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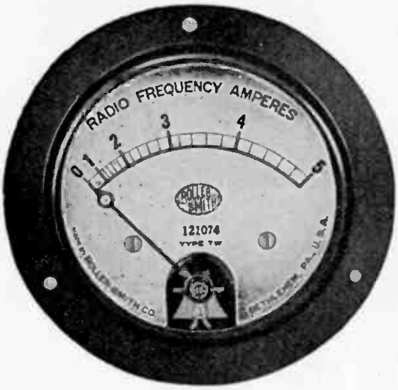

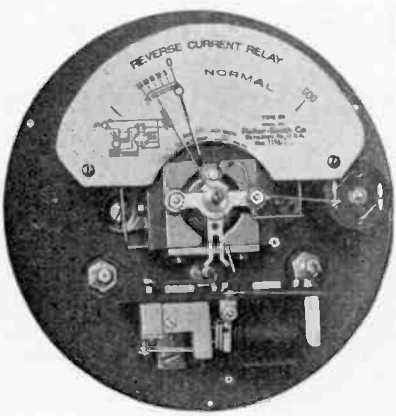

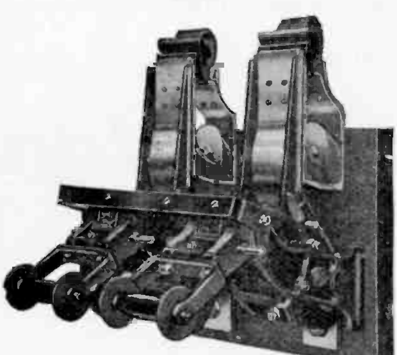

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Form—Manuscripts may be submitted by member and non-member contributors from any country. To be acceptable for publication manuscripts should be in English, in final form for publication, and accompanied by a summary of from 100 to 300 words. Papers should be typed double space with consecutive numbering of pages. Footnote references should be consecutively numbered, and should appear at the foot of their respective pages. Each reference should contain author's name, title of article, name of journal, volume, page, month, and year. Generally, the sequence of presentation should be as follows: statement of problem; review of the subject in which the scope, object, and conclusions of previous investigations in the same field are covered; main body describing the apparatus, experiments, theoretical work, and results used in reaching the conclusions; conclusions and their relation to present theory and practice; bibliography. The above pertains to the usual type of paper. To whatever type a contribution may belong, a close conformity to the spirit of these suggestions is recommended.

Illustrations—Use only jet black ink on white paper or tracing cloth. Cross-section paper used for graphs should not have more than four lines per inch. If finer ruled paper is used, the major division lines should be drawn in with black ink, omitting the finer divisions. In the latter case, only blue-lined paper can be accepted. Photographs must be very distinct, and must be printed on glossy white paper. Blueprinted illustrations of any kind cannot be used. All lettering should be $^3/_{16}$ in. high for an 8 x 10 in. figure. Legends for figures should be tabulated on a separate sheet, not lettered on the illustrations.

Mathematics—Fractions should be indicated by a slanting line. Use standard symbols Decimals not preceded by whole numbers should be preceded by zero, as 0.016. Equations may be written in ink with subscript numbers, radicals, etc., in the desired proportions.

Abbreviations—Write a.c. and d.c., kc, μf, $\mu\mu$f, emf, mh, μh, henries, abscissas, antennas. Refer to figures as Fig. 1, Figs. 3 and 4, and to equations as (5). Number equations on the right, in parentheses.

Summary—The summary should contain a statement of major conclusions reached, since summaries in many cases constitute the only source of information used in compiling scientific reference indexes. Abstracts printed in other journals, especially foreign, in most cases consist of summaries from published papers. The summary should explain as adequately as possible the major conclusions to a non-specialist in the subject. The summary should contain from 100 to 300 words, depending on the length of the paper.

Publication of Paper

Disposition—All manuscripts should be addressed to the Institute of Radio Engineers, 33 West 39th Street, New York City. They will be examined by the Committee on Meetings and Papers and by the Editor. Authors are advised as promptly as possible of the action taken, usually within one month.

Proofs—Galley proof is sent to the author. Only necessary corrections in typography should be made. *No new material is to be added.* Corrected proofs should be returned *promptly* to the Institute of Radio Engineers, 33 West 39th Street, New York City.

Reprints—With the notification of acceptance of paper for publication, reprint order form is sent to the author. Orders for reprints must be forwarded promptly as type is not held after publication.

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The Institute of Radio Engineers

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GENERAL INFORMATION

The PROCEEDINGS of the Institute is published monthly and contains the papers and the discussions thereon as presented at meetings.

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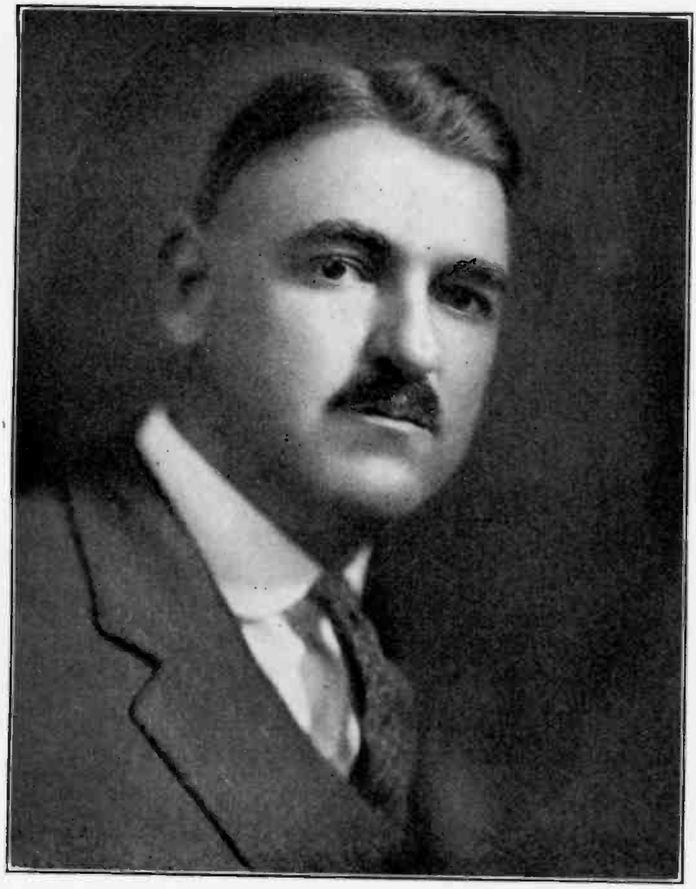

Leonard F. Fuller
Manager of the Institute, 1928

Leonard F. Fuller

MEMBER OF THE BOARD OF DIRECTION OF THE INSTITUTE, 1928

Leonard F. Fuller, born in Portland, Oregon, August 21, 1890, was graduated from Cornell University in 1912 with the M.E. degree. Immediately thereafter he entered the employ of the National Signalling Company of Brooklyn, N. Y. A few months later he joined the staff of the Federal Telegraph Company at San Francisco and in 1913 was made chief electrical engineer of that Company.

The ensuing six years were very actively filled with the development and manufacture of Poulsen arc transmitters for the Army and Navy. A number of stations for trans-oceanic service were built for the Navy in the United States, France, Panama and across the Pacific to the Philippines. While this work was under way Dr. Fuller contributed several papers on radio subjects to the PROCEEDINGS of the Institute. He also continued his studies, taking graduate work at Stanford University, from which he received the Ph.D. degree in 1919. This same year he was awarded the Morris Liebmann Memorial Prize by the Institute for his contributions to long-distance radio communication.

After the need for arc stations ended with the war, Dr. Fuller left the Federal Telegraph Company in 1919 to organize the Colin B. Kennedy Company of San Francisco for the manufacture of radio receivers. He was engaged in the activities of this company and in private consulting practice, specializing in power company communication problems, until 1923.

The next three years were spent in Schenectady and New York City in power company communication and radio receiver work. In 1926, Dr. Fuller returned to San Francisco for the General Electric Company in connection with new high voltage developments and the application of vacuum tubes to the problems of the light and power industry on the Pacific Coast.

Dr. Fuller was appointed a member of the Board of Direction of the Institute in January of 1928. He is Chairman of the San Francisco Section of the Institute, is a Fellow of both the Institute of Radio Engineers and the A.I.E.E., and a member of the American Physical Society.

CONTRIBUTORS TO THIS ISSUE

Austin, L. W.: (See PROCEEDINGS for February, 1928).

Ballantine, Stuart: (See PROCEEDINGS for April, 1928).

Breit, G.: Born in Russia, July 14, 1899. Radio Section, Bureau of Standards, 1918–1919, 1920–1921; received the Ph. D. degree from Johns Hopkins University in 1921; national research fellow, Leiden and Harvard Universities, 1921–1923; assistant professor, University of Minnesota, 1923–24; mathematical physicist, Department of Terrestrial Magnetism, Carnegie Institution of Washington since 1924.

Brown, J. E.: Born at East Marion, New York, September 11, 1902. Attended school of engineering, Cornell University, 1920–24. Test Department of General Electric Company, 1923; Radio Inspector with the U. S. Department of Commerce at Detroit, Michigan, 1924 to present date, engaged in inspection work, development of field-strength measuring apparatus, methods and measurements, and frequency measuring equipment. Member of the Institute.

Dahl, Odd.: (See PROCEEDINGS for March, 1928).

