to Europe during daylight so that it is in service practically 24 hours per day. Buenos Aires reads 22 meters from 5 P. M. to 8 A. M. E. S. T. and Berlin receives it between 6 A. M. and 4 P. M. E. S. T. Results to Berlin are also marked by reception on 22 meters during about four hours daily of "double signals" which seem to be caused by reception of the normal signal over the direct path New York to Berlin and also reception of the same signals some 1/8 to 1/10 second later arriving from the opposite direction around the earth. These phenomena are also observed on shorter waves. This subject has been given serious study by Mr. Erich Quaeck of Berlin, whose conclusions are published in an article appearing in the December, 1926 issue of "Jahrbuch der Drahtlosen Telegraphie und Telephonie". The difference in time of signal travel, is such that useful reception of traffic was impossible because of the "double signal" filling in the spaces between dots of the normal signal. A directional receiving system has been used to overcome this difficulty.

Short wave operations on the Pacific have in general confirmed the data and results obtained in trans-Atlantic operation. Conditions there have been such that regular and systematic use has not been carried out to the same extent as on the east coast and therefore no data can be submitted until further operation has afforded more opportunity to secure reliable and comprehensive information.

No mention is made in this paper of theories of short wave transmission and no attempt made to state a theory derived from the results obtained, nor to explain such results in terms of already propounded theories. The intention has been merely to record what has been done in this field commercially in the belief that such information will be found of benefit to those who are engaged in either theoretical or practical consideration of short wave developments.

In Section III, there is recorded a number of the problems encountered in the technical development of short wave transmitters.

III—TECHNICAL DEVELOPMENT OF TRANSMITTERS

The introduction of short waves for long distance communication has brought into being a technique widely different from that used in connection with the older long wave systems. The radio frequency currents are no longer generated directly in a dynamo-electric machine like the Alexanderson alternator but are produced entirely by means of vacuum tubes.

In contrast to the antennas for long waves, four hundred feet high and one and one-half miles long, we have for short waves antenna structures so small and insignificant in physical proportions that a casual visitor to a transoceanic station would not think of taking them seriously if he were not familiar with their effectiveness.

The revolutionary change in methods has presented a multitude of problems and difficulties requiring solution by the engineers engaged in the development. Most of these difficulties have had to do with the production of equipment capable of producing and handling the extremely high frequency energy in a manner suitable for communication purposes.

The investigation of short waves for long distance transmission was delayed for so many years because of the lack of equipment capable of producing sufficient power at very high frequencies. Utilization of short waves on a practical manner has depended almost entirely upon the development of vacuum tubes.

The technical development described has resulted from the close cooperation between the engineers of the RCA and those of the General Electric and Westinghouse Companies, particularly those responsible for the development of tubes and transmitters.

When powerful tubes capable of producing very high frequency currents were made available the development of short wave communication became so rapid that the engineers engaged in developing the tubes have been under constant pressure to make their product more and more adaptable to short wave operation. From the start the development of tubes has set the limit for the development of short wave transmitter equipment and the life of the tubes in service has proven to be one of the greatest single factors in the economics of the new system.

It is believed that most of the difficulties encountered in using the commercial tubes at very high frequencies have been due to the high radio frequency currents which flow through the connections to the tube elements and to the generally less efficient or more unstable circuits used in connection with the tubes.

The high currents through the tube connections are due to the dielectric capacities between the elements which become quite low reactances at high frequencies. These currents increase the temperature of the elements, particularly the grid, resulting in a tendency for the tube to become unstable due to electron emission from the grid and the higher temperatures combined with the severe conditions which the tube imposes upon itself due to instability, tend to evolve gas from the elements and destroy the usefulness of the tube.

The circuits used subject the tubes to increasingly severe conditions as the frequency is raised due to the necessity for increasingly accurate neutralization of the coupling between input and output circuits through the dielectric capacity of the tubes. The probable error from exact balances of this coupling increases in proportion to the frequency and increases the probability of the tube being subjected to too little or too great excitation or oscillation under improper conditions which tend to destroy it. Variation in temperature of tubes and circuits is alone sufficient to introduce serious difficulty in maintaining exact neutralization of the tube capacity in the ordinary radio frequency amplifier when used at wave lengths as short as fourteen or fifteen meters.

At first trouble was experienced due to the high temperature of the tube connections and to dielectric losses causing softening of the glass resulting in glass punctures but this trouble has been very greatly reduced by improvements in design.

It is also to be noted that the tube capacities set a limit to the capacity of the oscillating circuits used in the input and output of the tubes, and therefore determine the watt-less current circulating in these circuits. For very short waves the amount of this circulating current is of necessity greater than is desired and results in excessive circuit losses. In fact, if waves very much shorter than fourteen meters are used with the present tubes, most of the normal output of the tubes is lost in their associated circuits and nothing left over for the antenna.

It is significant that within about two years, due to the development of both tubes and circuits, the average life of tubes has increased in the ratio of about three-to-one.

Although the development of vacuum tubes has undoubtedly been the most important and most difficult problem in the commercial application of short waves it has been by no means the only one.

The maintenance of a constant frequency became a serious problem requiring solution. To obtain maximum usefulness the transmitters used should be capable of reception within a frequency band of about the same number of cycles as when long waves are used. To stay within this band requires that the percentage of frequency variation in both the transmitter and the receiver decreases in proportion to the wavelength. Thus for communication on a wavelength of 15 meters it is necessary to maintain a constancy about one thousand times greater than was required for long waves.

This problem has been solved by the adoption of the piezo-electric quartz crystal oscillator which was first used as a master oscillator in transmitter 2XAO at Belfast, Maine and which had proven quite satisfactory as a source of constant frequency. As a result of the use of the crystals, together with various refinements in their operation, the frequency of the transmitters and receivers can be held so constant that, the heterodyne note stays sufficiently fixed for hours, or even days without any adjustment to the equipment.

A further advantage resulting from the use of the quartz crystal master oscillator is the comparative simplicity and consequent low cost of the transmitter. This results from the fact that the output frequency is made independent of the effect of variation and ripple in the power supply, and alternating current may be used for lighting the filaments of the tubes. This brings about a very great saving in the amount and cost of the equipment used to make up the transmitter.

Next in importance to maintaining the frequency constant was the problem of amplifying the very small output from a crystal oscillator to the power required in the antenna in a manner which would give freedom from feed-back from the higher to the lower power stages and the resulting tendency for undesired oscillations. It has been previously found difficult to operate a chain of amplifiers even on relatively long waves without feed-back troubles, and the difficulties increase with the frequency. Shielding can be used to reduce such troubles but can not be relied upon to eliminate them entirely at very high frequencies. Also it was necessary that the effect of coupling between input and output circuits of each stage of amplifier be small and that there be no critical adjustments to get this result. In addition it may be noted that it is not practical to make and operate crystals at wavelengths short enough to be used to control the transmission directly, it being necessary to use a harmonic of the crystal.

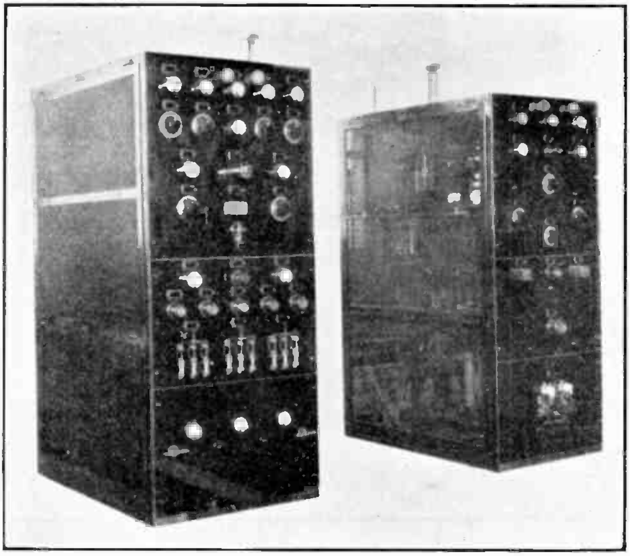

Figure 18—Short wave transmitter for Bolinas—14.1 meters, showing operating condition.

These requirements were met by using each of the intermediate stages as combination amplifiers and frequency multipliers. This was done by tuning the input circuit of the tubes to some particular frequency and the output circuit for the second or third harmonic of the input frequency. Due to the great difference in tuning between the input and output circuits the coupling between them can cause only a very small amount of feed-back and the neutralization of the tube capacity is no longer critical. Also the feed-back from the higher to the lower power stages cannot set up oscillations because of the very great difference in operating frequency.

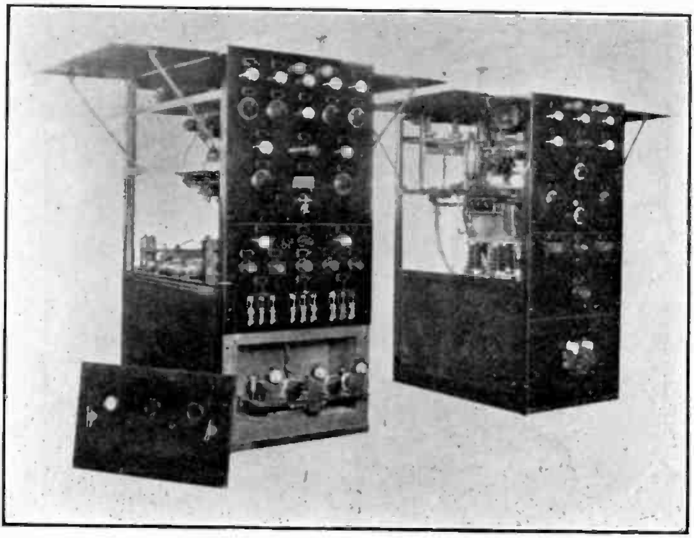

Figure 19—Short wave transmitter—14.1 meters, shields open showing accessability of parts.

Incidentally this system allows the greater part of the tubes in the system to operate at relatively low frequencies so that they are easier to handle and are not subjected to such heavy capacity currents.

In using a tube as a frequency multiplier, advantage is taken of the fact that when it is used as a high frequency oscillator or amplifer the anode current flows for only a small part of a half cycle and can be resolved entirely into harmonic components of the input frequency by tuning the output circuit for the second or third harmonic. In doing so there is only a little loss in efficiency and, due to the greater stability of the circuits, it is believed possible to be confident of obtaining in a practical manner, a greater output than can be relied upon if the tube is used as an ordinary amplifier at very high frequencies.

A third problem of major importance which requires solution before short waves can be used to full advantage for commercial communication is the reduction or elimination of fading. Up to the present time this problem has not been completely solved but some work has been done with promising results.

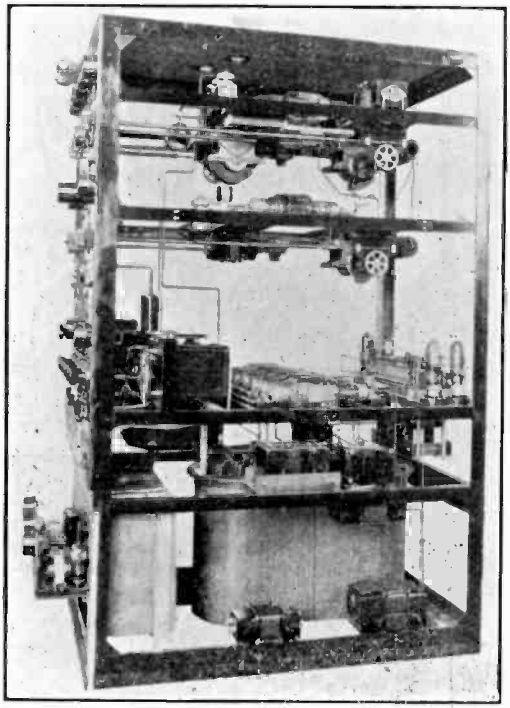

Figure 20—Short wave transmitter—14.1 meters, master oscillator and intermediate amplifier unit, side view.

Very early in the development of short waves it was observed that the fading did not occur simultaneously on two different frequencies transmitted from the same point simultaneously even though the difference in frequency might be very small. This immediately led to the conclusion that fading could be very greatly reduced by transmitting a band of frequencies instead of confining all the energy to a single frequency. This may be done by modulating the transmitted waves or by continuously varying their frequency. Both methods have been tried and were found to result in some improvement, although in no case was the fading eliminated. Since most of the receiving stations were required to transmit the signals over wire lines with some noise on them they preferred a single steady frequency which would give a pure note at the receiver easily distinguishable from line noises. The present transmitter models therefore do not have any provision for varying the frequency over a narrow band while keeping the average frequency fixed.

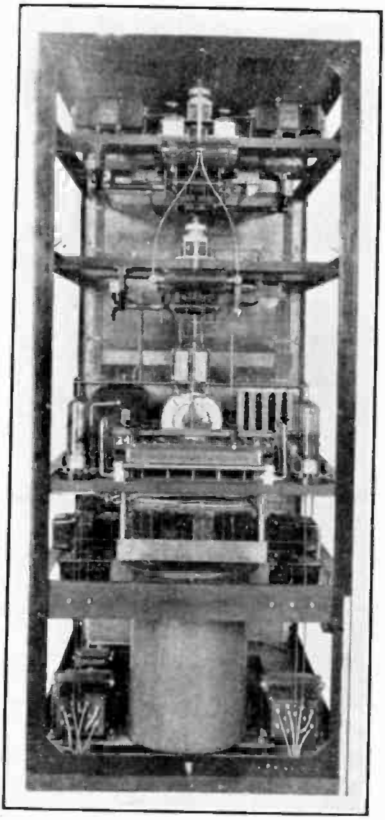

Figure 21—Short wave transmitter—14.1 meters, master oscillator and intermediate amplifier unit, rear view.

If the time comes when conditions at the receiving stations permit taking the variable frequency signals it will no doubt be found an advantage in some cases to do so.

Work which has been done in connection with reception promises much more important results than anything which can be done at the transmitter but this work is still under way and will be described at a later date.

The use of short waves has made it possible to construct directive antenna systems at a cost which is not prohibitive and the further development of such systems seems certain to bring about very great improvements in the effectiveness in the short wave transmitters now in commercial service. of short waves. A program of installation and development of directive antennas is under way; but a discussion of this subject would be too lengthy to be included in this paper.

Figures 18 to 23 inclusive are illustrative of a practical form in which the various developments have been embodied The particular equipment illustrated operates on a wavelength of 14.1 meters and was constructed for installation at Bolinas, California. Only the radio frequency units of the transmitter are shown. In addition to these units each transmitter includes a high voltage rectifier of conventional design.

Figure 15 shows a general view of the transmitter units totally enclosed as they would be used in service. Fig. 19 illustrates the accessibility of all parts. Fig. 20 gives a view of the assembly of the master oscillator and intermediate amplifier unit, while Fig. 21 gives a rear view of the last stage or power amplifier unit.

The master oscillator and intermediate amplifier unit forms a complete crystal controlled short wave transmitter having an output of 300 to 400 watts. It contains all the rectifiers necessary to supply anode and grid bias voltages. To make it ready for service requires the connection of only three leads to deliver 220 volts, three phase, 60 cycles, two leads for the telegraph control and two leads for the radio frequency output.

The crystal oscillator and first combination frequency multiplier and amplifier are in the metal box at the lower front of the unit where they are shielded from the other stages and where their temperatures may be automatically controlled when desired. RCA type UX-210 tubes are used in these two stages.

Two additional stages of combination frequency multiplier and amplifier using RCA UV-204A tubes are located in the upper part of the unit. There are two rectifiers, one using four UV-217A tubes and another using six UV-1651 tubes as a three-phase full-wave rectifier.

The keying is accomplished through the agency of a high-speed polarized relay which controls the grid bias potential on the UV-204A tube which is used as the second stage intermediate amplifier.

The power amplifier unit is designed to use two water-cooled tubes in the ordinary push-pull amplifier circuit. No change in frequency is made in this stage although there is some reason to believe it would be more satisfactory if it were used as a frequency multiplier.

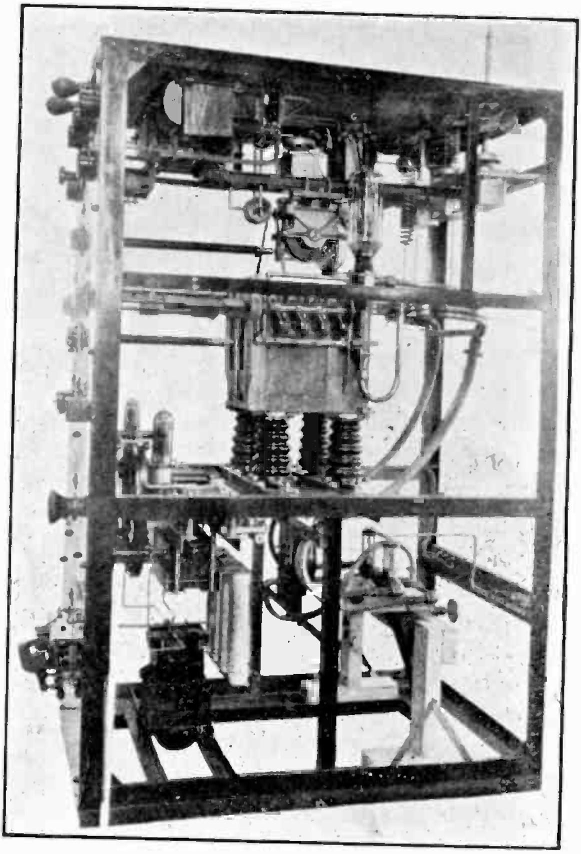

Figure 22—Short wave transmitter—14.1 meters, power amplifier unit, side view.

The unit contains its own rectifier for supplying grid bias potential to the water-cooled tubes consisting of two UV-217A tubes used for single-phase full-wave rectification.

It may be of interest to note that this type of amplifier has been designed to have the cooling water to the tubes fed through the conductor of the output circuit coil with rubber hose connections near the center of the coil. This very greatly reduces the radio frequency losses in the water connection because the center of the coil is substantially at zero potential radio frequency.

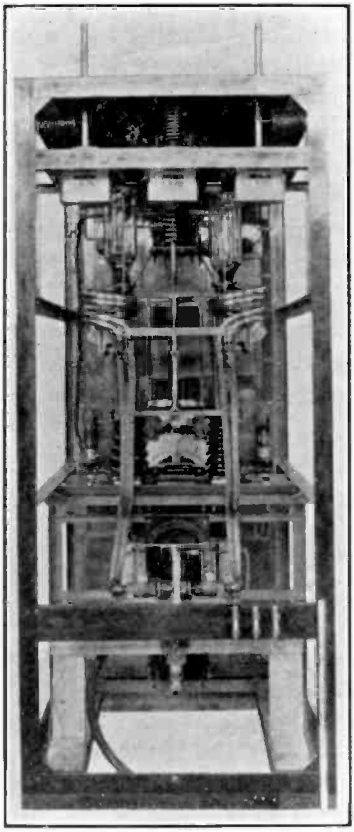

Figure 23—Short wave transmitter—14.1 meters, power amplifier unit, rear view.

It has been definitely determined that the formation of scale on the anodes of water-cooled tubes, a condition so frequently encountered in practice, is due to overheating of the anode accompanied by the formation of steam in the water jacket. Boiling has been eliminated by providing an adequate flow of cooling water with the result that the anodes may be expected to remain clean and bright throughout the life of the tubes.

Protection is provided against loss of cooling water pressure and flow by means of a contact-making pressure gauge and by two contact-making flow devices placed in the water outlet from each tube.

The tubes are protected against too rapid starting of the filaments by an auxiliary contact on the filament rheostat which makes it necessary for the operator to insert all the resistance before the voltage can be applied. A second auxiliary contact prevents application of the anode voltage unless the resistance is reduced again to approximately the normal value and the switching is so arranged that the anode voltage can not be applied until after the grid bias is on.

Very great care has been used to reduce all stray capacities and the inductance of connections to a minimum. This feature becomes increasingly important as the frequency is increased.

IV—ACKNOWLEDGMENT

Short wave communication is unique in that it is worldwide in its scope. A comprehensive mental picture of progress in this field of human activity involves the receipt and accumulation of data from all corners of the earth. It is obviously impractical to acknowledge individually, the splendid cooperation which has been extended by the various departments, and by the manufacturing companies of the Radio Corporation of America, or by its remotely located traffic correspondents in all parts of the world; but rather to express to all, appreciation for data and suggestions submitted from time to time. It is felt that communication by short waves will become an increasingly effective means for welding all the peoples of the earth into bonds of mutual understanding.

Synopsis: The development of short wave communication by the Radio Corporation of America is outlined. A summary of short wave installations, with call letters, wavelengths and services to which each installation is assigned, is submitted.

Traffic charts showing the diurnal and seasonal char-

acteristic of various wavelengths over typical circuits are shown.

An outline of the technical problems inherent to the development of tubes and transmitter circuits is discussed. Methods are described for obtaining proper operation of tubes and transmitters at these very short wave lengths.

The paper is illustrated with typical pictures and charts showing transmitter development and traffic performance.

SOME PRACTICAL ASPECTS OF SHORT-WAVE OPERATION AT HIGH POWER*

By

H. E. HALLBORG

I—PROPAGATION CHARACTERISTICS

The art of short wave transmission is so closely linked with the phenomena of propagation at these extremely high radio frequencies, that any contribution to our present all too meagre knowledge of the subject of short wave phenomena will doubtlessly be acceptable. The wave bands covered by this paper are those included within the 10-to 100-meter zone, or those having a frequency range of 3,000,000 to 30,000,000 cycles.

Early experiments with these frequencies produced results so erratic and contradictory that no symptoms of dependable laws of progapation were in evidence. Continued experimentation by many workers in this field however, indicates that short wave propagation is a wholly orderly process. It appears that nature again has refuted the challenge of being slipshod in any of its methods.

Evidence is increasingly cumulative that energy radiation at these frequencies is divisible into two wave groups and an intermediate zone as follows:

(a) A highly attenuated ground wave which follows closely the established law of attenuation at long waves.

(b) A slightly attenuated sky wave projected from the antenna at an elevation which insures that its transmission path is unobstructed by earthbound obstacles, traversing almost entirely the rarefied regions of the upper atmosphere.

(c) Intermediate between these two zones is one in which the signal becomes very weak, or entirely non-existent. This is the skip distance zone.

The nature of the propagation characteristic of short waves for distances not in excess of 3,000 miles have been

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*Received by the Editor April 4, 1927.

studied at the Radio Experimental Station of the General Electric Company at South Schenectady, New York. Figure 1 is a plot of the day and night signal audibilities as observed at South Schenectady for wave lengths of 26.4, 32.79, 50.2, 65.5 and 109 meters. A radical difference in propagation efficiency is indicated for both day and night observations. Skipping was observed on the shorter waves 26.4 and 32.79 only. The skip at night exceeds the day skip by a ratio of nearly two-to-one. Unfortunately these tests did not extend below 26.4 meters into the region where the skip distance and diurnal effects are most marked. It has been observed by many investigators that increase of wave frequency results in increase of skip distance, and decrease of ground wave range.

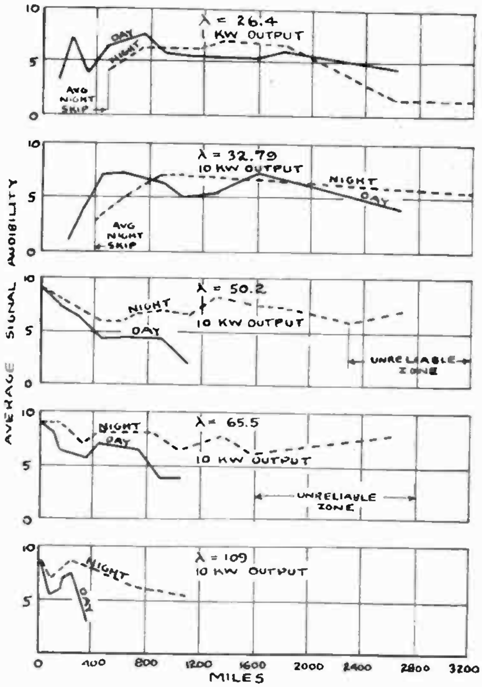

Figure 1—Day and night signals at various wavelengths.

SIGNAL CODE

0—No signal.
1—Just audible.
2—Unreadable.
3—Readable.
4—Faint.
5—Weak.
6—Fair.
7—Good.
8—Loud.
9—Strong.
10—Very strong.

The fact that a skip distance actually exists indicates that the energy is radiated at a considerable elevation. The further fact of long skip with shorter wavelengths indicates a relation between elevation and frequency. It is conceivable that the angle of projection may become so high that the wave front does not again come down to earth. This appears to be a plausible explanation for the ineffectiveness of frequencies greatly in excess of 30,000 kc. (10 meters)

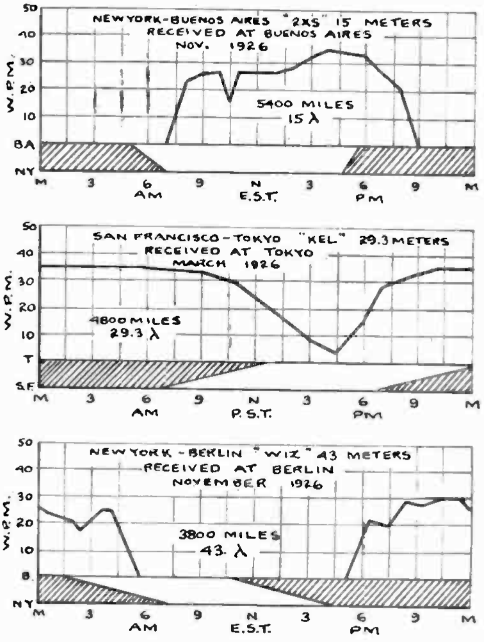

Figure 2—Diurnal signal variations on three typical wavelengths and traffic channels.

day or night. Even at frequencies as low as 15,000 kc. (20 meters) the atmosphere absorbtion at night is normally not sufficient to refract the wave front sufficiently to bring it down to earth. It will be noted that the physical mechanism of propagation may be accounted for without reference to an upper reflecting layer, but rather by the combined effects of wave frequency and the relative ionization of the atmosphere.

It is to be expected, if the above hypothesis is tenable, that light and darkness with their equivalent high and low ionization values will have a marked effect upon the strength of short wave signals.

This diurnal effect is well illustrated by the characteristic hour by hour signal intensities observed on 3 typical long distance circuits of the Radio Corporation world network as illustrated in Figure 2. It will be noted that the 15-meter signal is most effective during the daytime or during the period of high ionization. The overlap of 3 hours between 6 and 9 P. M. may possibly be explained by residual ionization of the atmosphere since it was summer at Buenos Aires when the data were obtained.

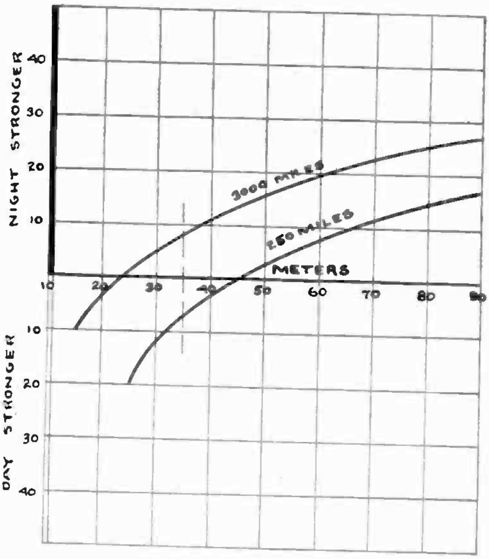

Figure 3—Relation between distance and day waves vs. night waves at 250 and 3000 miles.

The 43-meter signal is seen to be effective only during the hours of low ionization or when the transmitter is completely in darkness.

Intermediate between these extremes must be a frequency which is less susceptible to relative atmospheric ionization. This may account for a characteristic somewhat similar to that of the San Francisco-Tokyo result shown in the middle graph of Figure 2.

It will be apparent from the data already presented that certain wavelengths are most effective at night, whereas others are only effective in the daytime. This diurnal wave characteristic is also to a certain extent a function of distance. For instance, reference to Figure 3, shows that at a distance of 250 miles waves ranging from 45 meters and above are stronger night than day signals. At three thousand miles, wavelengths above 24 meters are night signals and below 24 meters have stronger day than night signals. The 35 meter wave may develop a day signal at 250 miles and a night signal at 3000 miles. This condition is indicated

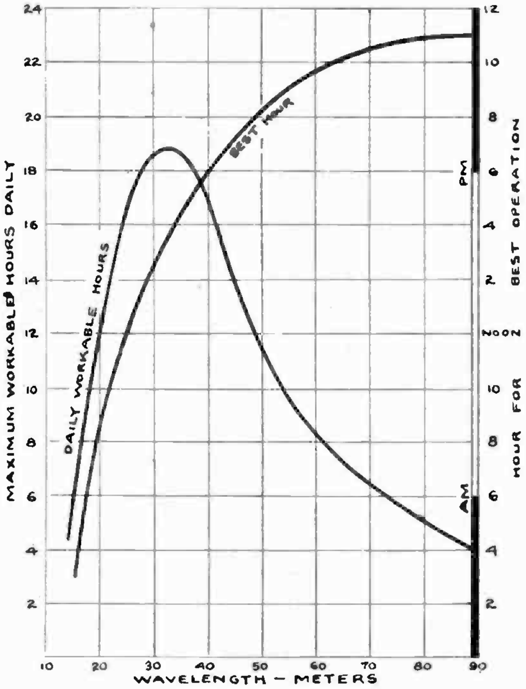

Figure 4—Diurnal characteristics for short wave transatlantic operation.

by the dotted vertical line of the figure. While the values submitted are not claimed to be exhaustive and invariable, they do indicate a definite trend which is being checked up by daily experience.

Many data have been accumulated by the Radio Corporation of America relative to the number of workable hours and the best hour for trans-Atlantic operation as a function of wavelength. These data are based upon an input of 10 kilowatts into a single wire vertical radiator. The results are plotted in Figure 4. It will be observed that a

33-meter wave gives the maximum number of hours of operation for trans-Atlantic working. It is also indicated that the day time band for this distance lies between 17 and 40 meters. It is also of interest to observe that with a non-directional type of antenna and 10 kilowatts antenna input at least two waves will be required to insure 24 hours of trans-Atlantic operation.

In further evidence of the fact that relative atmospheric absorption may account for the day and night effects above noted, signal strength versus distance characteristics have been calculated and plotted under conditions as shown in Figure 5. The daytime absorption coefficient value .0015 is that normally assumed at long waves over salt water. The night time coefficient .000075 is chosen as a result of observed experimental data on the 100-meter wavelength. The dotted curve indicates signal strength with zero atmospheric absorption assuming the signal to obey the inverse law only. Of particular interest is the "hockey stick" shape of the night signal characteristic. This indicates one possible explanation of the distance effectiveness of short waves

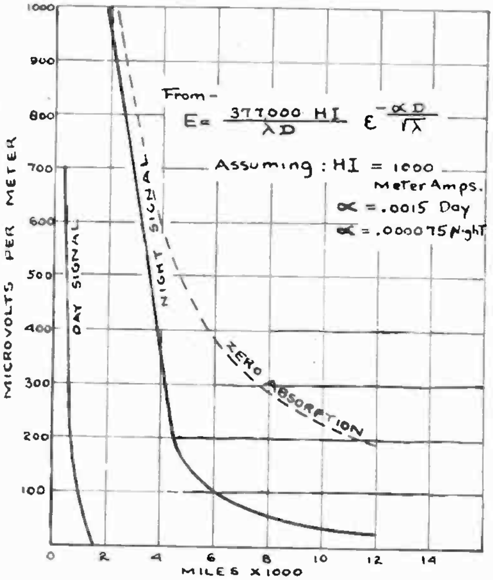

Figure 5—Calculated signal strength—100-meter wave over salt water.

in view of the remarkably good signal-to-static ratio which always obtains in the short wave band.