Diamond, Harry: Born February 12, 1900 in Quincy, Massachusetts. Received the B.S. degree from Massachusetts Institute of Technology in 1922 and the M.S. degree from Lehigh University in 1925. Engaged in air compressor work with the General Electric Company for one and one-half years; for four years instructor in electrical engineering at Lehigh University; summer work with the General Electric Company, the B.F. Sturtevant Company and the Boston Elevated Company. In Radio Section, Bureau of Standards, July 1927 to date. Associate member of the Institute.

Edwards, S. W.: Born at Dennison, Ohio, August 11, 1889. Employed by United Wireless Corporation of America 1908 to 1913; long-distance automatic calling, Ohio Telephone Company, 1913–14; appraisal engineering work, Columbus Railway, Light and Power Company, 1914–17; in charge of Eighth Radio District, U. S. Department of Commerce since 1917. At present time engaged as Supervisor of Radio, Eighth Radio District, in development of field-strength measuring apparatus and methods, constant frequency equipment and secondary standards for use by the Division, design of radio test cars for the Radio Division. Member of the Institute.

Hooper, Stanford C.: Associated with the radio work of the Navy since its earliest inception. Served two tours of duty as Fleet Radio Officer and three tours of duty as Head of the Radio Division of the Bureau of Engineering, Navy Department. During the Arms Conference in Washington served on the Advisory Committee; was also technical advisor to the American Delegation at the International Radiotelegraph Conference in Washington, 1927. Captain Hooper is at present Director of Naval Communications, with additional duties as Technical Advisor to the Federal Radio Commission. He is a Fellow in the Institute.

Shangraw, Clayton C.: Born at Richford, Vermont, April 2, 1896. Wentworth Institute, 1915–17; communications officer, Army Air Service, 1918–22; airplane pilot, New York Telephone Company, 1923; assistant and associate radio engineer, Signal Service at Large, Signal Corps Aircraft Radio Laboratory, Wright Field, Dayton, Ohio, 1927 to date. Associate member of the Institute.

Stowell, E. Z.: Born August 30, 1900 in Arlington, Mass. Received the B.S. degree from Tufts College, 1921; Ph. D. degree, American University, Washington, D. C., 1927. Assistant in physics at Tufts College, 1918–21; graduate assistant at University of Nebraska, 1921–23; With American Radio and Research Corporation in vacuum-tube research, 1920–21; assistant physicist, Bureau of Standards, June to August, 1922; In Optics Division, Bureau of Standards, 1924 to March 1925; assistant physicist, Radio Section, Bureau of Standards, March 1925 to December 1927. With the Federal Telegraph Company at Palo Alto, California, December 1927 to date.

Tuve, M. A.: (See PROCEEDINGS for June, 1928).

INSTITUTE ACTIVITIES

Suspension of Board Meetings During July and August

No meetings of the Board of Direction of the Institute were held during the months of July and August. The Board meets again on September 5th.

New Members To Be Elected

The attention of the Institute membership is called to the list of applicants for the various grades of membership, either for transfer or direct election, appearing on page 1270 of this issue. Applications from all of these members and non-members have been acted upon by the Committee on Admissions. These applications will be presented to the Board of Direction at its October 3rd meeting. Members objecting to the transfer or election of any persons listed should communicate with the Secretary of the Institute on or before September 30th.

1928 Membership Cards

As announced on several occasions in this section of the Proceedings, membership cards are being sent only upon specific request this year. If there are any members who desire 1928 cards, a request therefor should be addressed to the Institute. Cards for all grades of membership are available.

1928 Year Book

The 1928 Year Book, mailed as a supplement to the July issue of the Proceeedings, is now in the hands of all members. Any member who failed to receive a copy can secure a duplicate free of charge from the office of the Institute.

Through typographical error there is an unfortunate mistake in connection with the listing of the subcommittees of the Committee on Standardization, to be found on page 20 of the Year Book, in that the Subcommittee on Receiving Sets, J. H. Dellinger, Chairman, was omitted. This subcommittee (as reported from time to time in this section of the Proceedings) has been very active and has made considerable progress which has contributed to the thoroughness of the Preliminary Draft of Report of the Committee on Standardization which is being considered by the entire committee. Since Dr. Dellinger assumed the chairmanship of the Committee on Meetings and Papers, E. T. Dickey has been chairman of the Subcommittee on Receiving Sets.

It will be appreciated if the membership will call to the attention of the Institute office any errors of commission or omission in the membership lists of the Year Book, not previously reported.

New Bureau of Standards Publication

Beginning July, 1928, the Bureau of Standards publishes a new monthly journal, "Bureau of Standards Journal of Research", which will contain the bureau's research papers in the fields of physics, chemistry, engineering, and a number of special technologies including radio communication. The annual subscription rate is $2.75 with an extra charge of $0.75 for postage to countries outside the United States, Canada, Mexico and Cuba.

Members of the Institute will undoubtedly be interested in this journal. Subscriptions should be forwarded to the Superintendent of Documents, Government Printing Office, Washington, D. C.

1928–1931 Cruise of the *Carnegie*

Terrestrial Magnetism and Atmospheric Electricity for March, 1928 contains a program of scientific work on cruise VII of the non-magnetic ship *Carnegie*, which is making a three-year tour of the world under the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. A complete account of the work to be done, including a number of important investigations in the field of radio communication, appears in this issue of the above journal.

New Style of I.R.E. Emblem

The new member's emblem in the form of a screw-back lapel button, approximately one-half the size of the present emblem, is now available in the four colors for the various grades of membership.

The new emblem is of 14 k. gold and can be purchased for $2.75 postpaid from the Secretary of the Institute.

Committee Work

Committee on Constitution and Laws

The Committee on Constitution and Laws, R. H. Marriott, Chairman, has held a number of meetings throughout the summer in connection with its work in revising the Constitution and By-Laws of the Institute. The immediate work on the new Constitution has been completed by the Committee. The proposed Constitution will be submitted to the Board of Direction at its September meeting with a view to its being submitted to the membership of the Institute for approval at the same time the ballots for 1929 officers are mailed.

Changes in the Constitution have been slight, but the By-Laws of the Institute have been very extensively modified and amplified by the Committee.

Committee on Admissions

The Committee on Admissions held its regular monthly meeting on August 1st. The following members were present: R. A. Heising, Chairman; F. H. Kroger, and E. R. Shute. The Committee acted upon 11 applications for transfer or election to the higher grades of membership in addition to the election of a large number of Junior and Associate members.

Subcommittee on Bibliography

The Subcommittee on Bibliography of the Committee on Standardization held a meeting in the offices of the Institute on August 1st. The following members were present: C. A. Wright, Chairman; I. G. Maloff, W. C. White, C. E. Brigham, G. C. Southworth, R. D. Brown, Jr., and H. A. Frederick.

The principal questions under discussion at this meeting were (a) whether or not a bibliography should properly form a part of an Institute Standardization Report, (b) what should be the type and quality level of the references included, and (c) what should be the degree of completeness of the bibliography.

The opinion of the committeee was that the object of this bibliography is to amplify and make more intelligible the Standardization Report. Its educational object is warranted by the needs of those who will use the report. In view of this object it was agreed that the bibliography should contain a limited number of outstanding articles, some of them describing methods of testing and others presenting fundamentals of the various subjects covered by the Standardization Report. Recent articles will be given greater emphasis than older ones.

The kind and quality level of the articles included will be such that they will be intelligible to the average radio engineer throughout the country who might have use for the Standardization Report. Short descriptive paragraphs will be added after each reference, including information as to the kind and length of article. The references will be numbered in accordance with the Dewey System.

Personal Mention

C. D. Pitts is in the engineering department of the Electrical Research Products, Inc., at Philadelphia.

Burton E. Ebert has removed from Chicago to Philadelphia, where he is now connected with the Pooley Company.

E. H. Hansen of the Fox Case Movietone Corporation has been transferred from New York to Hollywood, California.

L. M. Cockaday, for a number of years technical editor of *Popular Radio,* is now on the radio staff of the New York Herald-Tribune.

Rear Admiral S. S. Robison, U. S. Navy, until recently Commandant of the 13th Naval District, is now Superintendent of the United States Naval Academy at Annapolis.

John B. Hawkins has recently become associated with the Newcombe Hawley Company of St. Charles, Illinois. Mr. Hawkins was formerly with the Nathaniel Baldwin Company.

Captain S. C. Hooper of the U. S. Navy is now Director of Naval Communications. He is also serving as one of the technical advisors to the Federal Radio Commission.

Charles H. Cross has resigned from the radio interference department of the Pacific Gas and Electric Company to become associated with the Radio Department of the Dollar Steamship Lines at San Francisco.

Thornton P. Dewhirst is practicing consulting work at 4909 Seventh Street, N. W., Washington, D. C. Mr. Dewhirst for several years was associated with the C. Francis Jenkins Laboratories of Washington.

J. H. Dellinger has been given a three months' leave of absence from the Radio Section of the Bureau of Standards to be Chief Engineer to the Federal Radio Commission. During Dr. Dellinger's absence from the Bureau, C. B. Jolliffe is serving as acting chief of the radio section.

OBITUARY

With deepest regret the Institute announces the death of

Frederick G. Simpson

For many years Mr. Simpson was connected with the Kilbourne-Clark Corporation of Seattle in the manufacture of radio apparatus. He served with that company as chief engineer, manager, and vice-president.