There is every indication that the Austin-Cohen transmission formula will be applicable to the short wave band when experience has indicated the normal values of the attenuation constant to be applied to each band of 1000 kc. The new values of this constant will probably lie between .000075 and .0005.

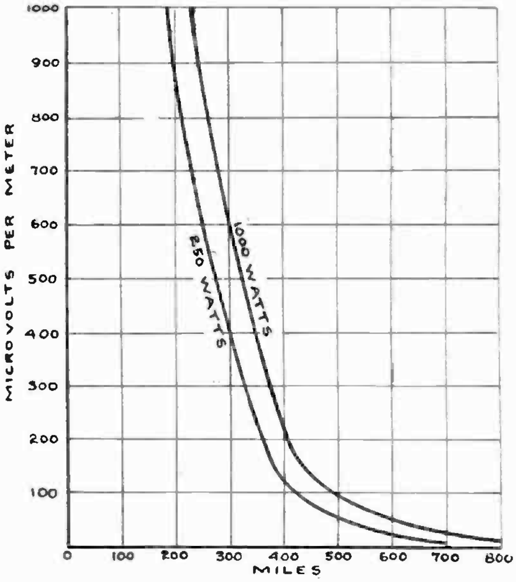

Figure 6—Comparative strength of signals calculated for 250 and 1000-watt antenna inputs at 29.5 meters $\alpha = 0.00075$.

Figure 6 is of interest in showing the relatively small calculated increase in signaling distance at 29.5 meters when the antenna power is increased, in the ratio of 4 to 1 namely from 250 to 1000 watts. This calculated result is well in agreement with practical experience.

II—FREQUENCY STABILIZATION

One of the problems of first importance in short wave operation is that of holding constant frequency. In order better to realize the significance of this problem it is sufficient to contemplate that the range of average audibility is usually taken as 20,000 cycles. If we assume that transmission is on a wavelength of 15 meters, or 20,000,000 cycles, then a frequency change of the order of one percent represents a cyclic change of 200,000 cycles. This one percent change is ten times the entire audible range. A change equal to the audible range is equal to a shift of frequency at 15 meters of only 1/10 percent. Good practice requires that the frequency shift shall be not in excess of 100 cycles. This means that at 15 meters a frequency change of $\frac{100}{20{,}000{,}000} = .0005$ per cent is the maximum permissible.

Of the various factors that contribute to stabilization of frequency the following may be enumerated:

(a) The filament emission must be kept at a constant value. A well regulated d-c. source is better than a-c. although obviously less flexible. Tests conducted on the West Coast by the writer in which the filaments were transferred from an a-c. to a d-c. source, all other conditions the same, proved that frequency shifts on a 29.3-meter transmitter could be introduced merely by the slight emission variations incident to the use of an a-c. source instead of d-c.

(b) The plate voltage supply must be well smoothed and the load regulation must be good. A ripple value of 1% or less, with a regulation not in excess of 10% may be considered good practice. In extreme cases it may be necessary to provide an auxiliary load which acts to keep the rectifier load constant under all conditions.

Thermal expansion in the coil or condenser units may change the circuit constants. This trouble may be eliminated by conservative design which results in lowering the unit stresses.

(d) Finally the frequency may be kept constant by piezo-electric crystal control. A quartz crystal has the property of oscillation of a fixed frequency determined by thickness. This oscillation frequency is maintained during the life of the crystal providing its thickness is not altered by thermal expansion. To insure constant temperature the crystal may be mounted in a separate container the temperature of which is controlled by a thermostat.

III—COMPARISON OF CRYSTAL CONTROL CIRCUITS

All circuits which utilize crystal control are similar insofar as they attempt to impress upon the antenna energy the frequency stability of the crystal. However, since the energy available at the crystal is a few watts at most, and that to be controlled several thousand watts, it is obvious that there are many pitfalls in the train of circuits from crystal to antenna. For this reason not all crystals succeed in justifying their prime reason for existence.

Crystal control circuits may be divided into three classes as follows:

(1) Crystal amplifier
(2) Harmonic selector
(3) Frequency doubler.

The crystal amplifier, Class (1), is distinguished from the others, in that the frequency of the crystal, and that at the antenna are the same. This means that the energy of the crystal must be applied to the antenna through a cascade system of straight amplification. There is consequently a practical limit to which this method can be applied which is determined by crystal thickness and life. Crystals are being ground for frequencies as high as 10,000 kc., or 30 meters, but for long life the use of a crystal ground to 3,000 kc., or 100 meters ,or above is preferable.

The harmonic selector circuit, Class (2), utilizes a thick crystal oscillating at 100 meters or above. This 100 meter oscillation is then fed to the grid of a selector circuit, the value of grid bias of which is adjusted so that the third, fifth or seventh harmonic as desired may be selected. The final frequency of operation is obtained in the selector stage, which is followed by a system of straight amplification. The energy available in the selector stage is roughly inversely proportional to the harmonic selected.

The Frequency Doubler Circuit Class (3) also utilizes a thick crystal oscillating at 100 meters or more. This 100-meter oscillation is then fed to the grid of a second stage the bias of which is adjusted to maximum amplification of the 2nd harmonic, or double frequency value. The second stage would thus oscillate at 50 meters assuming a 100-meter crystal. The second stage may then be similarly fed to a third stage adjusted to select the 2nd harmonic of the second stage namely, 25 meters, and so on. This system has the advantage of reducing direct coupling effects between stages and the disadvantage of less perfect control of regeneration.

Perfect control of the antenna energy by crystal requires that there shall be no parasitic oscillations in any of the amplifier stages. This requires that each stage shall have sufficient energy to drive the next succeeding stage without resort to regeneration.

IV—FEATURES OF DESIGN AND ADJUSTMENT OF 20-KILOWATT AMPLIFIER

It is obviously not possible in a brief summary of this nature to do more than indicate a few of the most essential features of the design or adjustment of a high power short wave power amplifier. Each detail of the apparatus would require to be separately considered, for a thorough analysis. This is obviously beyond the attempted scope of this paper. The most essential requirements for successful operation may be specified as follows:

Tank Circuits—These should be designed for a kilovoltage value at least 20 times the rated output of the driving tubes in kilowatts. This insures stability of operation in that the tubes readily deliver their energy to the tank circuits in preference to a parasitic circuit. Parasitic circuits are ever present at these "super frequencies."

Stabilizing Circuits. These should be designed with the shortest permissible leads and with the idea of reducing to a minimum the kilovoltage in these circuits.

Symmetry. The circuits must have mechanical and electrical symmetry, particularly in the push-pull type of amplifier to insure that the load is equally shared by the respective tubes.

Grid Leads. Tubes must be provided with extra heavy grid leads and seals due to the heavy charging currents that flow at these frequencies in the inter-electrode capacities. A value of 60 amperes in the grid lead of a water-cooled tube is not uncommon. The inter-electrode capacities of the tubes used must also be reduced to minimum practical values.

Stabilization. The success of any system of cascade amplifications depends upon suppression of regeneration in any or all of the stages. There are various means of stabilization one of which in the case of a push-pull amplifier is shown in Figure 7. It will be noted that the potential differences between grid and plate elements of the tubes are reduced by the adjustable balancing condensers connected as shown. The respective potentials of the various parts of the circuit at any instant are as indicated. In practice the process of stabilization adjustment is to excite the grids of the power amplifier with plate voltage off. By means of a pick-up loop meter, the power amplifier tank circuit is adjusted to resonance with the grid excitation. Resonance is indicated by a maximum reading of the loop meter coupled to the tank circuit. The process of stabilization is then to vary the stabilizing condensers until the pick-up loop meter indicates a minimum. These combined adjustments are therefore equivalent to the condition of tank circuit in tune with grid excitation and regeneration at the lowest value obtainable from the existing physical condi-

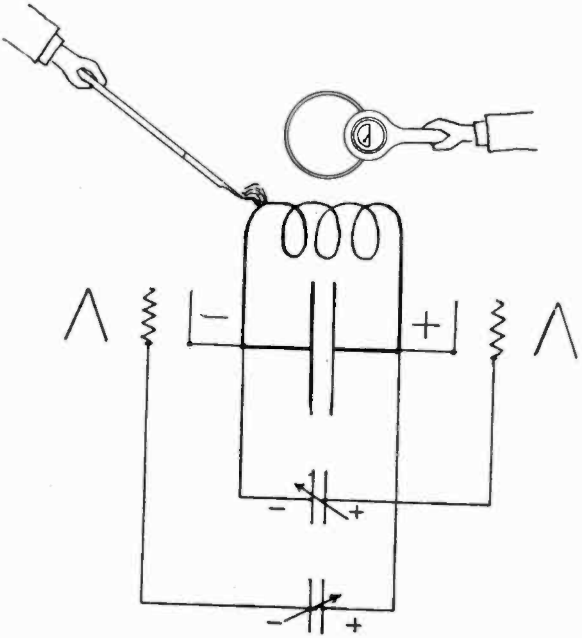

Figure 7—Capacity bridge method of neutralization, showing also application of pick-up loop and stick voltmeter.

tions of the circuits. Figure 7 also indicates the use of the "stick voltmeter". This useful device consists merely of a piece of pointed metal on the end of an insulating rod. The relative potentials of any parts of the circuit are gauged by the lengths of the respective arc discharges. This is a very simple but effective implement for the manipulation of high power short wave circuits.

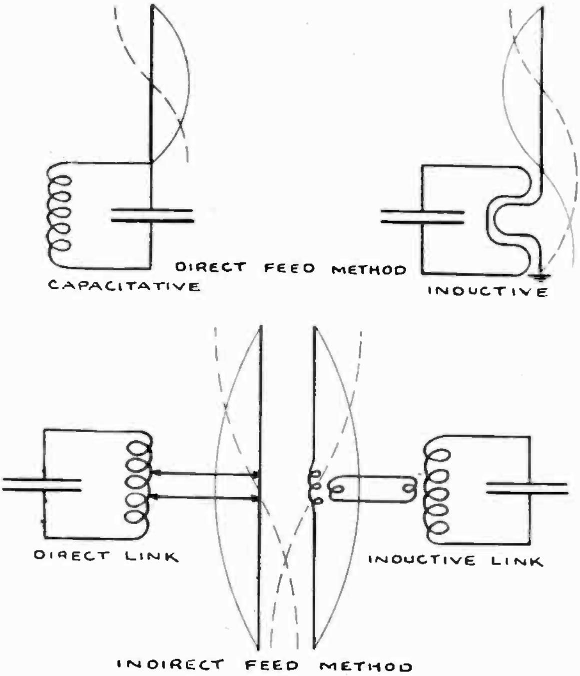

Figure 8—Methods of energizing S. W. Antennas.

V—ANTENNA AND FIELD SYSTEMS

With the advent of short wave transmission, the conventional forms of long wave antennas, which have involved quarter wave radiators in various combinations, have of necessity required radical modification. The underlying reason for this change of point of view is the fact that a relatively short antenna wire can be made several quarter wavelengths long. The result of this situation has been that radiators, in some instances very many wavelengths long, have been used. Short wave antennas are usually referred to as ½ wave, ¾ wave, full wave, 7/4 wave antennas, etc. They divide themselves normally into two groups as follows:

(a) Even harmonic antennas.

(b) Odd harmonic antennas.

Since these antennas are normally referred to as odd or even harmonic, and since the harmonic is considered as a quarter of one wavelength an important relation may be immediately established, namely: the relation between the transmitting wave in meters, and the physical equivalent wire length of the harmonic in feet. This relation is as follows: $\frac{\lambda}{4} = .82\ \lambda$ feet length of wire.

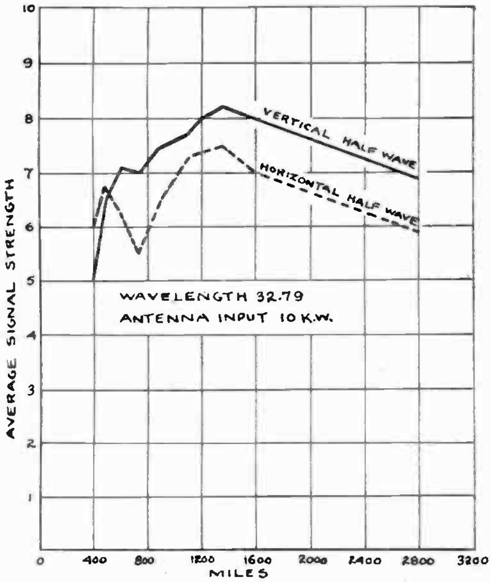

Figure 9—Comparison of signals from half wave vertical and horizontal antennas.

South Schenectady Tests.

In other words, the length of antenna wire in feet required for one quarter wavelength is equal to 82% of the wavelength in meters. This is on the assumption that the speed of wave propagation in the wire is the same as the speed of light which assumption is accurate enough for all practical purposes. From the above relation the actual physical length of any odd or even harmonic antenna may be calculated.

Figure 8 has been drawn to indicate various methods of energizing the short wave antenna system. The distribution of current and voltage in the antennas at any instant has been indicated by the solid and dotted waves respectively. The adoption of one antenna system or the other is usually determined by local conditions.

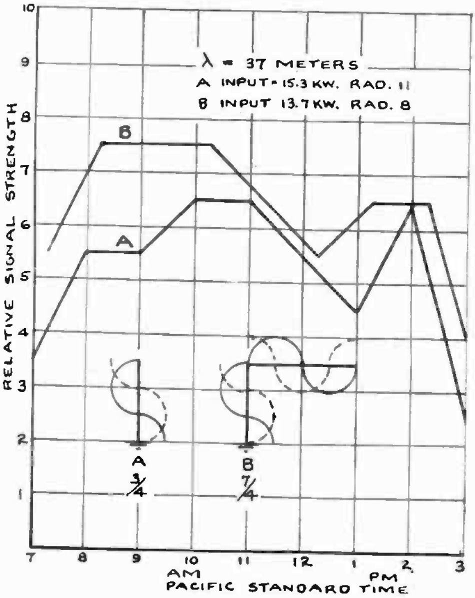

Figure 10—Comparative signal strengths from three-quarter and seven-quarter antennas.
Bolinas, Cal. transmitting, Kokohead, T. H., receiving.

Many tests are being conducted to determine the relative effectiveness of the various antenna types. The radiation effectiveness of any type of short wave radiator is comparatively so high that conclusive results are difficult to obtain. This subject is still being exhaustively investigated. In Figure 9 is shown a comparison obtained at South Schenectady of observed signals from a horizontal and vertical half wave antenna at 32.79 meters and 10 kilowatts antenna input. This data indicates the vertical half wave antenna to be superior to all distances above 500 miles.

Figure 10 plots the comparative strength of signals received at the Radio Corporation of America's station at Kokohead, Hawaii, from a $\frac{3}{4}$ and 7/4 wave antenna at the

Radio Corporation station at Bolinas, California, 2,100 miles distant. This comparison was carefully made by switching from one carefully tuned antenna to the other, alternately at fifteen minute intervals. The approximate forms of the antennas are as indicated at "A" and "B". It will be noted that the 7/4 wave antenna produced a much stronger signal throughout the test. Possible reasons for the greater effectiveness of the longer antenna are:

(a) Greater effective height
(b) Ground losses lessened
(c) Unit antenna stresses lowered.

Conclusive data on antenna systems are difficult to obtain. This subect is continually under investigation by the Radio Corporation and its associated companies. Valuable contributions to this interesting phase of short wave transmission including the effectiveness of directive systems may be expected in the near future.

VI—STATIC ON SHORT WAVE CIRCUITS

The striking advantage of the short wave for long distance communication is the excellent signal-to-static ratio, which is obtained. In fact static ceases to be a problem in the short wave art. Many instances have been noted in which the short wave signal has been entirely readable at the same time that long wave signals were being hopelessly mutilated. Static does exist on certain portions of the short wave band, principally in the spectrum above 30 meters; but it is seldom strong enough to be a practical obstacle to reception. Below 30 meters it may be safely considered as non-existent.

Figure 11 is a graphic record of the relative strengths of signal and static taken at the height of the static season, in July, 1926, on the Radio Corporation of America's New York-Berlin short wave circuits. The relative strength of static on 74 meters as compared to that on 43 meters is of interest. These measurements were made at the receiving station of the Telefunken Company at Geltow, Germany.

VII—DESTINY OF THE SHORT WAVE

It is interesting to speculate on the destiny of short wave communication in the light of present knowledge.

This speculation of course must be considered solely as the personal judgment of the writer. It assumes that the majority of the defects that now limit the full application of these "super frequencies" have been eliminated. It anticipates by some years the results of present research. Their destiny then may be anticipated as follows:

(a) To spread out the available signaling spectrum to enormous values.

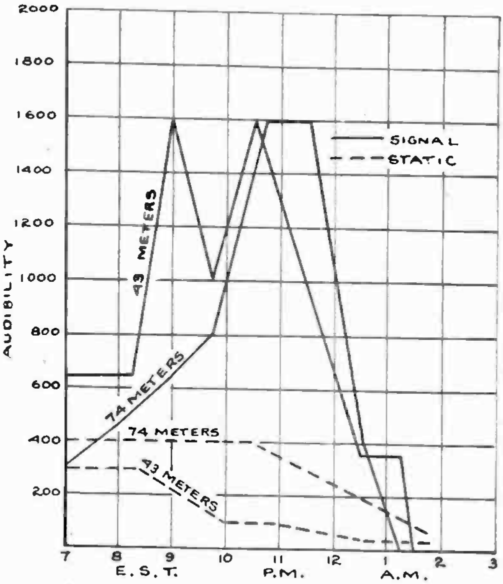

Figure 11—Comparative audibilities of signal and static. New York-Berlin circuit, July, 1926.

(b) To facilitate communication to great distances.

(c) To eradicate the static problem, especially in the tropics.

(d) To permit the fullest development of beam and directive radiation systems.

(e) To permit keying speeds far in excess of present accepted limits.

(f) To make possible the transmission of perfect facsimiles, heralding the end of telegraphy as we know it today.

(g) To form the inevitable background upon which intercontinental television will eventually be built.

VIII—ACKNOWLEDGMENT

The data which have been presented above obviously represent the work of a group of engineers of the radio Corporation of America, which has been engaged in the design of apparatus and the development of short wave communication under the direct supervision of Mr. C. H. Taylor, Chief Communications Engineer. The helpful suggestions of Messrs. E. V. Amy, H. H. Beverage, C. W. Hansell, F. H. Kroger, and C. W. Latimer, are particularly acknowledged and appreciated.

Summary: Propagation data over the frequency range of 3,000 to 30,000 kilocycles is submitted. A co-relation is shown between wave frequency and angle of projection of the wave front. The effect of ionization on the angle of projection is indicated. Some calculations are given of probable values of attenuation constant.

The importance of frequency stabilization is discussed. Three typical circuits for utilizing control crystals are described.

Features of the design and adjustment of a 20-kw. power amplifier are outlined.

Antenna and antenna feed systems are discussed. Graphical results of comparisons of various antenna types are given.

The relative importance of static at short wave lengths is considered.

The author's anticipation of the destiny of the short wave is summarized.

MAXIMIZATION METHODS
for
FUNCTIONS OF A COMPLEX VARIABLE

BY
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In a previous paper it was shown that maximization of the absolute value of a function of a complex variable could be obtained, in some cases very easily, by proper use of the derivative of the function. It will now be shown that there are a number of different conditions that may be imposed upon the derivative, with various results.

Figure 1 shows, in the complex plane, a curve representing the locus of a function of a complex variable as the independent variable traces a certain path (not shown).

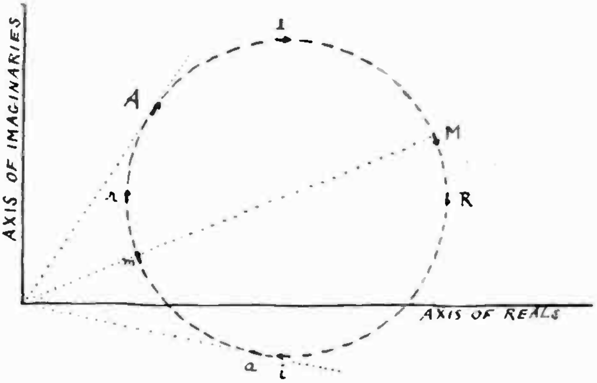

Figure 1

When the independent variable moves an infinitestimal amount dz the dependent variable F moves an amount dF which is an infinitesimal vector forming part of the curve of Figure 1. Furthermore, $dF = \frac{dF}{dz}\,dz$.

Five conditions immediately suggest themselves to be imposed upon dF:

(1) Require dF to be parallel to the axis of real quantities by equating to zero the imaginary part of $\frac{dF}{dz}dz$ (in other words, argument of $\frac{dF}{dz}dz = 0°$ or $180°$. The solution of this equation gives the value of z that makes the imaginary part of F stationary in value, usually a maximum or a minimum as at "*I*" or "*i*" of Figure 1.

(2) Require dF to be parallel to the axis of imaginaries by equating to zero the real part of $\frac{dF}{dz}dz$ (in other words, $arg \frac{dF}{dz} dz = \pm 90°$). The solution of this equation gives the value of z that makes the real part of F stationary in value, usually a maximum or a minimum as at "*R*" or "*r*" of Figure 1.

(3) Require dF to be parallel to F by equating to zero the imaginary part of $\frac{\frac{dF}{dz}dz}{F}$. The solution of this equation gives the value of z that makes the argument of F stationary in value, usually a maximum or a minimum as at "*A*" or "*a*" of Figure 1.

(4) Require dF to be perpendicular to F by equating to zero the real part of $\frac{\frac{dF}{dz}dz}{F}$. The solution of this equation gives the value of z that makes the absolute value of F stationary in value, usually a maximum or a minimum as at "*M*" or "*m*" of Figure 1.

(5) Require dF to vanish by equating to zero both the real and imaginary parts of $\frac{dF}{dz}$. The solutions of these two equations give the conditions under which F is momentarily entirely unaffected by a small change in z. This state of affairs is not shown in Fig. 1.

Following are examples to illustrate the application of the above five processes, the examples being so chosen that the correctness of the results is easily checked by other methods. The examples are worked out at somewhat greater length than would be necessary in actual practice.

(1) Suppose it is desired to determine what adjustment

of the condenser in Figure 2 will make the reactance of the divided circuit a maximum or minimum. Calling the impedances of the two branches Z_L and Z_C, the value of F is $\frac{Z_L Z_C}{Z_L + Z_C}$ and the independent variable is Z_C. Following rule (1) equate to zero the imaginary part of $\frac{Z_L^2}{(Z_L + Z_C)^2}\, dz_c$. But since the *change* in Z_C is purely imaginary (the condenser being free from losses) the equation may be written: zero equals the real part of $\left.\frac{Z_L}{Z_L + Z_C}\right)^2$. For the purpose of this particular problem it is more convenient to express this equation in the alternative manner: *arg* $\left(\frac{Z_L}{Z_L + Z_C}\right)^2 = \pm 90°$. From this it follows that *arg* $\left(\frac{Z_L + Z_C}{Z_L}\right)^2 = \mp 90°$, whence *arg* $\left(\frac{Z_L + Z_C}{Z_L}\right) = \mp 45°$ or $\pm 135°$ which may be written *arg* $(Z_L + Z_C) =$ *arg* $Z_L \mp 45°$, *or* $=$ *arg* $Z_L \pm 135°$. But of these four possibilities only two make the real part of $(Z_L + Z_C)$ positive, as it must be if the circuit resistances are positive. Therefore the only two conditions to be considered are *arg* $(Z_L + Z_C) =$ *arg* $Z_L - 135°$ and *arg*$(Z_L + Z_C) =$ *arg* $Z_L - 45°$. If Z_C is so adjusted as to satisfy the first of these the reactance of the divided circuit will be at its maximum value, while if Z_C is so adjusted as to satisfy the second condition the reactance will be a minimum—that is, in this circuit the reactance will have its greatest negative value. It is of interest to note from the above two conditions that if *arg* Z_L is less than $45°$ no positive maximum can occur. Usually however such circuits as that of Fig. 2 have rather low resistances, and in this case greatest positive reactance and greatest negative reactance occur when Z_C is so adjusted as to make the reactance measured around the closed circuit approximately equal to the resistance. If this reactance measured around the circuit is condensive, the reactance of the divided circuit is inductive, and vice versa.

(2) Let a voltage e be applied to an impedance z. The resulting current is $\frac{e}{z}$ and the power absorbed is the real part of the product of voltage and current. In this case the

complex function F is $\frac{e^2}{z}$ and to find out under what condition its real part is maximum apply rule (2), which leads to the equation: zero equals the real part of $\left(\frac{-e^2}{Z^2}dz\right)$. Before going any further we must decide in what manner z is to be varied. Two simple cases will be considered, (a) the imaginary part of z is kept constant while the real part is varied, and (b) the real part of z is kept constant while the imaginary part is varied. In the first case dz is a real quantity, so the condition becomes: zero equals the real part of $-\frac{e^2}{Z^2}$. This is obviously satisfied if $\arg z$ is $\pm 45^\circ$ or $\pm 135^\circ$. In other words, for maximum power the resistance should

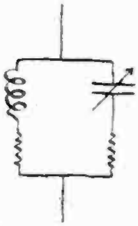

Figure 2

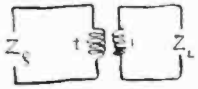

Figure 3

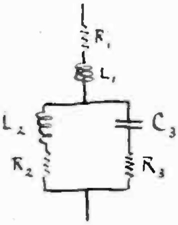

Figure 4

be adjusted to equal the reactance. In case (b) dz is imaginary, hence $-\frac{e^2}{Z^2}$ is real. This condition is satisfied if $\arg z$ equals 0, 180, or ± 90. In other words the power is maximum if the reactance component of z is made zero, and minimum only if the reactance becomes infinite.

(3) Suppose that in the circuit of Fig. 2 it is desired to determine the condenser setting that makes the angle of lead or lag of the divided circuit the greatest. That is, when will $\arg F$ be maximum or minimum where F is $\frac{Z_L Z_C}{Z_L + Z_C}$? Applying rule 3 we get the equation: zero equals the imaginary part of $\frac{Z_L^2}{(Z_L + Z_C)^2} dz_C \div \frac{Z_L Z_C}{Z_L + Z_C}$. But since dz_C is purely imaginary this is readily reduced to $\arg \frac{Z_L}{Z_C}\left(\frac{1}{Z_L + Z_C}\right) = \pm 90^\circ$ whence $\arg (Z_L + Z_C) = \arg Z_L - \arg Z_C \pm 90^\circ$. If the circuit resistances are positive only the latter alterna-

tive may be used. Hence the condenser must be so adjusted that if a voltage were inserted in the closed circuit a current would be produced that would lag the voltage by an angle as many degrees less than *90* as the sum of the angles by which Z_L and Z_C fail to be pure reactances. For example if $arg\ Z_L = 85°$ and $arg\ Z_C$ is between *89°* and *90°* then $arg\ (Z_L + Z_C)$ must lie between *84°* and *85°*. That is, the condenser should be so adjusted that current in the closed circuit would lag voltage by between 84 and 85 degrees. This gives the value of capacity fairly closely so that $arg\ Z_C$ may be estimated more closely than originally assumed, and using this more accurate value the adjustment of the condenser may be obtained still more closely, and so on till as good an approximation as desired is attained. The interesting thing about this problem is that for values of capacity between zero and infinity there is only a minimum of the argument, and this corresponds usually to a condensive reactance of the divided circuit.

(4) Fig. 3 shows a generator of internal impedance Z_g connected through an ideal transformer (that is, one having no losses or leakage, and infinite reactance windings) of turns ratio to a load of impedance Z_L. The problem is to find what turns ratio will result in the greatest load current. The expression for load current is easily found to be $\frac{t\,e}{Z_g + t^2 Z_L}$, and this is the function F to be maximized. Following rule 4, set zero equal to the real part of $\frac{Z_g - t^2 Z_L}{Z_g + t^2 Z_L}\,\frac{d\,t}{t}$ It is readily shown, either geometrically or by substitution of assumed real and imaginary parts for Z_g and Z_L, that this equation is satisfied by $t^2 = \left|\frac{Z_g}{Z_L}\right|$ which is a well known rule.

(5) The impedance of the circuit element shown in Fig. 4 is $Z_1 + \frac{Z_2 Z_3}{Z_2 + Z_3}$. Call this impedance F and apply rule 5, considering frequency as the independent variable. The resulting equation is $0 = \frac{dz_1}{df} + \frac{Z_2^2 \frac{dz_3}{df} + Z_3^2 \frac{dz_2}{df}}{(Z_2 + Z_3)^2}$. It is easy to show that if $R_2 = R_3$ and $f^2 = \frac{1}{4\pi^2 L_2 C_3}$ the real part of the second

term is zero, and the imaginary part becomes $j2\,L_2\left(R^2-\frac{L_2}{C_3}\right)\frac{1}{4R^2}$. So in order to satisfy the equation it is only necessary to add the condition $L_1=2L_2\left[\frac{L_2}{C_3}-R^2\right]\frac{1}{4R^2}$ An interesting case occurs when $L_1=0$ and $R^2=\frac{L_2}{C_3}$ for in this case the derivative is zero for all values of frequency, so that the impedance of the combination is completely independent of frequency. This case is only one of several of the sort.

In conclusion, it should be noted that no test has been given for determining whether or not it is legitimate to differentiate a given function of a complex by the same formal process as used for functions of real variables. The reason for omitting so fundamental a necessity is that the test may be found in any text book on complex functions, and also because any function obtained from circuit theory will almost surely be analytic, which means that it can be differentiated exactly as though all the letters represented real quantities.

SUMMARY—The maxima and minima of a function of a real variable are found by equating to zero the derivative of the function. In the case of a function of a complex variable however the derivative is a vector quantity, so that conditions may be imposed upon its direction as well as upon its magnitude. These various conditions lead to maxima and minima of the various aspects of the function. Rules are developed for setting up equations giving the various maximizing conditions, and a simple example is given illustrative of the use of each rule.

A MATHEMATICAL STUDY OF RADIO FREQUENCY AMPLIFICATION*

BY

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INTRODUCTION

There are two general methods of radio frequency amplification, tuned and untuned. The latter is seldom used except in super-heterodyne circuits in conjunction with one or more tuned units or a band pass filter to provide the selectivity. Theoretically, this untuned super-heterodyne with a band pass filter is the best type possible. However, the voltage amplification of the untuned type of transformer is at present very unsatisfactory, as tube and winding capacities are exceedingly troublesome.

There are two methods of tuning in use. We may either tune the frequency to the circuits or the circuits to the frequency. The first is the super-heterodyne method and the second is the common method of the neutrodyne and similar circuits.

It is this latter type that we shall study particularly though many of our results are more general than this.

Throughout we shall assume a steady state, leaving transients for further consideration. By this assumption we may apply the ordinary vector methods of alternating current theory.

THE AIR CORE TRANSFORMER

The fundamental circuit of the transformer is that shown in Figure 1, where the symbols have their usual meaning.

In terms of vectors and complex operators† we may

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*Presented before the Canadian Section at Toronto, January 5, 1927.