During the world war he served as radio material officer in the Navy at Boston, returning to civil life with the rank of Commander in the Reserve.

During more recent years he was directing engineer and vice-president of the Simpson Radio Corporation, which manufactured radio apparatus embodying Mr. Simpson's inventions. At the time of his death, Mr. Simpson was in charge of radio engineering for the Robert Dollar Steamship Company.

He was elected to Membership in the Institute in 1913 and was made a Fellow in 1915.

He died on March 16th, 1928 at Seattle, Washington.

Volume 16, Number 9 *September, 1928*

THE USE OF RADIO FIELD INTENSITIES AS A MEANS OF RATING THE OUTPUTS OF RADIO TRANSMITTERS*

By

S. W. Edwards[1] and J. E. Brown[2]

([1]Supervisor of Radio, U. S. Department of Commerce, Detroit, Michigan; [2] Radio Inspector, U. S. Department of Commerce, Detroit, Michigan.)

Summary—*A method is described by means of which the outputs of radio transmitters could be regulated by Federal authority as required by law in terms of measured radio field intensities instead of watts power in the transmitter or antenna circuits. The method was developed from surveys made on five different radio broadcast stations. For purposes of example, figures are given only for radio broadcast stations. The figures given may not be those which might be ultimately desirable for regulation purposes; however, they are usable as a means of explanation and demonstration and, therefore, serve the purpose for which this paper is intended. The method is developed on averages taken from actual measurements and is applicable to all conditions found in the broadcast band at the present time.*

In dealing with radio transmission as an efficient means of communication there are two factors vitally essential and under human control which should be regulated if maximum success is to be obtained. Without careful assignment and regu-ation of these two factors, complete satisfaction will not be realized generally. These factors are the power and frequency of transmission.

Since regulation of these two things is very necessary to successful radio transmission it would seem that each of them should be given careful study so that the best results possible may be achieved. The study of frequency regulation is quite complete and has been pursued closely since almost the very beginning of radio. Unfortunately, the study of power regulation has not received as much attention and as a result the same terminology and methods are used today as have always been used. With the hope that further interest will be stimulated in the subject this paper attempts to deal with the problem of power regulation of radio transmitters and sets forth a suggested method which is believed to be somewhat of an improvement over methods now used.

For purposes of example the regulation of power and the rating of transmitters operating in the broadcast band of 1500

* Original Manuscript Received by the Institute, June 13, 1928.

to 550 kilocycles will be discussed, inasmuch as it seems that the greatest benefits of the method about to be outlined could be realized here, although the scheme is applicable to all frequencies with equal facility. Insofar as technical reasons are concerned it has been presumed that the power which could be alloted to a broadcast station was determined only by the amount of interference which would be caused another station operating on the same frequency, and by the amount of interference which the broadcast listener located near the transmitter would find in trying to listen to some other station on an adjacent frequency. These two reasons represent the technical premises on which

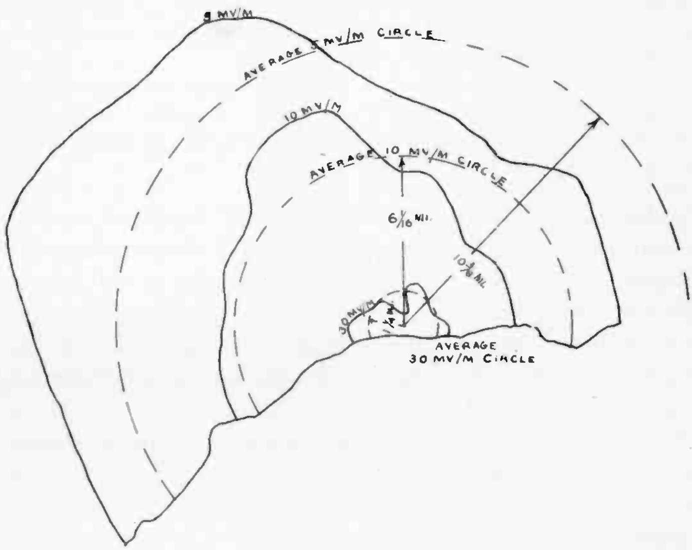

Fig. 1—Station A
Effective height, 21.7 meters; antenna current, 8 amperes; frequency, 850 kilocycles.

power has heretofore been regulated. In considering these two things it should be borne in mind that neither of them were, or could have been, measured quantitatively by the regulating governmental bodies. The answers to both questions were determined largely by experiment, estimation, and past experience. From the time the first radio transmitter was built its power was expressed in terms of watts, and the external effect which it produced was estimated from this quantity insofar as regulation was concerned. The term watts of power has been widely interpreted and applied perhaps in the most popular forms of watts power in the antenna, or on the plates of the oscillator or radio-frequency amplifier tubes, or in terms of total watts input to transmitters. It is quite well recognized at this time that none of these methods, all of which in the end only show power somewhere in the circuit, is of any real value in determining the external effect which a radio transmitter will produce.

Considering the two technical premises on which the output of a radio transmitter is regulated, it will be readily seen that from the point of view of the present time and with present methods and equipment only one of these is of major importance. This is the regulation of power so that the broadcast listener does not get such a strong signal that with present day receiving equip-

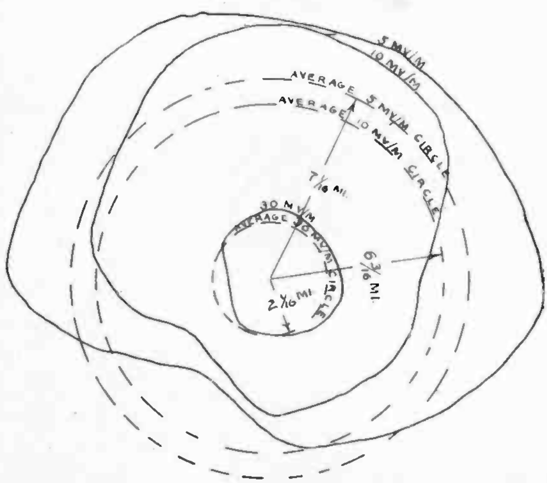

Fig. 2—Station B
Effective height, 39.5 meters; antenna current, 6 amperes; frequency, 700 kilocycles.

ment he cannot receive a reasonable number of stations without interference and still have a signal of maximum value for good high-quality reception. It is believed that it is quite generally conceded at this time that the operation of two or more radio stations on the same frequency is not good engineering practice unless they are of very low power and separated by very great distances. There are economic and technical reasons why this is so. When it is considered that a 1-kilowatt transmitter is classed as of very medium power at this time and when consideration is given to the cost of such a transmitter, it will at once be apparent that such transmitters should not be required to duplicate frequencies, knowing as we do that under favorable conditions two such transmitters in the United States, irrespective of distance separation, will cause a beat note somewhere in this country. Considering then the regulation of power of a radio station in its most exact technical and economic sense, there is only one reason why power should be regulated, this reason being, as stated before, to see that the broadcast listener gets the best possible service without undue interference and that the broadcaster be placed in a position where he can realize the maximum result on his investment. On the basis of this argument, pro-

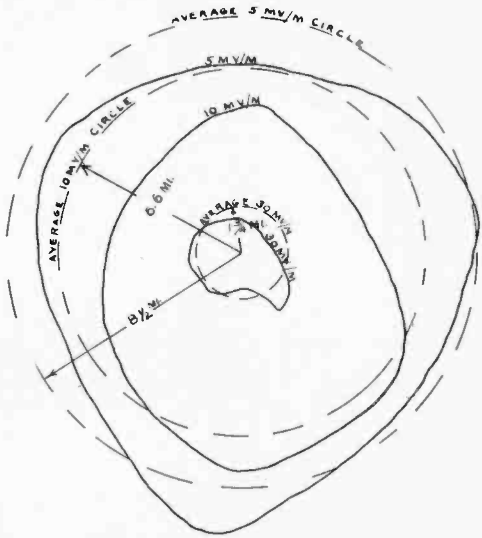

Fig. 3—Station C
Effective height, 23.5 meters; antenna current, 7.8 amperes; frequency 640 kilocycles.

posals and facts on the regulation of power of radio transmitting stations operating in the broadcast band, and with powers at one kilowatt and greater, are presented.

A suggested method of regulating the outputs of radio broadcast transmitters not in terms of watts of power but in terms of measured radio field intensities is offered. These measured radio field intensities could be expressed in terms of microvolts or similar terms per meter, at specified distances. In short, it is suggested that the output of a radio transmitter be regulated on the basis of the actual external effect which it produces and not on the estimate of what effect a certain amount of power in watts found in some part of the transmitter will produce.

It has been quite definitely established by various capable and independent engineers that radio field intensities on the order of ten thousand microvolts per meter will furnish very excellent radio reception. Signals of this strength have a level above most interfering noises which includes ordinary summertime static and inductive disturbances. While signals below this value are capable of providing excellent reception, nevertheless, taken under all conditions of summer and winter and with all ordinary interferences, a signal intensity of ten thousand microvolts per meter is of such a level that high-quality reproduction will be obtained.