†All vectors and complex operators are printed in Clarendon type, scalars are in ordinary type. If a distinguishing mark is required in script, a bar or dot over the letter will provide it. This is usually unnecessary.

equate the emfs. and impedance drops around each circuit. We get

$$\mathbf{E}_1 = \mathbf{Z}_1 \mathbf{I}_1 - \mathbf{m}\,\mathbf{I}_2 \tag{1}$$

$$0 = \mathbf{Z}_2 \mathbf{I}_2 - \mathbf{m}\,\mathbf{I}_1 \tag{2}$$

where $\mathbf{Z}_1 = R_1 + X_1 j$, $X_1 = \left(L_1\omega - \frac{1}{C_1\omega}\right)$, $\mathbf{m} = M\omega j$, etc.

Eliminating $\mathbf{I}_1$ and solving for $\mathbf{I}_2$ we get

$$\mathbf{I}_2 = \frac{\mathbf{E}_1}{\frac{\mathbf{Z}_1\mathbf{Z}_2}{\mathbf{m}} - \mathbf{m}}\,. \tag{3}$$

This is a general vector equation for the secondary current which we shall have to study to find out how to make it a maximum. We could continue to work with vectors[1] but it is better to change to absolute values. We have

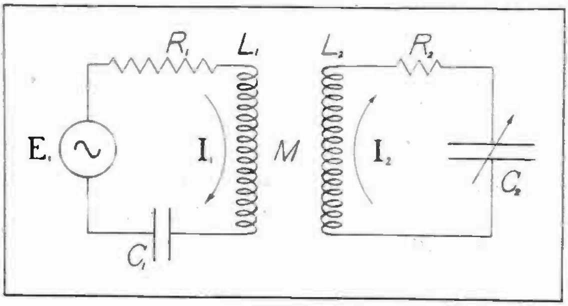

Figure 1—The Fundamental Circuit of the Transformer

$$\mathbf{Z}_1\mathbf{Z}_2 = (R_1 + X_1 j)(R_2 + X_2 j) = a + bj, \tag{4}$$

where $a = R_1 R_2 - X_1 X_2$,

and $b = R_1 X_2 + R_2 X_1$.

Then (3) becomes

$$\mathbf{I}_2 = \frac{\mathbf{E}_1}{\frac{a+bj}{M\omega j} - M\omega j} = \frac{\mathbf{E}_1}{\frac{b}{M\omega} - \left(\frac{a}{M\omega} + M\omega\right)j}\,. \tag{5}$$

If $K\mathbf{I}_2$ is the conjugate of $\mathbf{I}_2$,

$$I_2^2 = \mathbf{I}_2 K\mathbf{I}_2 = \frac{E_1^2}{\left(\frac{b}{M\omega}\right)^2 + \left(\frac{a}{M\omega} + M\omega\right)^2} = \frac{E_1^2}{M^2\omega^2 + 2a + \frac{a^2+b^2}{M^2\omega^2}}, \tag{6}$$

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[1] W. B. Roberts, PROCEEDINGS I. R. E., Vol. 14, No. 5, Oct. 1926, "A Method for Maximization in Circuit Calculation."

which is the general equation in scalars in place of the vector equation (3).

CONDITIONS FOR MAXIMUM

(a) If M only varies I_2 is a maximum when

$$M^2\omega^2 = \sqrt{a^2 + b^2} = Z_1 Z_2\,, \tag{7}$$

as may be seen by inspection of (6) or by differentiating.

(b) If X_2 only varies, I_2 is a maximum when

$$\frac{da}{dX_2} + \frac{1}{M^2\omega^2}\left(a\,\frac{da}{dX_2} + b\,\frac{db}{dX_2}\right) = 0\,, \tag{8}$$

which, on substituting for (a) and (b), leads to

$$X_2 = \frac{M^2\omega^2}{Z_1^2} X_1\,. \tag{9}$$

(c) If X_1 only varies, I_2 is a maximum when

$$X_1 = \frac{M^2\omega^2}{Z_2^2} X_2\,. \tag{10}$$

Now these three maximum conditions are not independent. If we satisfy any two of them the third is also satisfied. All three are satisfied if

$$\frac{X_1}{R_1} = \frac{X_2}{R_2} \tag{11}$$

and $M^2\omega^2 = Z_1 Z_2 = R_1 R_2 + X_1 X_2 = \frac{R_2}{R_1} Z_1^2\,.$ (12)

But these two equations can always be satisfied by adjusting any two of X_1, X_2 and M; it is not necessary to vary all three.

The most obvious result of this is that it is unnecessary to tune an aerial which is coupled to a tuned secondary circuit.

MAXIMUM SECONDARY CURRENT

When equations (11) and (12) hold the general equation (6) reduces to the simple form

$$I_2 = \frac{E_1}{2\sqrt{R_1 R_2}} \tag{13}$$

This is the maximum possible secondary current.

A TUBE CONSTANT

A tube acts as a generator with an emf. μE_g where E_g is the grid voltage, and an internal resistance R_p, the plate impedance. Then for an interstage transformer we have

$$E_1 = \mu E_g$$

$$R_1 = R_p, \text{ very closely,}$$

and the voltage applied to the next grid is

$$\frac{1}{C_2\omega} I_2 = L_2\omega\, I_2, \text{ nearly,}$$

for $L_2\omega = \frac{1}{C_2\omega}$ nearly in an interstage transformer.

Hence the amplification is, under ideal conditions,

$$\frac{E_{g2}}{E_{g1}} = \frac{1}{2} \cdot \frac{\mu}{\sqrt{R_p}} \cdot \frac{L_2\omega}{\sqrt{R_2}} \cdot \tag{14}$$

Now $\frac{\mu}{\sqrt{R_p}}$ is a tube constant* which should be used in place of the mutual conductance as a measure of its efficiency in a radio frequency circuit, while $\frac{L_2\omega}{\sqrt{R_2}}$ is a factor of the secondary coil which might well be listed for various coils.

THE PRIMARY CURRENT

From (2) and (3) we get

$$\mathbf{I}_1 = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \frac{M^2\omega^2}{\mathbf{Z}_2}} \cdot \tag{15}$$

Under ideal conditions, when (11) and (12) hold, this reduces to

$$\mathbf{I}_1 = \frac{\mathbf{E}_1}{2R_1} \cdot \tag{16}$$

Hence we see that the reaction from the secondary current is to make the primary circuit effectively a pure resistance of twice its true value; all primary reactance has in effect disappeared.

THE SECONDARY CURRENT

From equations (3), (11) and (12) we get:

$$\mathbf{I}_2 = \frac{\mathbf{E}_1}{2\sqrt{R_1 R_2}} \cdot \frac{X_1 + R_1 j}{Z_1} \cdot \tag{17}$$

This shows that when the reactance of the primary circuit is small in comparison with its resistance the secondary

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*The square of this constant, $\left(\frac{\mu}{R_p}\right)$, is sometimes used; it is then a conductance.

current leads the primary voltage by nearly a right angle. The departure from a right angle is just enough to provide the reactive voltages required in the primary.

ENERGY RELATIONS

The power dissipated in each circuit is:

In the primary, $I_1^2 R_1 = \dfrac{E_1^2}{4 R_1}$, (18)

In the secondary, $I_2^2 R_2 = \dfrac{E_1^2}{4 R_1}$. (19)

Both are the same, which is the required condition for the maximum output from the primary circuit to the secondary circuit.

FIXED MUTUAL INDUCTANCE

In many circuits the primary reactance and the mutual inductance are fixed, only the secondary reactance is varied. Sometimes the mutual inductance is varied in a rough manner with the secondary condenser. The question of the behaviour of these circuits arises.

THE PRIMARY CURRENT

Substituting (9) into (15) we get

$$\mathbf{I}_1 = \mathbf{E}_1 \cdot \frac{\left(R_1 R_2 + \dfrac{M^2 \omega^2}{Z_1^2} X_1^2\right) - X_1 \left(R_2 - R_1 \dfrac{M^2 \omega^2}{Z_1^2}\right) j}{M^2 \omega^2 R_1 + Z_1^2 R_2} \tag{20}$$

which shows that if M is greater than its proper value, the nature of the primary reactance is in effect reversed, an inductive reactance is changed to a condensive reactance and vice versa.

If M is less than its proper value, the nature of the primary reactance is unchanged.

THE SECONDARY CURRENT

Substituting (9) into (3) we find the maximum secondary current when X_2 only is varied to be

$$\mathbf{I}_2 = \frac{\mathbf{E}_1}{\left(\dfrac{M\omega}{Z_1} R_1 + \dfrac{Z_1}{M\omega} R_2\right)} \cdot \frac{X_1 + R_1 j}{Z_1}. \tag{21}$$

Comparing this with (17) we notice that the phase with respect to the primary voltage is the same as under the best conditions. On reducing (21) to its scalar equivalent we get

$$I_2 = \frac{E_1}{\left(\frac{M\omega}{Z_1} R_1 + \frac{Z_1}{M\omega} R_2\right)} . \tag{22}$$

Using this formula the curves for an aerial type and an interstage type of transformer were drawn. They are shown in Figures 2 and 3 respectively. For simplicity the resistances are assumed not to vary with the frequency, thus making all three curves have the same peak in each case. An equivalent aerial with lumped constants is assumed.[2]

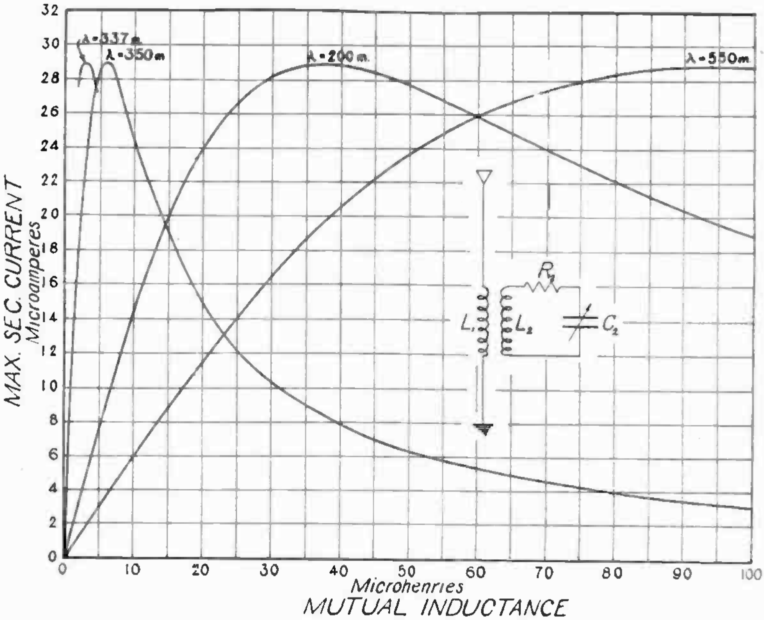

Figure 2—Characteristics of an Aerial Type Transformer when the secondary only is tuned. Three wavelengths, 200, 350 and 550 meters are shown. The constants used are:

$R_1 = 30$ ohms
$R_2 = 10$ ohms
$L_1 = 100$ microhenrys
$L_2 = 290$ microhenrys
$C_1 = 320$ micromicrofarads
$C_2 = 350$ micromicrofarads
$E_1 = 1$ millivolt
Natural Primary Wavelength = 337 meters

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[2] J. M. Miller, Bureau of Standards, Scientific Papers, No. 326. "Electrical Oscillations in Antennas and Inductance Coils."

Figure 2 is extremely interesting as it shows that very loose coupling is required at and around the frequency for which the aerial is naturally resonant. This has been called an absorption band because, with fixed coupling, as is often used, the response is very poor in this region. But it is not an absorption band in any sense of the word, it is merely a band of frequencies in which the coupling must be very accurately adjusted to small values.

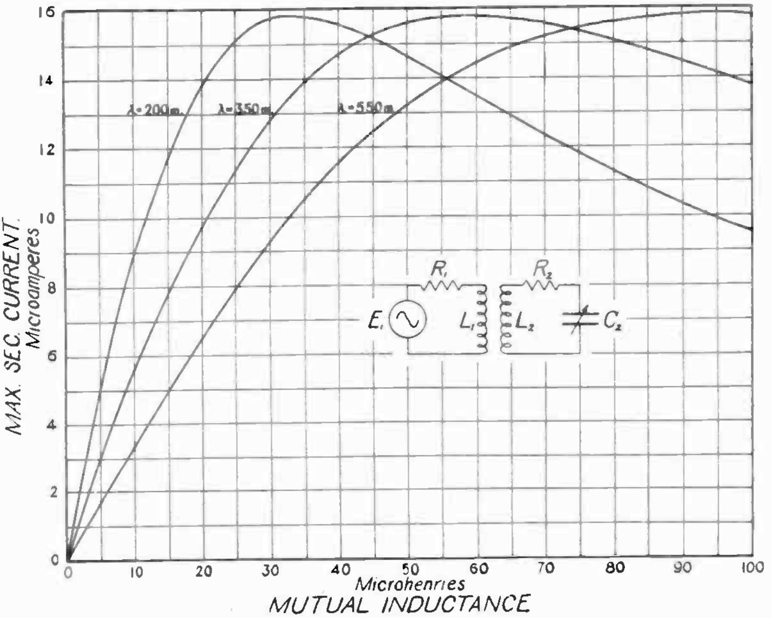

Figure 3—Characteristics of an Interstage Type Transformer when the secondary only is tuned. Three wavelengths, 200, 350 and 550 are shown. The constants used are:

$R_1 = 10{,}000$ ohms $R_2 = 10$ ohms
$L_1 = 46$ microhenrys $L_2 = 290$ microhenrys
$C_1 = \infty$ $C_2 = 350$ micromicrofarads max.
$E_1 = 10$ millivolts

This band may be avoided by using a series condenser in the aerial so as to make its natural frequency higher than any in range over which the set must operate. A loading coil will also have the same effect by decreasing the natural frequency below the lowest of the range.

But in case some one local station is troublesome we may use this loose-coupling band as a means of getting greater selectivity in the region of that station by making our aerial naturally resonant to that station. This almost seems contrary to common sense at first.

Figure 3 shows that the coupling of all transformers should be varied with the frequency but that in the interstage transformer the high primary resistance makes the adjustment very rough at all frequencies.

TUBE CAPACITIES

In all radio amplification the capacities between tube elements are troublesome. Various methods have been devised for neutralizing the grid to plate capacity to prevent all interaction between the grid circuit and the plate circuit other than the true electronic action of the tube. All of these methods are simply inductance capacity bridges, or perhaps just capacity bridges, some in the grid circuit, some in the plate.

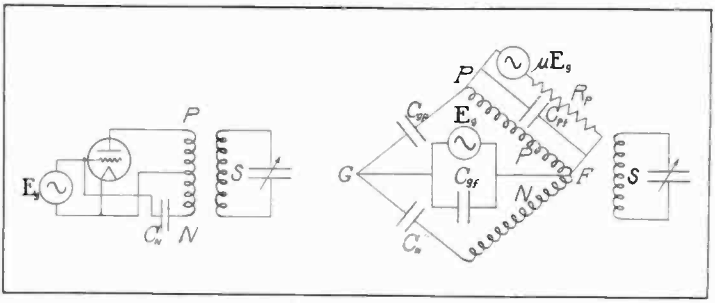

Figure 4—The Roberts' Circuit and its Equivalent Bridge Form.

The Roberts' circuit and its equivalent bridge arrangement are shown in Figure 4. This bridge is not quite perfect, for the primary coil *P* has some resistance, whereas it should have none at all, and the coefficient of coupling between *N* and *P* is never quite unity as it should be.

Note that the primary and the neutralizing coil should be quite closely coupled and *must* be related to the secondary in a symmetrical manner, for the secondary has a greater effect upon the primary emf. than the primary itself.

We also see that the tube has an input capacity of nearly $(C_{gf} + 2C_{gp})$, while there is an output capacity shunting the plate to the filament which is effectively $(C_{pf} + C_{gp})$. It is at least C_{pf} in any circuit.

In case any should think this negligible just note that at 1,500 kilocycles, 10 micromicrofarads had an impedance of 10,600 ohms, which is of the same order as the plate impedance of many tubes.

OUTPUT CAPACITY

Let us call the output capacity C_o, which must include all capacities from plate to filament. The equivalent circuit is shown in Figure 5.