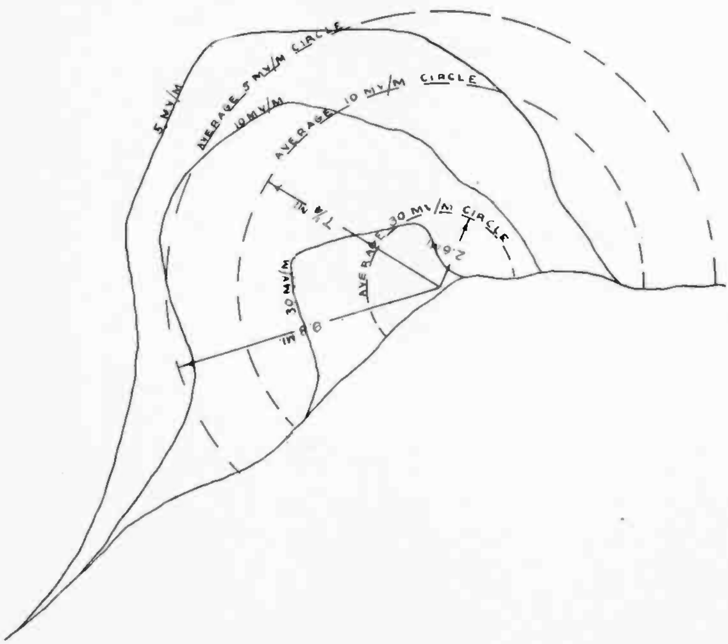

Fig. 4—Station D
Effective height, 32.3 meters; antenna current, 8 amperes; frequency, 770 kilocycles.

The problem then is to regulate the output of existing and future radio transmitters so that the largest possible number of broadcast listeners will receive signals of 10,000 microvolts per meter or more, at the same time bearing in mind that too great a signal must not be delivered to a large number of listeners. The matter is one of balance having the reception of a high quality signal on one side and not so great a signal as to interfere with reception on the opposite side.

For the purposes of this paper it was decided to call signals above 30,000 microvolts per meter interfering signals, or signals which would very likely not permit a broadcast listener with an average set to receive any considerable number of stations other than those with a level of 30,000 or more microvolts per meter. In order to have some flexibility on the question of just what constitutes the minimum signal strength which gives consistent high-quality reception, values down to 5,000 microvolts per meter

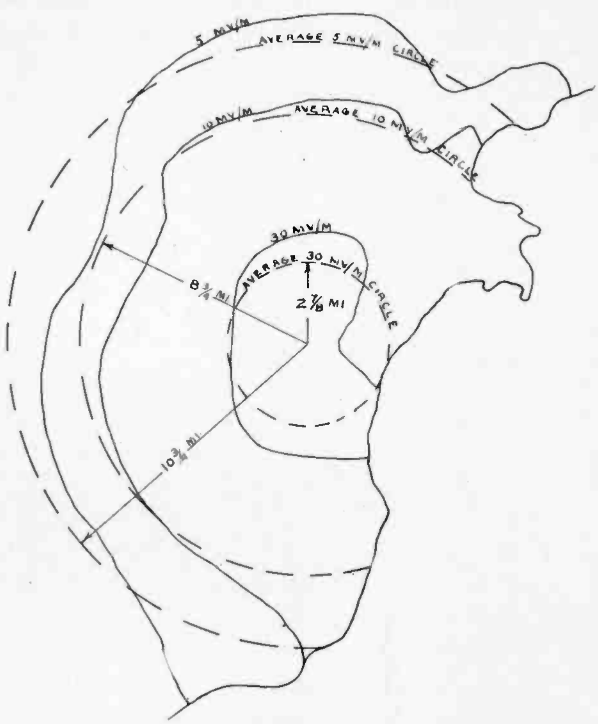

Fig. 5—Station E
Effective height, 18.8 meters; antenna current, 6.8 amperes; frequency 1110 kilocycles.

are used. Keeping these three values as working figures and bearing in mind that in the ideal allocation of frequencies in the broadcast band the only reason for the regulation of power is for the purpose of giving the greatest number of broadcast listeners signals lying between the values of 5,000 and 30,000 microvolts per meter, the following method of power regulation was developed.

The figures and working data were taken from five radio field-intensity surveys made on the same number of different stations in various widely separated cities in the United States, east of the Mississippi River. The stations measured are typical of the trend of the art at the present time. (See Radio Service Bulletin, March, 1927). The stations surveyed had antenna input powers varying from 750 to 3,500 watts and were operating on frequencies from 640 to 1,070 kilocycles. Since the original surveys covered widely varying powers, it was necessary to reduce them all to the same value so that comparisons could be made. The arbitrary figure of 1 kilowatt was chosen as being typical of the average station and being a good value to work

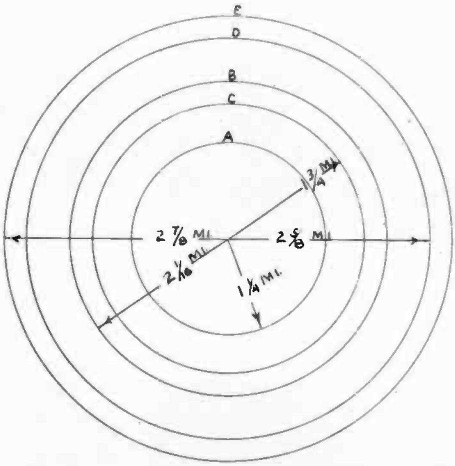

Fig. 6—Average 30-Millivolts-per-Meter Fields of Five 1,000-Watt Radio Stations.

with, for the reason that a station of such power if properly located is capable of propagating a 10,000-microvolt-per-meter signal over the major portion of most cities. This reduction was accomplished by means of the conventional square law method, the results of which when checked in several ways against an actual reduction of power at the transmitter showed no error of any consequence. The operation involved the reduction of three powers, 750 watts, 1,500 watts and 3,500 watts to 1,000 watts on which power the other two stations measured were operating.

The 5,000-, 10,000- and 30,000-microvolt-per-meter fields of each of the stations was plotted using the same scale dimensions. This operation then reduced the original measured values to the same comparable form in graphic manner. The five radio field-intensity maps placed in this form are shown in Figs. 1, 2, 3, 4, and 5.

Radio stations A, B, C, and D are located in cities varying in size from 500,000 to 1,500,000 population. Station E is located in the country some twenty miles removed from a city of 1,500,000 inhabitants. Since stations A, B, C, and D were located in all cases in metropolitan areas, in some cases directly on large steel buildings, in others adjacent to them, the fields are necessarily much more erratic and of considerably lesser extent than station E which is far removed from any absorptive or shadowing body. For this reason station E could not be in all cases compared

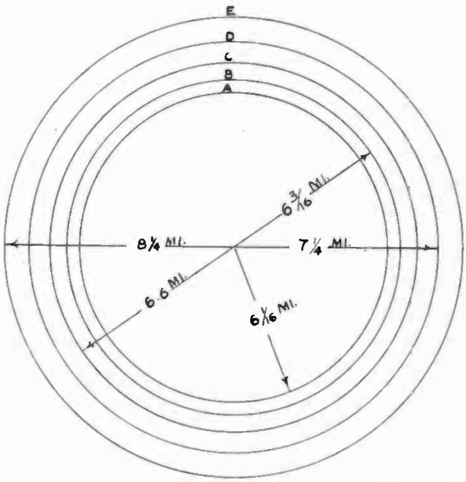

Fig. 7—Average 10-Millivolts-per-Meter Fields of Five 1,000-Watt Radio Stations.

with the other stations even after its field had been reduced to what would be its normal coverage at 1,000 watts of power.

Having reduced the surveys to that point where they represented equal values of output power at the transmitter and to the same scale of distances, the question arose as to what was the average distance at which the average 1,000-watt transmitter delivered fields of 5,000, 10,000 and 30,000 microvolts per meter. In searching for the answer the average 5,000-, 10,000- and 30,000-microvolt-per-meter fields of each of the stations were drawn. These are depicted by the circles shown on each of the field-intensity contour maps. This average field was arrived at for each contour line value by taking the average of the distances at which each individual contour occurred. Since the original surveys were made by making frequent measurements on a number of radii extending away from the transmitter as a center, the distances on each of these radii (at which for example the 30,000 microvolt per meter contour line was found) were averaged, giving as a result the average distance at which a 30,000 microvolt-per-meter signal might be found. This procedure was followed for each of the three stations giving as an individual result for each field the average distances at which signals of 5,000, 10,000 and 30,000 microvolts per meter are found. Circular fields for each value using the average distances obtained as radii are drawn on each of the contour maps. These average

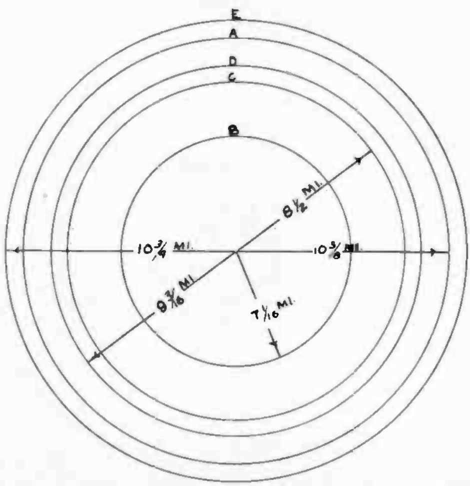

Fig. 8—Average 5-Millivolts-per-Meter Fields of Five 1,000-Watt Radio Stations.

fields for the five stations are grouped under the three values of 5,000, 10,000, and 30,000 microvolts per meter and shown in Figs. 6, 7, and 8.

The average of all of the distances at which for example the 30,000-microvolt-per-meter field occurred was then taken. This value shows the average distance at which will be found the 30,000-microvolt-per-meter signal from a 1,000-watt transmitter. The same procedure was followed for the 5,000- and 10,000-microvolt-per-meter lines. The average distance for the 30,000-microvolt-per-meter signal is found to be 2⅛ miles; for the 10,000-microvolt-per-meter signal $6^{15}/_{16}$ miles or for all practical purposes 7 miles, and for the 5,000-microvolt-per-meter signal 9¼ miles. These three average fields are shown in Fig. 9. These values of signal voltage and of distance are of course all based on stations located in cities of some size and, therefore, are rather heavily attenuated. Computed radii of the ideal average fields of these four stations operating under conditions of no attenuation would show that a field of 30,000 microvolts per meter might be expected at four miles, a signal voltage of 10,000 microvolts per meter might be expected at 12 miles, and a signal voltage of 5,000 microvolts per meter might be expected at a distance of 24 miles. Estimated values of the average distances at which these three signal levels might be expected on a 1,000-watt

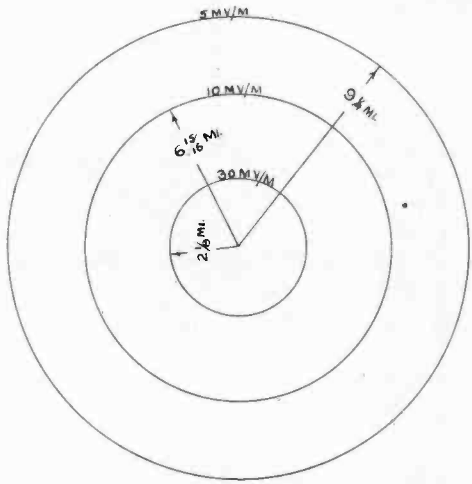

Fig. 9—Average 5-, 10-, and 30-Millivolts-per-Meter Fields of A Typical 1,000-Watt Radio Station.

station located in the country would be 30,000 microvolts per meter at 3½ miles, 10,000 microvolts per meter at 11 miles, and 5,000 microvolts per meter at 22 miles. These last mentioned figures are based on the results of the one survey made on a well-located station in the country.

Of all these figures those derived for the three values of fields of a station located in the city are at the present time most interesting and perhaps most important. They at once afford an avenue of approach to the much-debated questions of just how much power a station located in the business or other district of a city should use and just where the station should be located.

Although these figures represent an average value, the greatest deviation of any one of them from the average in the specific case of 10,000 microvolts per meter at 7 miles is $^{15}/_{16}$ mile or 13 per cent. In the case of stations located in the city, this can be considered a very good figure when all of the factors which enter into radio transmission under such conditions are considered.

The figures show quite conclusively that most 1,000-watt transmitters located in business districts in cities produce practically the same external field. By virtue of this fact, then, the value of 10,000 microvolts per meter at 7 miles becomes a real

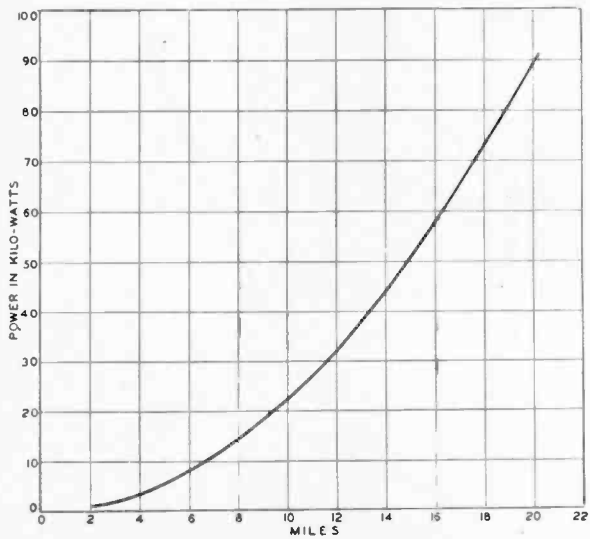

Fig. 10—30-Millivolts-per-Meter Field at Various Distances with Various Powers with City Attenuation.

working figure for 1,000-watt transmitters, and there is no reason why this figure cannot be made to serve as a standard from which the field intensities at various distances for other powers can be computed. In connection with this standard figure the other two values of 30,000 microvolts per meter at $2\frac{1}{8}$ miles and 5,000 microvolts per meter at $9\frac{1}{4}$ may also be classed as of similar value and equally applicable.

The greatest deviation from the 30,000-microvolt-per-meter field at $2\frac{1}{8}$ miles is 40 per cent. While this is large insofar as percentage is concerned when it is applied to the possible deviation it becomes small since the deviation is not greater than 0.8 of a mile. This special instance of a 40 per cent variation is due to the fact that one of the stations had a very small 30,000-micro-volt-per-meter average field, and therefore becomes of still less importance. But for this small field the deviation would not be greater than approximately 25 per cent, which is really the fair percentage to be applied.

The value of 5,000 microvolts per meter at 9¼ miles likewise does not vary from the individual average curves by more than 22 per cent. While these figures are taken from surveys of only five different stations, the results obtained seem to indicate that there is a very considerable similarity between them, and there is

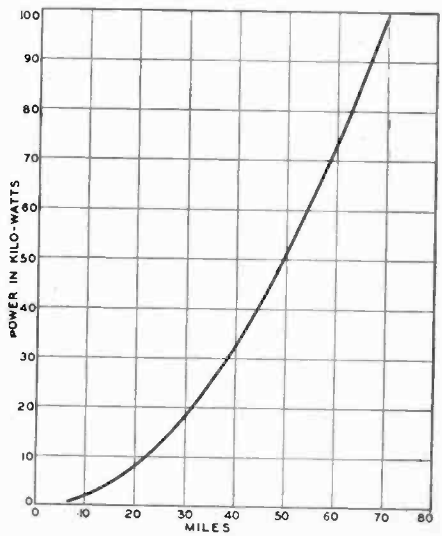

Fig. 11—10 Millivolts-per-Meter Field at Various Distances with Various Powers with City Attenuation.

reason to believe that this similarity holds for the majority of radio stations in operation.

Using these results as a working basis, the following method is suggested by which the output of any radio station can be regulated in terms of signal strength. The examples chosen are typical of every case of radio transmission which a governmental regulating body has to consider.

As a first case, an individual or organization decides that it would be desirable to enter the broadcasting field. The law requires that application forms be submitted for a radio station construction permit before any part of the station can be constructed.

This form shows exactly where the station will be located, the facilities which will be used, the type and power of transmitter, as well as the reasons for which it is desired. If the station is located in the residential section of a town or city, it is quite obvious that it cannot be permitted to set up a field in excess of 30,000 microvolts per meter over an area in which a large number of listeners reside. If there are many listeners within the 2⅛-mile circle, it is quite obvious that the power must be less than 1,000 watts. If the station is in the center of a business section the confines of which extend 2⅛ miles approximately in all directions from the transmitter, the power can certainly be of at least 1,000

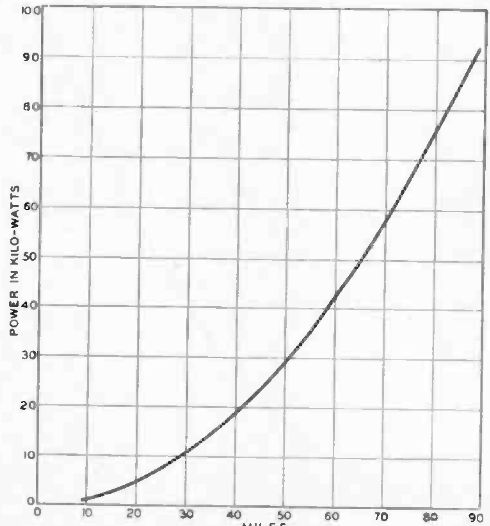

Fig. 12—5-Millivolts-per-Meter Field at Various Distances with Various Powers with City Attenuation.

watts, and should the business district be larger the power can be increased accordingly. It will be seen at once that there is a limit to this flexible condition in all instances with but one or two exceptions, these exceptions being the two largest cities in this country which make it doubtful if the power of city-located stations can ever exceed perhaps 2,000 to 3,000 watts without causing undue interference. The limit of the two exceptions mentioned is perhaps reached between 3,000 and 5,000 watts.

Considering these things, then, anyone putting in a radio broadcast station in a city can so locate it that he can use as much as 1,000 or 1,500 watts successfully by carefully choosing the station location.

Now if it is desired at some future time to increase the station's power to perhaps 5,000 watts, it is necessary that a suitable site in the country be chosen for the station's location. Here again the station is located so that the 30,000-microvolt-per-meter signal does not have within its confines too great a population. Reference to the curves in Figs. 10 and 13 will show that for a 5,000-watt transmitter, a location between 4.5 and 9 miles away from the city limits can be chosen. Since the station is to be located in the country and away from all absorptive and

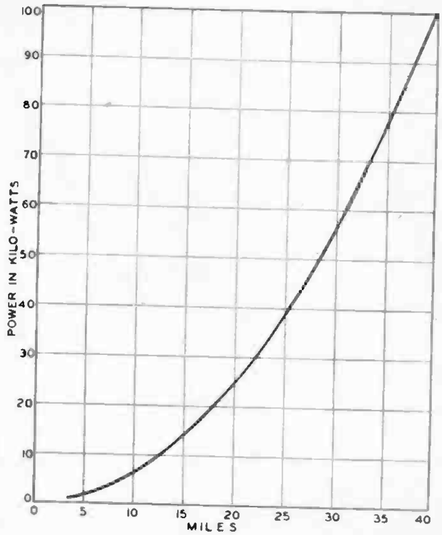

Fig. 13—30-Millivolts-per-Meter Field at Various Distances with Various Powers with No Attenuation.

shadowing bodies, it follows that the attenuation will be less, and therefore the signal will be somewhat greater than that predicted by the curve with attenuation. A value of distance of perhaps seven to nine miles would then seem advisable. These curves also show the distances which must be used for all powers up to 100,000 watts. Curves 2 and 3 show on what distances 5,000 and 10,000 microvolts per meter signal respectively can be expected.