Let the voltage from "a" to "b" $= \mathbf{V}_x$.

Then we may write the equations

$$\mathbf{V}_x = \mathbf{E}_1 - R_p\,(\,\mathbf{I}_o + \mathbf{I}_1\,), \tag{23}$$

$$\mathbf{V}_x = \mathbf{Z}_1\,\mathbf{I}_1 - \mathrm{m}\,\mathbf{I}_2, \tag{24}$$

$$\mathbf{I}_o = \mathbf{V}_x\ C_o\,\omega j, \tag{25}$$

$$0 = \mathbf{Z}_2\,\mathbf{I}_2 - \mathrm{m}\mathbf{I}_1, \tag{26}$$

where $\mathbf{Z}_1$ does not include R_p as it has previously.

Eliminating $\mathbf{V}_x$ and $\mathbf{I}_o$ we get

$$\frac{\mathbf{E}_1}{1 + R_p\,C_o\,\omega j} = \left(\mathbf{Z}_1 + \frac{R_p}{1 + R_p\,C_o\,\omega j}\right)\mathbf{I}_1 - \mathrm{m}\mathbf{I}_2 \tag{27}$$

$$0 = \mathbf{Z}_2\,\mathbf{I}_2 - \mathrm{m}\,\mathbf{I}_1 \tag{28}$$

From these equations it is seen that the tube behaves exactly as though it had a complex amplification factor

$$\mu = \frac{\mu}{1 + R_p\,C_o\,\omega j}\,, \tag{29}$$

and a complex plate impedance*

$$\mathbf{R}_p = \frac{R_p}{1 + R_p\,C_o\,\omega j} = \frac{R_p}{1 + R_p^2\,C_o^2\,\omega^2} - \frac{R_p^2\,C_o\,\omega}{1 + R_p^2\,C_o^2\,\omega^2}\,j \tag{30}$$

which is as though the plate impedance were reduced in the ratio of $\dfrac{1}{1 + R_p^2\,C_o^2\,\omega^2}$ and a series capacity $\dfrac{1 + R_p^2\,C_o^2\,\omega^2}{R_p^2\,C_o\,\omega}$ were in the plate circuit.

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*This is merely a special case of a general theorem which says that generators in parallel, having emfs. E_1, E_2, ------E_n, any of which may be zero, and impedances Z_1, Z_2, ------Z_n, are exactly equivalent to one generator with an impedance Z, where $\dfrac{1}{Z} = \dfrac{1}{Z_1} + \dfrac{1}{Z_2} + \text{------}\,\dfrac{1}{Z_n}$ and an emf. $E = Z\left(\dfrac{E_1}{Z_1} + \dfrac{E_2}{Z_2} + \text{------}\,\dfrac{E_n}{Z_n}\right)$. This is easily proved as above by assuming an unknown bus bar voltage.

The effect of the output capacity upon the secondary current is a slight change in phase and value. If we neglect the resistance and reactance of the primary coil in comparison with the fictitious plate impedance and the reactance of the fictitious series condenser there is no change whatever.

We may prove this by substituting (29) and (30) into (17) or by studying the vector diagram to which these equations lead.

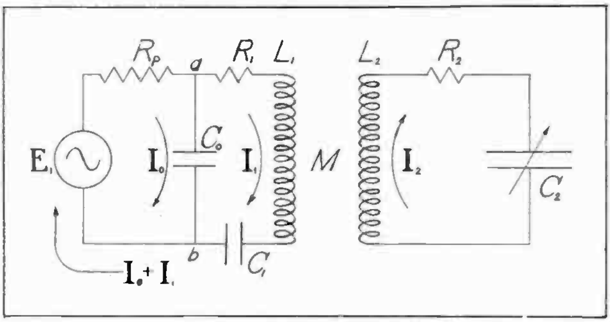

Figure 5—Fundamental Circuit of the Interstage Transformer When the Output Capacity of the Tube is Considered.

However, the output capacity forces the secondary circuit to have a considerable condensive reactance which in turn forces a considerably closer coupling than we should expect if we neglected it, for equations (11) and (12) must be satisfied to get the best results.

To construct this note that

$$\mathbf{E}_1 = \frac{\mu \, \mathbf{E}_{g1}}{1 + R_p C_o \omega j}, \tag{31}$$

which lags $\mathbf{E}_{g1}$ by an angle $tan^{-1} R_p C_o \omega$

$$\text{and } \mathbf{I}_1 = \frac{\mathbf{E}_1}{2\left(R_1 + \dfrac{R_p}{1 + R_p^2 C_o^2 \omega^2}\right)}, \tag{32}$$

which is in phase with $\mathbf{E}_1$

Then we have

$$\mathbf{E}_2 = M \omega j \, \mathbf{I}_1, \tag{33}$$

which leads $\mathbf{I}_1$ by 90°.

Now $\mathbf{I}_2$ leads $\mathbf{E}_2$ by an amount $tan^{-1} \dfrac{X_2}{R_2} = tan^{-1} \dfrac{X_1}{R_1}$, which is usually only slightly less than $tan^{-1} R_p C_o \omega$. This brings $\mathbf{I}_2$ nearly at right angles to E_{g1} and its value is given by

$$I_2 = \frac{E_1}{2\sqrt{\left(R_1 + \frac{R_p}{1 + R_p^2 C_o^2 \omega^2}\right) . R_2}} \quad . \qquad (34)$$

Finally the condenser voltage E_{g2} lags nearly $90°$ behind $\mathbf{I}_2$ and is given by

$$E_{g2} = \frac{\mathbf{I}_2}{C_2 \omega j} \quad . \qquad (35)$$

which completes the diagram.

Other vectors can be added as desired.

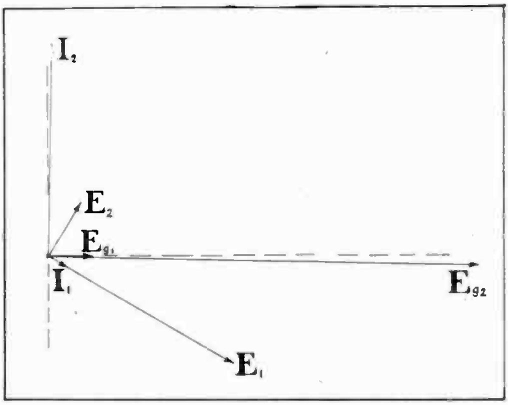

Figure 6—A Vector Diagram of the Interstage Type Transformer When the output capacity is considered.

REGENERATION

Strictly speaking, the regenerative transformer also comes under the heading of radio frequency amplification. However, it is far too lengthy and important a subject to be added here, as it requires to be treated from first principles and not as an extension of this work.

MUTUAL CAPACITY

We have throughout assumed that the capacity between the primary and the secondary is negligible. A very little thought will show that all such capacity is very objectionable, especially as the two coils are usually connected together at one end by a common battery. Such capacity must be kept as small as possible.

SUMMARY: The necessary conditions for the maximum secondary current are $\frac{X_1}{R_1} = \frac{X_2}{R_2}$ and $M^2 \omega^2 = Z_1 Z_2$ which may be established with only two variables making it unnecessary to tune the primary. The secondary current is then

$$I_2 = \frac{E_1}{2\sqrt{R_1 R_2}}$$

This leads to a tube constant $\frac{\mu}{\sqrt{R_p}}$ as a measure of its efficiency in a R. F. amplifier, also a coil constant $\frac{L\omega}{\sqrt{R}}$ for the secondary coil efficiency.

When the secondary only is tuned the maximum secondary current occurs when $X_2 = \frac{M^2 \omega^2}{Z_1^2} X_1$. Curves of this maximum secondary current are given in Figures 2 and 3 and discussed there.

The effect of tube output capacity is then studied, the solution being made to depend upon the previous work. In fact all additional problems such as combined impedance and mutual inductance coupling, mutual capacity between the windings, etc., can be made to depend upon the fundamental solution in a similar manner. We find that the effect of the output capacity is the same as though the tube had a complex amplification factor and a complex plate impedance.

DISCUSSION ON VACUUM TUBE NOMENCLATURE* (CHAFFEE)

M. W. Arps: While the writer agrees with Mr. Metcalfe that a nomenclature suitable for printing at moderate cost is desirable, it is desired to take exception to his estimate of the number of readers of the Institute interested in a paper of this kind.

Without a nomenclature of the extent of Dr. Chaffee's it would not be possible to write out the equations for the solution of certain vacuum tube problems, a fair example of of which was Dr. Chaffee's article on "Detection" in Volume 15 Number 2 (February, 1925) Proceedings.

The value of articles of this nature are not in the number of readers that are immediately interested, but in the number of members of the Institute who will have occasion to use this article in the next five years, and will have the paper available when they do become interested in this subject.

It is not believed anyone would deliberately set down and calculate the efficiency of a detector by the formulas as given. On the other hand, after my engineer had found by test that one vacuum tube was better than the average, it is believed there would be no more exact, or quicker method of locating the reason the tube was better, than to measure the constants of the tube, drop them into Dr. Chaffee's formulas, and grind out the result.

Even though they never read the paper through until the need arises, the fact that an engineer engaged in radio consulting work may be called on at almost any time to handle a problem of this nature is what makes papers of this kind of value to members of the Institute.

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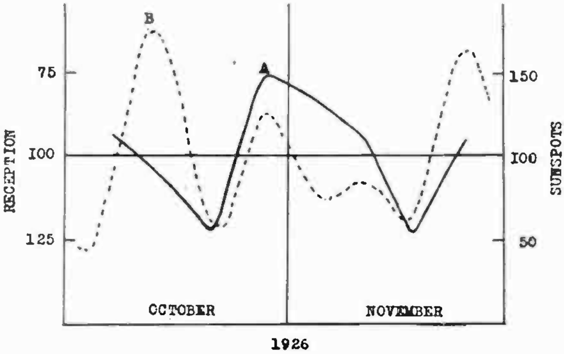
*Proc. I. R. E., Vol. 15, No. 3, March 1927, p. 182, discussion p. 253.

DISCUSSION ON
LONG DISTANCE RECEIVING MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1925 (L. W. AUSTIN)

Greenleaf W. Pickard: Mr. Sreenivasan's discussion[1] of Dr. Austin's Paper contains a short tabulation of weekly averages of Bangalore reception of Madras Radio, the distance being 295 kilometers and the frequency 75 kilocycles. Although the period of this tabulation is too short for a good comparison with terrestrial and cosmic elements, it may be of interest to contrast these measurements with sunspots for the same interval. Taking his weekly averages as ratios with the mean of the entire series, and plotting with inverted ordinates, the full-line curve A is obtained. The dotted-line curve B is made from the daily ratios of moving 7 and 27 day averages of the Wolfer Provisional Sunspot Numbers.



These curves suggest an inverse relation between Indian reception measurements and solar activity, such as that which I have found[2] for Dr. Austin's day reception at Washington from distant low frequency stations during 1926. It

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[1] Proceedings of the Institute of Radio Engineers, Vol. 15, No. 2, page 155, February, 1927.

[2] Proceedings of the Institute of Radio Engineers, Vol. 15, No. 2, Fig. 4, page 93, February, 1927

would be very interesting if Mr. Sreenivasan would compare, by the method which I have indicated above, a longer series of his 1926 measurements with sunspots, to determine whether this apparent inverse relation persists throughout the year.

In view of an investigation now in progress, in which I have already analyzed Dr. Austin's reception data for 1917, 1922 and 1923, finding in each of these years a direct instead of an inverse relation between sunspots and day reception, it would seem that 1926 might in this regard be an exception to a general rule.

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY

Issued Feb. 15, 1927—March 29, 1927

By

JOHN B. BRADY

Patent Lawyer, Ouray Building, Washington, D. C.

1,617,618—ELECTRIC CONDENSER—H. A. DOUGLAS, of Bronson, Mich. Filed June 16, 1924, issued Feb. 15, 1927.

1,617,467—RADIO SIGNALING SYSTEM—L. S. UPHOFF, of Brooklyn, N. Y. Filed Dec. 30, 1922, issued Feb. 15, 1927. Assigned to American Telephone & Telegraph Co.

1,617,956—CRYSTAL DETECTOR—L. LANE, of Habana, Cuba. Filed March 10, 1925, issued Feb. 15, 1927.

1,617,974—RADIO SIGNALING SYSTEM—W. C. WHITE, of Schenectady, N. Y. Filed Aug. 23, 1915, issued Feb. 15, 1927. Assigned to General Electric Co.

1,618,017—F. LOWENSTEIN, of New York. Filed June 28, 1910, issued Feb. 15, 1927. Assigned to Radio Corporation of America.

1,618,018—F. LOWENSTEIN, of Rockaway Park, N. Y. Filed Feb. 25, 1915, issued Feb. 15, 1927. Assigned to Radio Corporation of America.

1,618,255—VARIABLE NEUTRALIZING CONDENSER—JOHN J. WOOD, Denver, Colo. Filed May 16, 1925, issued Feb. 22, 1927.

1,618,298—VALVE AMPLIFIER—HANS E. RUKOP, Berlin, Germany. Filed Sept. 3, 1921, issued Feb. 22, 1927. Assigned to Gesellschaft fur Drahtlose Telegraphie.

1,618,299—AERIAL SYSTEM EMPLOYED IN RADIO SIGNALING—S. B. SMITH and G. M. WRIGHT, Chesterfield, England. Filed Mar. 8, 1921, issued Feb. 22, 1927. Assigned to Radio Corp. of America.

1,618,399—VARIABLE CONDENSER—R. M. WISE and E. G. DANIELSON, San Francisco, Cal. Filed July 26, 1924, issued Feb. 22, 1927. Assigned to E. T. Cunningham.

1,618,499—ELECTRICAL APPARATUS—C. P. WHITE, Lynn, Mass. Filed Nov. 6, 1923, issued Feb. 22, 1927.

1,618,468—RADIO RECEIVING EQUIPMENT—J. C. R. PALMER, New Rochelle, N. Y. Filed June 13, 1923, issued Feb. 22, 1927. Assigned to Western Electric Co.

1,618,816—LIGHT CONTROL SWITCH—H. R. DAVIES, Valley Cottage, N. Y. Filed May 3, 1918, issued Feb. 22, 1927. Assigned to Industrial Research Corp.

1,618,974—VARIABLE CONDENSER—C. N. CAHUSAC, Newark, N. J. Filed Apr. 16, 1925, issued Mar. 1, 1927. Assigned to U. S. Tool Co. Inc.

1,619,201—CONDENSER—J. A. FRIED, Flushing, N. Y. Filed Apr. 29, 1926, issued Mar. 1, 1927. Assigned to Dubilier Condenser Corp.

1,619,223—CONDENSER—H. R. VAN DEVENTER, New York City. Filed May 17, 1924, issued Mar. 1, 1927. Assigned to Dubilier Condenser Corp.

1,619,318—ELECTROSTATIC DETECTOR AND AMPLIFIER—F. E. SUMMERS, Near Memphis, Mo. Filed Jan. 19, 1920, issued Mar. 1, 1927. Assigned to Magnavox Co.

1,619.544—RADIO APPARATUS—A. F. SNAFORD, Knoxville, Tenn. Filed Aug. 21, 1925, issued Mar. 1, 1927.

1,619,318—ELECTROSTATIC DETECTOR AND AMPLIFIER—F. E. SUMMERS, near Memphis, Mo. Filed Jan. 19, 1920, issued Mar. 1, 1927. Assigned to Magnavox Co.

1,619,545—RADIO APPARATUS—A. F. SANFORD, Knoxville, Tenn. Filed Sept. 23, 1925, issued Mar. 1, 1927.

1,619,597—ELECTRICAL CONDENSER—M. CLARK, Chicago, Ill. Filed Feb. 1, 1926, issued Mar. 1, 1927.

1,619,892—MEANS FOR TRANSFERRING HIGH FREQUENCY ENERGY—R. S. OHL, New York City. Filed Dec. 4, 1924, issued Mar. 8, 1927. Assigned to American Telephone & Telegraph Co.