Figs. 10, 11, and 12 are drawn under the conditions of average medium-sized city attenuation and are typical of the least distance at which signals of the values shown can be expected for given amounts of power. They represent the lower limit. Figs. 13, 14, and 15 represent the distances at which signals of 5,000, 10,000, and 30,000 microvolts per meter with no attenuation can be expected. They represent the maximum possible distances under any conditions over which signals of the values given could ever be expected. These signal values are given for all distances possible with powers up to 100,000 watts.

These two sets of curves under the two conditions of maximum and minimum attenuation are the limits of ordinary radio broadcast transmission and at a glance show what can be expected from a radio transmitter of any power in use in broadcasting

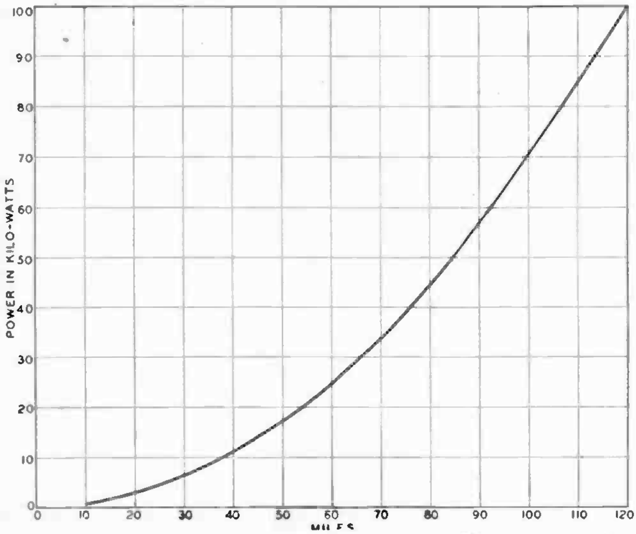

Fig. 14—10-Millivolts-per-Meter Field at Various Distances with Various Powers with No Attenuation.

today. They are, of course, just as applicable to any amount of power that the future may bring forth.

To return to the case of the new broadcast station, the applicant may upon the advice of the regulatory body so locate this apparatus that the maximum amount of output can be used. This location has now been made on the basis of actual working figures and is no more the result of estimation and guess. Certainly this method is much better than any which has been used in the past or is now used. The applicant has only to say where he desires the good service area to be, and how large he desires it to be with respect to the location of his station and the maximum amount of power possible can be granted for this location. The benefits accruing to the broadcast listener are so apparent under this scheme as to require no discussion.

Now that the station's location has been decided upon and the power has been granted in accordance with the location, the construction permit can be granted. A field-strength survey is then made of the station using this power and the ultimate possible and final power allotment is decided upon from the results of the survey. The problem has then been given a solution and the station located and powered on the basis of sound engineering principles. The broadcaster has at once been placed

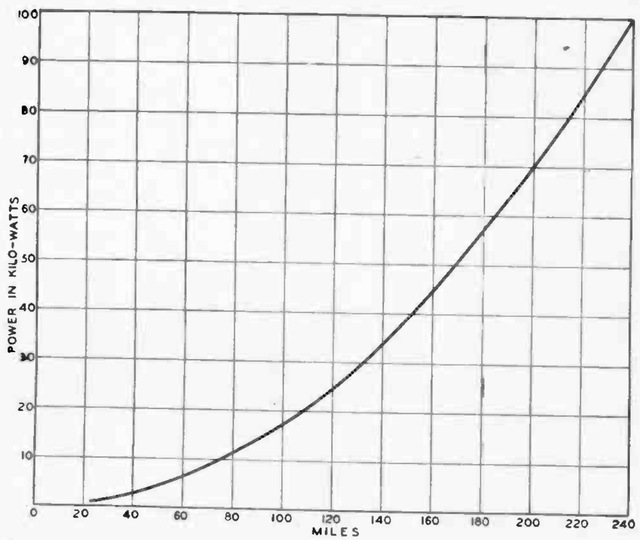

Fig. 15—5-Millivolts-per-Meter Field at Various Distances with Various Powers with No Attenuation.

in a position to realize the maximum on his investment and the broadcast listener has been given the conditions most favorable to best reception.

Were the output of radio broadcast stations to be regulated on the basis of signal voltages instead of watts power somewhere in the circuit of the transmitter as at the present time, the greatest problem would be the disposition of existing stations. The answer would be found in identically the same manner as described in the case of the new station.

As an example a transmitter which is now using 1,000 watts of power could so continue provided that no great number of listeners reside within the $2^1/_8$-mile circle. If the station is so located that this is not the case, then the power of the station must be reduced so that the 30,000-microvolt-per-meter field does not encompass too many listeners. Should the listeners be located at a greater distance the power may be accordingly raised until the limit is reached.

Stations now classed as 100- or 500-watt transmitters, or any other power, would be regulated in exactly the same manner as described above for higher powers.

In each case, the method would be to assign the power which the charts included in this paper would indicate as being capable of producing the maximum possible field up to 30,000 microvolts per meter to the edge of heavy population in any locality. This amount is determined by reference to the values as shown on the charts having included attenuation and those without. At the first opportunity then an actual radio field-intensity survey on the station would be made and the final output determined as a result of this survey.

The third and final example of what would happen were the method of power regulation described to be adopted would be that of an existing station which desires to raise its power. The question would quickly be decided as in the two previous cases by reference to the proper charts. These would show just how much of an increase could be granted, keeping in mind the principles set forth in this paper as governing factors. If the station desired to raise power to such an extent that the necessity arose for a country location, the exact distance of the station from any great number of broadcast listeners could be at once stated, and the final allotment set by a regular survey of the field.

Should this new method of power regulation be adopted, no great difficulty would be experienced in introducing the change. In the first place, the Radio Division of the Department of Commerce through its field offices is well-informed of the conditions surrounding each of the broadcast stations now in existence. This necessitates a working knowledge of every one of the cities of importance in the United States with reference to just where the station is located, how far distant the majority or even any considerable number of broadcast listeners reside, and the other points which have immediate bearing on the subject. This information is possessed by the Radio Division and, therefore, makes this part of the problem comparatively simple. In any case the final value of power would be determined by a field-intensity survey on each station so that should any errors have been made in the preliminary assignment they would be corrected.

The question of just how the change from the old to the new method could be made has been met with a suggested answer. Another problem also arises as to just what under this new method the stipulations in the license should be. It seems quite proper to suggest that the principles already laid down be made to serve again and that the license be made to read that for the case of a given station its field shall not show an excess of 30,000 microvolts per meter at any distance greater than that at which a considerable number of broadcast listeners are found, this distance to be expressed in miles as found for the specific case. The approximate amount of power or antenna current which will set up this field can also be stated for the convenience and guidance of the station's operating personnel. For the specific case of a station which is located approximately 2⅛ miles from any great number of listeners, the license could be made to read perhaps in this fashion. "This station is permitted to so operate that at no distance greater than 2⅛ miles plus or minus 10 per cent shall there be found a radio field intensity greater than 30,000 microvolts per meter plus or minus 5 per cent."

The variation of 5 per cent plus or minus in the instances of field intensity and 10 per cent for distance would seem advisable so that the irregularities of the fields of stations may be taken care of satisfactorily. The figures 5 and 10 per cent are suggested ones and can finally be settled when a greater number of surveys have been made. If necessary as a further precaution, the distances at which the 5,000 and 10,000 microvolts per meter signals plus or minus 5 per cent variation in signal and 10 per cent in distance variation can also be set forth.

So far in this paper there has only been considered a new method of rating and regulating the output of radio broadcast stations and a method by which the new scheme could be put in force.

The method by means of which each of the surveys for this purpose would be made is described. As stated before, the tentative values of 5,000, 10,000, and 30,000 microvolts per meter signal strength are the important ones insofar as power regulation is concerned. The individual surveys on each station could, therefore, be made with a view toward the emphasis of the contour lines having these values.

The radial method of making surveys has been used exclusively in gathering the data used in this paper and has been found highly satisfactory.

The procedure followed in such a survey is to select streets or roads leading away from the transmitter radially making measurements at frequent points along each of these radial directions as far as is required. Past practice has been to make measurements every three-tenths of a mile, making each measurement at a street corner or other place which can be accurately found on a map of the locality under survey. By this means each measurement can be definitely and accurately located when the contour lines are drawn. The short distance between measurements is a reasonable insurance that no great change can take place in the signal being measured without becoming at once apparent. The radial directions are selected so that as the distance increases outward from the center or transmitter, the distance between points on any two adjacent radii does not become great. As a typical example, a station on which measurements were made for a distance of approximately 8 miles in each direction was measured along radii separated by angles of approximately 35 deg. Experience seems to indicate that the method is a sound one and that it is easily applicable under all conditions.

Following this method, readings will be made which will definitely locate the 30,000-,10,000-,and 5,000-microvolt-per-meter lines. By searching for only these three lines it becomes possible to make a fast survey containing all of the desired information. When gathering the data for the 30,000-microvolt-per-meter contour line, information as to the locations of any large number of broadcast listeners would also be collected and properly noted on the radio field-intensity map.

A brief analysis of the important factors about each of the stations might be of interest. Station A is located in a large city to the west of a number of large steel buildings, its antenna being hung between two steel buildings. Station B is located in a large steel structure north of the steel building area of a medium-sized city. The antenna system is rather poor, the ground system is only fair, and the soil conditions in the country immediately surrounding the transmitter are not conducive to best results.

Station C is located in a medium-sized city having no great number of steel buildings, none of any great size. A good antenna system is used and conditions are generally conducive to good transmission. Station D is located to the east of a large city having many steel buildings of large size. It is itself located on a large steel building. Station E is located 15 miles outside the city limits of a large city in a purely country location. Transmission from it is naturally very good.

There has been presented in the foregoing paragraphs a suggested method by means of which the rating of outputs of radio transmitters would be changed from terms of power in the transmitter to terms of signal strength. It is well-recognized that no method or principle, whether scientific or not, is of any value unless it is of a general nature. It must be such that all variable factors entering into the question can be used in a standard manner, which will always produce the same result. No principle can ever be a true one unless it contains within the statement of its make-up on applicable generalization of all the factors upon which it is founded. Every attempt has been made to subject the principles of power regulation on the basis of signal voltages as stated to as vigorous tests as could be found so that a true generalization might be drawn.

The undesirability of giving the power rating in watts of a radio transmitter as an index of its ability as a transmitter becomes more and more apparent. In these days of high-quality transmission, the term has long out-lived its period of usefulness. It is well-known that stations of equal power do not necessarily serve the same areas equally well. Many cases of this condition are evident today in radio broadcasting. This factor is of the utmost importance to the broadcaster and to the broadcast listener. And with the progression of time it is going to become increasingly so. The broadcast listener can never be assured of optimum reception until sufficient power is used in radio broadcasting to set up fields of a high order. The broadcaster who today stands the expenses of broadcasting can never be placed in his best position until existing stations radiate sufficiently strong signals to furnish reliable service over the areas desired. Certainly all of these facts and indications make essential the adoption of a method of power output regulation which is based on actual results secured and not on a figure which is comparatively meaningless. The only answer discernible at this time seems to be the measurement of radio field intensities and the use of these measurements for regulation purposes.

Experimental work over a period of two and a half years indicates that field-intensity measurements have many meritorious features. It is extremely unfortunate that more work in this field has not been done and that methods and apparatus have not been earlier developed. It is only of comparative recent date that accurate equipment has been made available which can be used for this work. It is earnestly hoped that with the advent of this apparatus the study of radio transmission phenomena will receive more interest and will continue on a wider scale than in the past.

Volume 16, Number 9 *September, 1928*

NOTE ON RADIO-FREQUENCY TRANSFORMER THEORY*

By

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Summary—*In the mathematical analysis for radio-frequency amplifiers employing tuned transformer coupling, the effect of the distributed capacitive coupling existing between the transformer windings has heretofore been neglected. General equations including this effect are here developed. It is shown that with these equations a closer agreement between computed and experimental results can be obtained.*

The presence of capacitive coupling changes the amount of mutual inductance necessary to obtain optimum amplification at a given frequency, at the same time reducing the optimum voltage gain. The manner of variation with frequeny of the equivalent transformer primary impedance is also altered.

RADIO-FREQUENCY transformer theory has for some time been reduced to mathematical treatment.[1] The accepted equations are simple and usually quite effective. In many cases, however, computations based on these equations are not in entire agreement with careful laboratory measurements. As will be shown in this note, this lack of agreement is due chiefly to the existence of a capacitive coupling between the primary and secondary windings which modifies the transformer performance, but the effect of which is considered negligible in the usual analysis. When this factor is not neglected, the resultant equations, which will be developed below, yield a closer agreement with experimental data.

An exact consideration of the capacitive coupling is difficult because of its distributed nature. In Fig. 1 is shown the equivalent circuit diagram corresponding to a stage of radio-frequency amplification employing tuned transformer coupling, in which the distributed capacitive coupling is replaced by a lumped value C_o. Since the primary and secondary windings are ordinarily connected together at one end through the batteries,

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Publication approved by Director, National Bureau of Standards of the U. S. Department of Commerce.

[1] Electric oscillations and electric waves. G. W. Pierce. McGraw-Hill Book Co.

A mathematical study of radio-frequency amplification. V. G. Smith. Proc. I. R. E., 15, 525–536; June, 1927.

Tuned radio-frequency amplifiers. R. S. Glasgow. *Journal* A.I.E.E., 47, 327–331; May, 1928.

this approximation should prove sufficiently close, particularly since the effective value of C_o can be readily measured.[2] R_1 represents the tube plate resistance plus the radio-frequency resistance of the transformer primary, L_1 the primary inductance, M the mutual inductance between windings, and R_2, L_2, and C_2 the constants of the secondary circuit.

With the currents as indicated, the circuit equations are, respectively:

$$E_1 = R_1 I_1 + j\omega L_1 I_2 - j\omega M I_3 \tag{1}$$

$$O = R_2 I_3 + j\omega L_2 I_3 - j\omega M I_2 - \frac{j}{\omega C_2}(I_1 - I_2 + I_3) \tag{2}$$

$$E_1 = R_1 I_1 - \frac{j}{\omega C_o}(I_1 - I_2) - \frac{j}{\omega C_2}(I_1 - I_2 + I_3) \tag{3}$$

The solution of the above equations for I_3 is of chief interest. An expression for the equivalent transformer impedance when

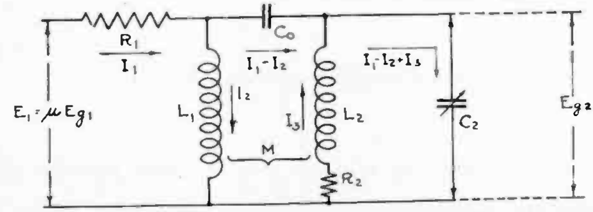

Fig. 1—Equivalent Circuit of A Stage of Radio-Frequency Amplification in Which Effect of Capacitive Coupling between Transformer Windings Is Considered.

referred to the primary side will also be derived. Substituting the value for I_2 from (1) in (2) and (3) and simplifying, (4) and (5) are obtained.

$$I_1\left\{\frac{MR_1}{L_1} - \frac{R_1}{\omega^2 C_2 L_1} - \frac{j}{\omega C_2}\right\} + I_3\left\{R_2 + j\omega L_2 - \frac{j}{\omega C_2} + \frac{jM}{\omega C_2 L_1} - \frac{j\omega M^2}{L_1}\right\}$$
$$= E_1\left\{\frac{M}{L_1} - \frac{1}{\omega^2 C_2 L_1}\right\} \tag{4}$$

$$I_1\left\{R_1 - \frac{R_1}{\omega^2 C_2 L_1} - \frac{R_1}{\omega^2 C_o L_1} - \frac{j}{\omega C_2} - \frac{j}{\omega C_o}\right\}$$

[2] This measurement was carried out by the usual negative intercept method of determining distributed capacity.

$$+I_3\left\{\frac{jM}{\omega C_2L_1}+\frac{jM}{\omega C_oL_1}-\frac{j}{\omega C_2}\right\}=E_1\left\{1-\frac{1}{\omega^2C_2L_1}-\frac{1}{\omega^2C_oL_1}\right\} \quad (5)$$

Solving for I_3 and rationalizing

$$I_3=\frac{E_1\left\{\frac{M-L_1}{C_2}+\frac{M}{C_o}\right\}\left\{\left(\frac{Z_1}{C_2}+\frac{Z_2}{C_o}\right)-j\left(\frac{Z_3}{C_2}+\frac{Z_4}{C_o}\right)\right\}}{\left(\frac{Z_1}{C_2}+\frac{Z_2}{C_o}\right)^2+\left(\frac{Z_3}{C_2}+\frac{Z_4}{C_o}\right)^2} \quad (6)$$

where

$$Z_1=R_1(L_1+L_2-2M)+R_2L_1-\frac{R_1}{\omega^2C_o}$$

$$Z_2=R_1L_2+R_2L_1-\omega^2R_1C_o(L_1L_2-M^2)$$

$$Z_3=\omega(L_1L_2-M^2)-\frac{R_1R_2+\frac{L_1}{C_o}}{\omega}$$

$$Z_4=\omega(L_1L_2-M^2+L_1R_1R_2C_o)-\frac{R_1R_2}{\omega}$$

Similarly, solving (4) and (5) for I_1 and placing $Z_1{}^1=\frac{E_1}{I_1}$, we have for the equivalent transformer primary impedance

$$Z_1{}^1-R_1=\frac{\{AC+BD\}+j\{DA-BC\}}{C^2+D^2} \quad (7)$$

where $A=(L_1L_2-M^2)(C_2+C_o)-\frac{L_1}{\omega^2}$

$$B=\frac{R_2L_1}{\omega}(C_2+C_o)$$

$$C=R_2L_1C_2C_o-\frac{R_2}{\omega^2}(C_2+C_o)$$

$$D=\omega C_2C_o(L_1L_2-M^2)-\frac{1}{\omega}(C_2L_2+C_o[L_1+L_2-2M])+\frac{1}{\omega^3}$$

Equation (7) will be referred to later.