1,619,974—VALVE OPERATING MECHANISM—G. E. A. HALLETT, Dayton, O. Filed Nov. 24, 1924, issued Mar. 8, 1927. Assigned to General Motors Research Corp.

1,620,020—VARIABLE CONDENSER—C. HARDY, New York City. Filed Dec. 10, 1923, issued Mar. 8, 1927. Assigned to Amsco Products, Inc.

1,620,204—FREQUENCY INDICATION AND CONTROL—R. A. HEISING, Millburn, N. J. Filed Dec. 29, 1924, issued Mar. 8, 1927. Assigned to Western Electric Co. Inc.

1,620,231—RADIO ANTENNA SYSTEM—D. W. RICHARDSON, Princeton, N. J. Filed Apr. 26, 1922, issued Mar. 1, 1927.

1,620,244—VARIABLE CONDENSER—F. E. SWOPE, JR., Philadelphia, Pa. Filed May 18, 1923, issued Mar. 8, 1927.

1,620,318—HIGH FREQUENCY ARC CONVERTER—R. R. BEAL and H. F. ELLIOTT, Palo Alto, Cal. Filed Jan. 9, 1922, issued Mar. 8, 1927. Assigned to Federal Telegraph Co.

1,620,655—DIRECTIVE RADIO RECEIVING SYSTEM—R. A. HEISING, East Orange, N. J. Filed Sept. 8, 1920, issued Mar. 15, 1927. Assigned to Western Electric Co.

1,620,656—CARRIER WAVE SIGNALING SYSTEM—R. A. HEISING, Millburn, N. J. Filed Dec. 1, 1924, issued Mar. 15, 1927. Assigned to Western Electric Co., Inc.

1,620,973—RADIO RECEIGING CIRCUIT—W. KAUFMAN, Paterson, N. J. Filed Apr. 14, 1923, issued Mar. 15, 1927.

1,621,034—RADIO RECEIVING SYSTEM—J. SLEPIAN, Swissvale, Pa. Filed Jan. 13, 1922, issued Mar. 15, 1927. Assigned to Westinghouse Electric & Mfg. Co.

1,621,037—RECEIVING SYSTEM FOR HIGH FREQUENCY ELECTRICAL OSCILLATIONS—A. H. TAYLOR and L. C. YOUNG, Washington, D. C. Filed Jan. 19, 1924, issued Mar. 15, 1927.

1,621,058—ELECTRIC CONDENSER—O. BURGER, Berlin, Charlottenburg, Germany. Filed Feb. 10, 1925, issued Mar. 15, 1926. Assigned to Westinghouse Electric & Mfg. Co.

1,621,062—RADIO SYSTEM—L. W. CHUBB, Edgewood Park, Pa. Filed June 17, 1920, issued Mar. 15, 1927. Assigned to Westinghouse Electric & Mfg. Co.

1,621,253—VARIABLE ELECTRIC CONDENSER, VARIOMETER AND THE LIKE—A. F. HOLLIDAY, Wigan, England. Filed Dec. 8, 1924, issued Mar. 15, 1927.

1,621,379—VARIABLE CONDENSER—T. T. RODGERS, M. A. GIBLIN, F. K. MOORE and G. T. MOORE, Milwaukee, Wis. Filed Sept. 24, 1924, issued Mar. 15, 1927. Assigned to Rodgers Radio Corp.

1,621,659—CONDENSER—J. B. DEMPSTER, Iowa City, Ia. Filed Dec. 14, 1922, issued Mar. 22, 1927.

1,621,721—VARIABLE CONDENSER—G. W. HAYDEN, Oak Park, Ill. Filed Apr. 16, 1926, issued Mar. 22, 1927.

1,621,722—ELECTROSTATIC CONDENSER—G. W. HAYDEN, Oak Park, Ill. Filed July 6, 1926, issued Mar. 21, 1927.

1,621,901—ELECTRICAL APPARATUS—W. H. PRIESS, of Montclair, N. J. Filed Dec. 5, 1921, issued Mar. 22, 1927. Assigned to Wireless Specialty Apparatus Company.

1,621,992—VALVE GENERATOR ARRANGEMENT—A. MEISSNER, of Berlin, Germany. Filed Sept. 3, 1921, issued March 22, 1927. Assigned to Gesellschaft Fur Draftlose Telegraphie M. B. H. Hallesches.

1,621,998—ARRANGEMENT FOR ELIMINATING DISTURBING WAVES IN RADIO FREQUENCY CIRCUITS—M. OSNOS, of Berlin, Germany. Filed Apr. 30, 1923, issued Mar. 22, 1927. Assigned to Gesellschaft Fur Draftlose Telegraphie M. B. H. Hallesches Ufer 12/13.

1,622,000—RADIO TELEGRAPH RECEIVING SYSTEM—H. J. ROUND, London, England. Filed Feb. 2, 1923, issued Mar. 22, 1927. Assigned to Radio Corp. of America.

1,622,025—SYSTEM OF RADIOTELEGRAPHY—H. CHIREIX, Paris, France. Filed July 20, 1923, issued Mar. 22, 1927.

1,622,033—RADIOTELEPHONY—A. N. GOLDSMITH and J. WEINBERGER, New York City. Filed May 26, 1922, issued Mar. 22, 1927. Assigned to Radio Corp. of America.

1,622,052—ELECTRICAL CONDENSER—W. J. RICKETTS, Crofton Park, England. Filed Sept. 7, 1926, issued Mar. 22, 1927.

1,622,170—SUPPLY CIRCUITS FOR RADIO SETS—J. G. ACEVES, New York City. Filed Apr. 29, 1922, issued Mar. 22, 1927. Assigned to Crocker-Wheeler Company.

1,622,297—RADIO PRINTING TELEGRAPH SYSTEM—G. S. VERNAM of River Edge, N. J. Filed Dec. 29, 1924, issued Mar. 29, 1927. Assigned to American Telegraph & Telephone Co.

1,622,370—MULTIPLE ANTENNA SYSTEM FOR RADIOCOMMUNICATION—L. ESPENSCHIED, of Queens, N. Y. Filed Sept. 3, 1921, issued Mar. 29, 1927. Assigned to American Telephone & Telegraph Co.

1,622,389—RADIO COMMUNICATION DEVICE—B. F. MEISSNER, of Chicago. Ill. Filed Nov. 6, 1922, issued Mar. 29, 1927.

1,622,459—RADIO DETECTOR—B. H. LUNDQUIST, of Providence, R. I. Filed Feb. 29, 1924, issued Mar. 29, 1927.

1,622,604—BERYLLIUM FILAMENT—A. NYMAN, of New York, N. Y. Filed Nov. 7, 1924, issued Mar. 29, 1927. Assigned to Dubilier Condenser Corporation.

1,622,654—RADIO TRANSMISSION SYSTEM—D. G. LITTLE, of Wilkinsburg, Pa. Filed July 20, 1922, issued Mar. 29, 1927. Assigned to Westinghouse Electric & Mfg. Co.

GEOGRAPHICAL LOCATION OF MEMBERS ELECTED MAY 4, 1927

Transferred to Member Grade

Connecticut,	Hartford, 1711 Park St.	Beekley, F. C.
Pennsylvania,	Pittsburgh, 218 Beech St., Edgewood	Little, Donald G.
England,	Essex, Ilford, 1 Montreal Road,	Cooper, J. A. J.

Elected to Member Grade

Spain,	Cartagena, Submarine Naval Base,	Matres, Trinidad

Elected to Associate Grade

Alabama,	Gadsden, 246 S. 5th St.,	McCormack, J. E.
California,	Berkeley, 2531 Channing Way,	Culley, Lester D.
	Jackson, National Hotel,	van Thiel, Jan
	Los Angeles, 2200 S. Union Ave.,	Hankins, Marvin J.
	San Diego, 4177 Alabama St.,	Doig, John H.
Colorado,	Boulder, R. No. 1, Box 77,	Sammons, Floyd
Connecticut,	South Manchester, Manchester Hospital,	Watt, Earl W.
Delaware	Wilmington, 211 S. Grant Ave.,	Mertz, John M.
Dist. Columbia	Washington, 2017 "O" St., N. W.,	Shortland, James W.
Florida,	Jacksonville, 502 Spearing St.,	Ffoulkes, Cecil E.
	Melbourne, Melbourne Elec. Co.,	Christensen, B. J.
	Tampa, 226 Hyde Park Ave.,	Fisher, Carroll S.
	West Palm Beach, P. O. Box 3243,	Leftwich, E. H.
Illinois,	Chicago, 4940 Lowell Ave.,	Kehm, Clarence H.
	Chicago, 1024 N. Calif. Ave.,	Mazur, Robert S.
	Chicago, 5740 Laftin St.,	McConnell, Harold
	Chicago, 1511 Sedgwick St.,	Parisek, Edward E.
	Decatur, 1538 N. Edward St.,	Spies, Mack C.
	Evanston, 732 Hinman Ave.,	Giard, E. A.
	Fort Sheridan, Signal Corps.,	Maki, George J.
	Maywood, 1926 So. 6th Ave.,	Peary, Malcolm J.
	Quincy, 412 N. 4th St.,	Johnson, J. Robert
Indiana,	North Vernon, Platter Cabinet Co.,	Martin, James A.
Iowa,	Burlington, 914 University Place	Jeffrey, Byron B.
	Cedar Rapids, 526 "C" Ave., East,	Miller, Calir R.
	Dubuque, 3100 White St.,	Long, Frank E.
Kansas,	Ft. Leavenworth, Box 506,	Deremer, Chas. W.
	Lawrence, 200 West 12th St.,	Weedfall, Wm. W.
	Wichita, 509 Winne Bldg.,	Crabtree, Clyde A.
	Wichita, 522 S. Main St.,	Riggs, A. V.
Kentucky,	Berea, Berea College, Box 732	Bryant, Earl A.
	Owensboro, 306 Frederica St.,	Field, Robert W.
Louisiana,	New Orleans, Trop. Radio Tel. Co.,	Whitney, Chas. L.
Maine,	Bangor, 66 Kenduskeag Ave.,	Preston, George D.
Maryland,	Baltimore, 14 S. Broadway	Millhollin, Lorren E.
Massachusetts,	Boston, The Shepard Stores, WNAC,	Stone, C. Willis
	East Springfield, Westinghouse E & M	Coulson, Everett J.
	Haverhill, Postal Teleg-Cable Co.,	Taylor, B. H.
	Roxbury, 3 Westminister Terrace,	Canner, William
	Watertown, 12 Appleton Terrace,	Church, Vallette S.
	Waverly, 105 Beech St.,	McManus, Cornelius F.
Michigan,	Detroit, 11543 Linwood Ave.,	Forna, Alfred A.
	2207 Philip Ave., Apt. 3,	Prange, Harry F.
	Flint, 734 Louisa St.,	Morgan, Ernest W.
	Hartford,	Devore, W. D.
Missouri,	Columbia, Stephens College,	Lewis, Earl W.
Nebraska,	Omaha, 1206 Dominion St.,	Kotera, William J.
	Omaha, Brandies Store,	Thompson, Harry E
Nevada,	Reno, 1035 Sierra St.,	Hauschild, John P.
New Jersey,	Camden, Hotel Camden,	Martin, C. Oakley
	Ventor City, 11 S. Fredericksburg Ave.,	Sharkey, Wm. J.

New York,	Albion, 17 Lincoln St.,	Yahnke, Wm. J.
	Brooklyn, 2245 East 23rd St.,	Domes, Morris M.
	Brooklyn, 1084 New York Ave.,	Hoefler, Raymond L.
	Brooklyn, 190 Jerome St.,	Kent, Stephen F.
	Brooklyn, 446 Prospect Ave.,	Maxfield, Lewis S.
	New York, 814 Hewitt Place,	Abrahamian, Garo R.
	New York, 522 West 136th St.,	Baldwin, Chester P.
	New York, 2030 Grand Central Ter.,	Bryan, Herman W.
	New York, 1749 Grand Concourse,	Fischer, Leonard O.
	New York, 100 East 42nd St.,	Hunt, Henry T.
	New York, c-o Postmaster, USS Porter	Kortes, George T.
	New York, 345 East 33rd St.,	Mackay, William A.
	New York, 81 East 119th St.,	Nicolai, Erwin W.
	New York, 331 West 83rd St.,	Shine, L. J.
	New York, 4068 Broadway,	Waas, Albert
	Rochester, 15 Caledonia Ave.,	Dodson, George W.
	Schenectady, 103 Nott Terrace,	Brackett, Richard T.
	Schenectady, 1411 State St.,	Dunning, Orville M.
	Stapleton, Staten Island, uscg Colfax,	Hines, Joseph
N. Carolina,	Winston-Salem, Box 806,	Kickler, E. M.
Ohio,	Alliance, 112 S. Liberty Ave.,	Morgan, O. K.
	Cleveland, 3987 West 22nd St.,	Ermatinge, Alex E.
	Cleveland, 3545 Storer Ave.,	Fouse, Harold
	Cleveland, 1071 E. 98th St.,	Hoefele, H. E.
	Cleveland, 1726 St. Clair Ave.,	Talkes, Louis N.
	Cleveland, 18112 Kinsman Blvd.,	Thomas, William W.
	Cleveland, 14709 Coit Road,	White, Louis A.
	Cleveland, 891 East 105th St.,	Woolf, Louis M.
	Columbus, 604 East Town St.,	Newby, Raymond W.
	Dayton, 2130 West 3rd St.,	Bickel, Howard I.
	Dayton, 1219 Kemper Ave.,	Greene, Chas. E.
	Dayton, 1262 Detzen Ave.,	Hopkins, A. R.
	Dayton, 1268 Detzen Ave.,	Loftis, Homer J.
	Dayton, 1041 Bolander Ave.,	Reynolds, F. D.
	Wyoming (P. O. Lockland)	Boes, W. W.
Pennsylvania,	New Castle, Union Trust Bldg.,	Martin, Norman A.
	Philadelphia, 3702 Hamilton St.,	Ayer, Oliver G.
	Philadelphia, 4013 Spring Garden St.,	Frazier, Howard S.
	Philadelphia, 1835 Arch St.,	Nichols, J. J.
	Philadelphia, 3622 N. 15th St.,	Schulmerich, Geo. J.
	Philadelphia, 3004 N. Howard St.,	Tarzian, Sarkes
	Pottsville, East Penn Elec. Co.,	May, W. L.
Rhode Island,	Thornton, 1149 Plainfield St.,	Grain, Everard B.
So. Carolina,	Charleston, 308 King St.,	Land, Joe N. Jr.
Texas,	Dallas, 3022 Peabody Ave.,	Glass, Robert Z.
	Dallas, 919 Graham Ave.,	White, Newell N.
	Plano, Box 154,	Hays, Howard D.
	San Antonio, 839 East Texas Ave.,	Kush, Fred W.
Washington,	Tacoma, 3617 "E" Street,	Miller, Geo. C.
W. Virginia,	Wheeling, 2116 Market St.,	Spence, M. R.
Wisconsin,	Milwaukee, 216 West Water St.,	Heim, Carl
	Milwaukee, 598-17th St.,	Luecker, Fred W. Jr.
	Owen,	Smith, C. Everrett
Canada,	Ontario, Hamilton, Can. Westinghouse,	Kelterborn, W. H.
	Ontario, Toronto, Christiest Mil. Hospital,	Chapman, Edmund V.
	Ontario, Toronto, 292 Carlton St.,	Mosley, R. F.
	Sask., Moose Jaw, 1135 2nd Ave., N. W.	Bagly, B. deF.
	Sask., Regina, 2208 McIntyre St.,	McKinnon, Clifford J.
England,	London SW 2, 170 Leander Road,	Roose, Theo. R.
	Huddersfield, 12 Queens Square,	Hilton, F. C. B.
	Sheffield, 123 Sandford Grove Rd., Nether Edge,	Bagshaw, G. W.
	Birkenhead, Tranmere Park, 35 Milton Rd.,	Tudor, George W. N.
	Notts., West Bridgford, 172 Trent Blvd.,	Kynaston, B. H. J.
Ireland,	Co. Antrim, Whitehead "Chesterfield"	Neill, Frank R.
New Zealand,	Auckland, Bucklands Beach, Hattaway Ave.,	Dickson, L. R.
	Wellington, 102 Oriental Parade,	Swain, Noel

Elected to Junior Grade

Arkansas,	Little Rock, 3914 West 13th St.,	Edwards, Julian
California,	Glendale, 115 N. Adams St.,	Eilers, John
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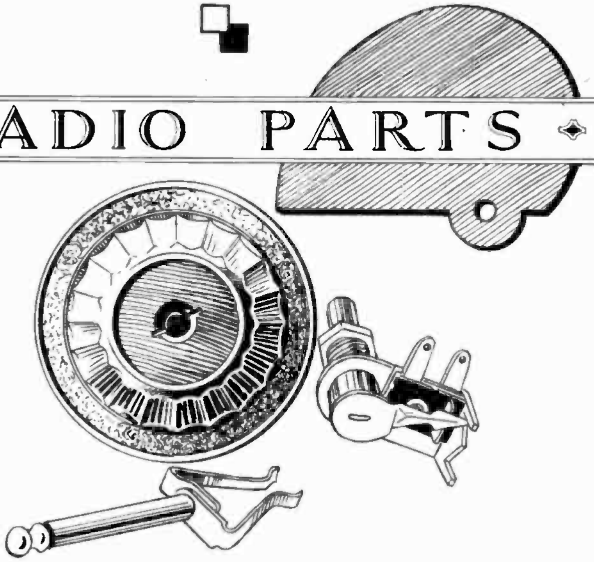

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—in power supply units

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There are available Vitrohms to give you noiseless, dependable service wherever resistance is indicated in a current or power supply circuit.

Vitrohms do not age or change in resistance value after use. Ten, twenty or thirty years of constant use under all conditions are every-day records of Vitrohms.

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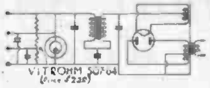
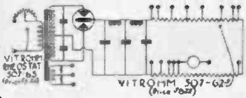


RAYTHEON A-B-C
350 m.a. CURRENT SUPPLY UNIT

*Uses Vitrohm Resistor 507-62**
and Vitrohm Rheostat 507-63



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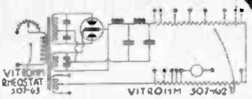

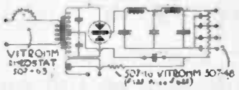

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85 m.a. CURRENT SUPPLY UNIT

Uses Vitrohm Resistors
507-16 and 507-48**

Vitrohms are "pre-aged" wire wound on porcelain tubes and protected by fused-on vitreous enamel for the permanent protection of resistance wire and terminals.

Per square inch of surface, Vitrohms have greater watt dissipation than any other resistor.

Send 15c for "How To Use Resistance in Radio." It contains many circuits of interest to all experimenters. Bulletin 507 describing Vitrohms for radio is sent without charge upon request.

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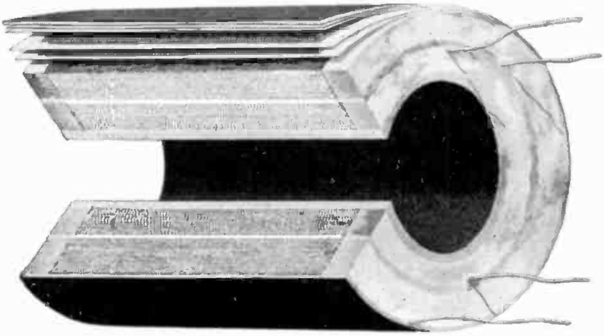
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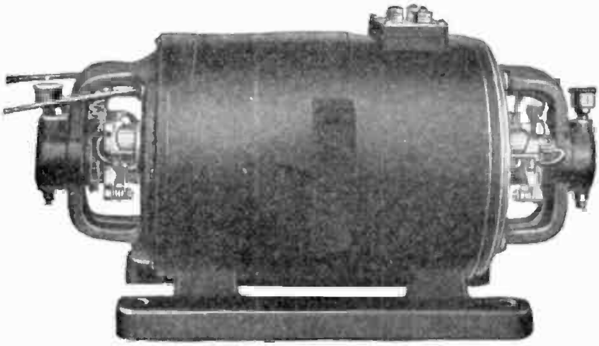
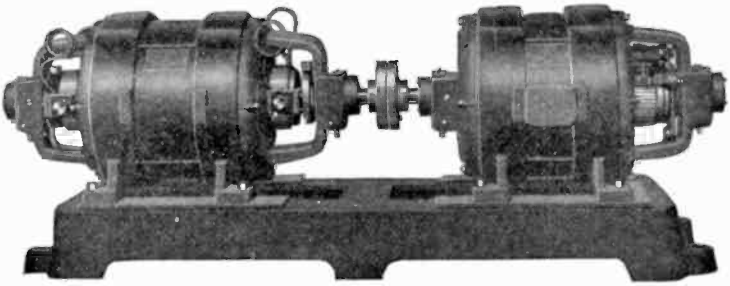
Coil impregnated throughout and ends sealed with highest grade insulating compound.
Special insulation between primary and secondary.

Always specify—
"ESCO" Maximum miles per watt Power supplies for transmission.



"ESCO" has developed a line of over 100 standard 2-bearing Motor-generators for plate or filament. These include D.C., A.C., single phase and polyphase motors.



"ESCO" two and three unit sets have become the accepted standards for transmission. The "ESCO" line consists of over 200 combinations. These are covered by Bulletin 237C.

Our engineers are always willing to cooperate in the development of special sets.

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Height—42 in. Width—25½ in.
Depth—19 in.

The New Model 6H

The ultimate set—Kolster Radio 6H. This unusually attractive cabinet of high-lighted stump walnut includes a Kolster 6-tube single control radio and—the new Kolster Power Cone Reproducer with built-in "B" supply for set.

Height—53⅛ in. Width—27 in.
Depth—18½ inches

The Kolster Radio Compass, the use of which permits the safe navigation of vessels during thick or foggy weather, is also manufactured by this company.

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Resistors for series operation of 199 and 201-A Type Tubes in A. C. operated sets

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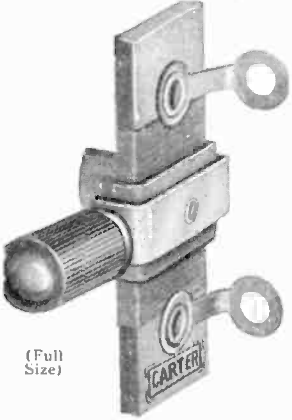

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Code No. PA-500
500 ohms

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Adjustable Resistors for screw driver adjustment designed for circuits where only occasional adjusting is necessary.

New Voltage Control for "B" Battery eliminators.

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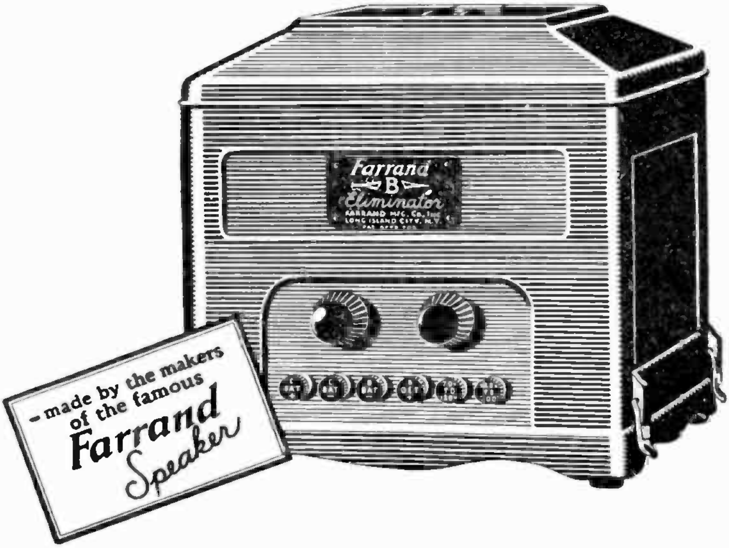

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These characteristics of Ferranti Audio Frequency Transformers warrant your serious attention

High amplification ratio with flat curve.

High primary inductance maintained under normal operating conditions.

Low leakage reactance resulting in uniform amplification at high frequencies.

Primary winding of ample cross section to withstand continuously, plate currents resulting from all usual operating conditions.

No compound or fibrous material used in construction, therefore low self and mutual capacity with durability and long life.

Core of specially tested material, of ample cross section. Laminations thoroughly insulated and assembled to produce an efficient magnetic circuit.

Primary shunted with built in condenser of correct capacity.

Every transformer subjected to ten tests to insure uniformity of product.

Tested to one thousand volts between primary and secondary, and between primary and secondary and ground; therefore specially suited for use with power tubes requiring high plate voltages.

For the best results use two Ferranti audio frequency transformers, type AF-3, ratio 3.5/1.

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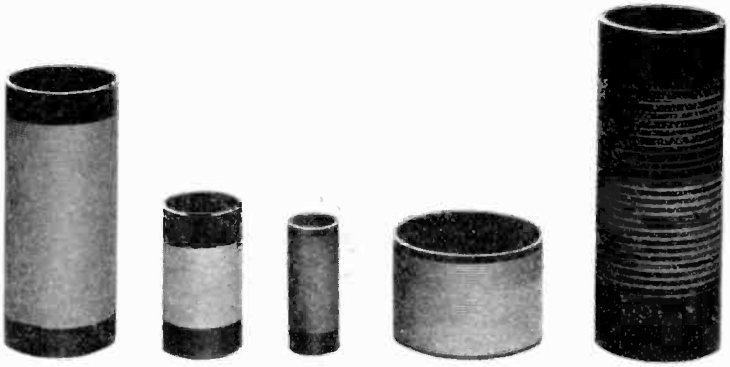

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Tobe High Voltage Power Pack Type Condenser

This is a high-voltage condenser for use with the 216-B Rectifying Tube, supplying 400 to 500 volts for the plate of the UX-210 power tube. Designed primarily for use with the Amertran Power Pack, it is equally applicable to all similar B-current supplies and power amplifiers.

Now made also in a block containing condensers with taps 2-4-4 Mfd. Price of this B-BLOCK Type 766—$12.00.

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—are made just as well as it is possible to make them. They are made and sold to stand up in service and do the work for which they are intended. Their ratings are conservative:—for instance, the new TINYTOBE Condenser in capacities of from .00007 to .02 will stand 1500 volts A. C. continuously, and will stand 2200 volts A. C. for one minute. Yet has been rated at only 500 volts D. C. operating voltage.

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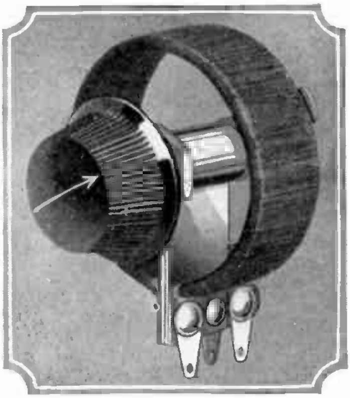

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Power Rheostat and Potentiometer

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CENTRALAB WIRE WOUND FIXED RESISTORS

A flat, compact fixed resistance of ample area for power service. Resistance wire is wound on asbestos and held in place with heat-proof cement that also strengthens the resistor. Practically heat-proof and indestructible. Will dissipate up to 50 watts in open air at a temperature below 482 degrees F. Resistors are 5" long, 1½" high and only 1/16" thick. Several resistors can be mounted side by side on the same two mounting screws, making a simple and space saving assembly. Special resistances or resistance taps will be furnished manufacturers on quotation.

SMALL, compact yet with large overload factors, these new Centralab wire-wound controls are designed especially for light socket power equipment.

Built-in permanency. These new controls are constructed of heat-proof materials. No fibre to warp or to burn out. All parts riveted or spot-welded together. High temperatures have no effect on performance or materials. The overload factor is limited only by the carrying capacity of the wire used and the FUSION POINT of the wire is the limiting temperature.

Laboratory test of 250 ohm sample showed dissipation of 53 watts at 482 degrees F.

The space required for mounting is the same as that for standard type—diameter 2 inches, depth behind panel one inch. Single hole mounting.

Centralab Quality assures permanency and reliability. Prices are reasonable and are based upon resistance and quantity desired. WRITE FOR FULL PARTICULARS.

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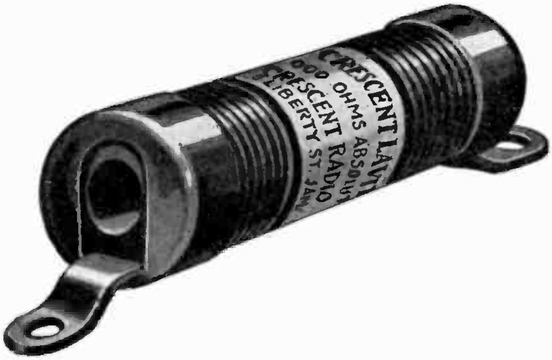
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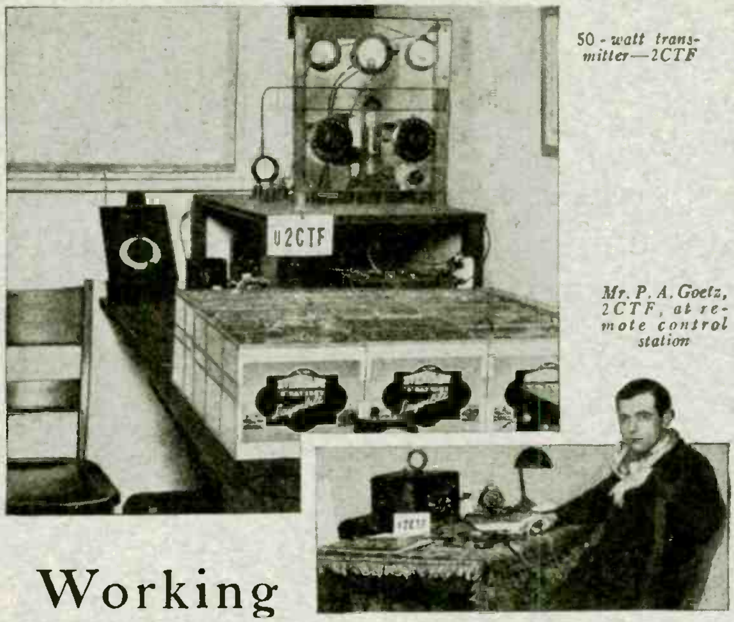

50-watt transmitter—2CTF

Mr. P. A. Goetz, 2CTF, at remote control station

Working the world with Layerbilts

Over a year ago Philip A. Goetz used ten Eveready Layerbilt "B" Batteries in testing the short wave transmitter which he built for the Putnam Expedition. Following those tests the same batteries were used on Mr. Goetz's own transmitter, 2 CTF, which had been using 1200 volts of rectified AC on the UV-203-A tube. With the batteries for plate supply some remarkable DX was made. Chile 2 BL was worked January 26, 1927, at 11.30 P. M. E.S.T. He reported 2 CTF sigs as r 3, very steady, DC. The next day Brazil 1 AP was worked for nearly an hour. Brazil reported sigs r 4 to r 5, making perfect copy of all msgs. Soon after this, more Layerbilts were added to the bank to provide 650 volts to a special battery-powered transmitter using a UX-210 tube. Using this combination of new Layerbilts with old ones that had seen practically a year of the hardest kind of service, Mr. Goetz has worked Australian OA 3 VF, and German EK 4 DBA.

Records such as these are not at all unusual for good short wave transmitters using battery power. Nor are such life records for the Eveready Layerbilt uncommon, for it has proved itself to be the longest lasting "B" battery ever built, for receivers as well as for transmitters.

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WTAM—*Cleveland*
WWJ—*Detroit*
WGN—*Chicago*
WOC—*Davenport*
WCCO {*Minneapolis* / *St. Paul*}
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