Referring to Fig. 1, the output voltage Eg_2 is equal to very nearly $\omega L_2 I_3$. The stage voltage amplification is consequently

$$K = \frac{Eg_2}{Eg_1} = \frac{\mu \omega L_2 I_3}{E_1} \tag{8}$$

where I_3 is as defined by (6). At a fixed frequency the voltage amplification is a maximum when I_3 is a maximum. Considering the tuning capacity C_2 as the variable, I_3 is a maximum when $\frac{dI_3}{dC_2}$ equals zero. Performing this operation two solutions are obtained both of which, upon eliminating negligible terms, resolve into (9).

$$\frac{Z_1}{C_2} + \frac{Z_2}{C_o} = 0$$

Substituting the values for Z_1 and Z_2 from (6) and simplifying, (10) is obtained for the adjustment of C_2 necessary to make I_3 a maximum. ($R_2 L_1$ has been dropped out, being negligible in comparison with the other terms).

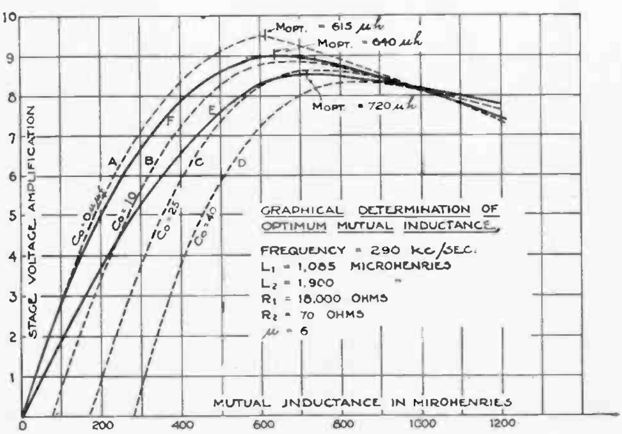

Fig. 2—Graphical Determination of Optimum Mutual Inductance

$$C_2 = \frac{\dfrac{1}{\omega^2} - C_o(L_1 + L_2 - 2M)}{L_2 - \omega^2 C_o (L_1 L_2 - M^2)} \tag{10}$$

Substituting the condition expressed by (9) in (6) and simplifying, we have (11), in which C_2 has the value indicated in (10).

$$I_{3_{max}} = \frac{jE_1\{MC_2-(L_1-M)C_o\}}{\frac{L_1}{\omega}-\omega R_1R_2L_1C_2C_o-\left\{\omega(L_1L_2-M^2)-\frac{R_1R_2}{\omega}\right\}\left\{\{C_2+C_o\right\}} \tag{11}$$

It is interesting to note that in the special case when no capacitive coupling exists ($C_o=0$), (10) and (11) reduce to

$$C_2 = \frac{1}{\omega^2 L_2} \tag{12}$$

$$I_{3_{max}} = \frac{j\omega M E_1}{\omega^2 M^2 + R_1 R_2} \tag{13}$$

which are, respectively, the value of C_2 necessary to resonate the secondary when acting alone and the maximum secondary current obtained by adjusting C_2 according to the simpler analysis (which neglects C_o).

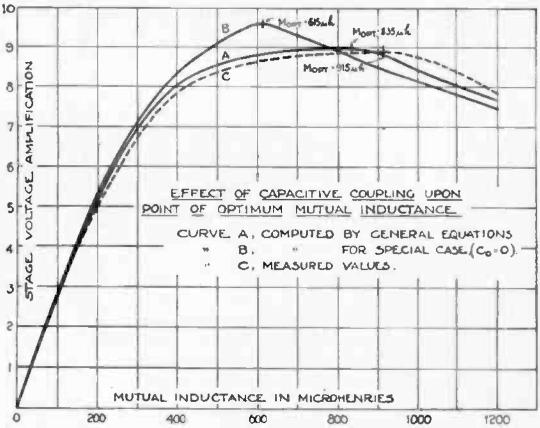

Fig. 3—Effect of Capacitive Coupling upon Point of Optimum Mutual Inductance.

Referring to (11) and (13), and considering M as the variable factor, I_{3max} will reach an optimum value when $\frac{dI_{3max}}{dM}=0$. For the simpler case, when C_o is negligible, this yields (14) as the condition for optimum coupling at a given frequency.

$$\omega^2 M^2 = R_2 R_1 \tag{14}$$

When the effect of capacitive coupling between windings can not be neglected, however, the condition for optimum amplification is given by the more complicated expression of (15) (the differentiation being based on the approximation that C_2 is independent of M).

$$M^2 - \frac{2L_1C_o}{C_2+C_o}M - \left(\frac{R_1R_2}{\omega^2} - L_1L_2 + \frac{L_1}{\omega^2(C_2+C_o)} - \frac{R_1R_2L_1C_2C_o}{C_2+C_o}\right) = 0 \quad (15)$$

Equations (14) and (15) are equivalent when C_o is equal to zero.

Since, in general, a variation in M involves also a variation in L_1 and C_o, it is evident that an accurate predetermination of the optimum mutual inductance is possible only when C_o is negligible.

It is practicable to keep L_1 constant while M is varied. C_o will also vary. The value of optimum inductive coupling may

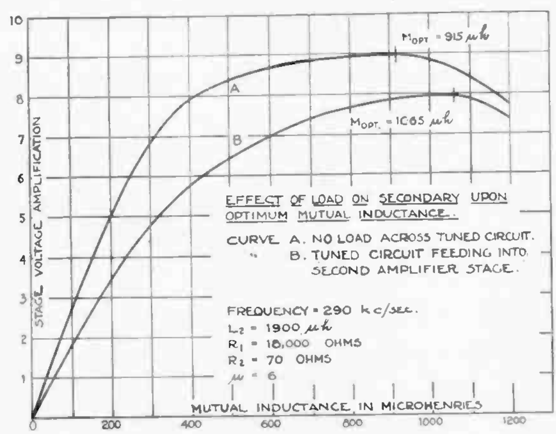

Fig. 4—Effect of Load on Secondary upon Optimum Mutual Inductance.

then be obtained by a graphical solution, as illustrated in Fig. 2. The constants of the experimental transformer used in this computation are collected in Table I. Curves A, B, C, and D were calculated by (8) and (11) and correspond to four assumed values of C_o. Since C_o increases as M is increased, the actual variation of amplification with mutual inductance will be as indicated by curve E. The ordinates of this curve will lie progressively on curves A, B, C, and D depending upon the value of C_o corresponding to a given value of M. Curve F shows how the amplification varies with the mutual inductance when the relative capacitive coupling is smaller than for curve E. Note that as the capacitive coupling is increased, the mutual inductance necessary for optimum amplification at a given frequency also increases, the actual magnitude of the optimum amplification being somewhat reduced.

TABLE I

CONSTANTS OF EXPERIMENTAL TRANSFORMER

Transformer Winding	Type of Winding	No. of turns and Size of Wire	Winding Length	Inductance in micro-henries	Resistance at 290 kc ohms
Primary	1¼ in. single layer solenoid	250 turns No. 34 single enameled wire	1¾ in.	1085	
Secondary	1¾ in. single layer solenoid	250 turns No. 34 single enameled wire	1¾ in.	1900	70

In the laboratory, M was varied by varying the number of turns on a 1¼ in. diameter primary coil form, using the secondary

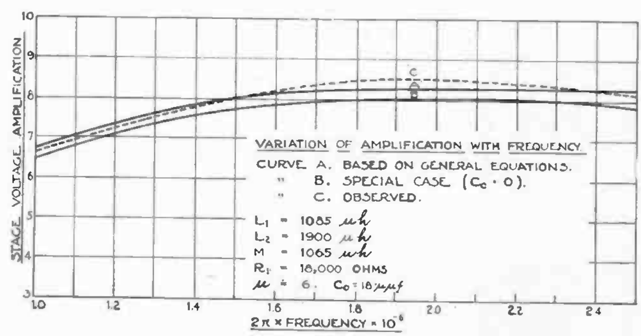

Fig. 5—Variation of Amplification with Frequency.

indicated in Table I. The mutual inductance was adjusted to the desired value and L_1, C_0 and K were measured. Data of a sample run are given in Table II. Using these data, curve A of Fig. 3 was calculated by means of (8) and (11). When the capacitive coupling is zero, (8) and (13) may be used; curve B corresponding to this condition. Curve C shows the actual variation of amplification with M as obtained by test. It will be observed that when the effect of C_o is considered, a much better agreement with laboratory measurements is obtained. Even then there is a slight discrepancy between computed and measured values; due in part to the effect of the tube output capacitance and partly to the increase in R_2 because of the tube voltmeter connected across the tuned circuit. Both effects tend towards overcoupling. The curves of Fig. 4 show that the point of optimum amplification occurs at a still larger value of mutual inductance if the stage output circuit feeds into a second amplifying stage, thereby further increasing the effective secondary resistance. Curve *A* corresponds to curve *C* of Fig. 3, while curve *B* is for the condition outlined, this being the usual state of affairs in practice. The optimum mutual inductance becomes 1065 rather than 915 microhenries.

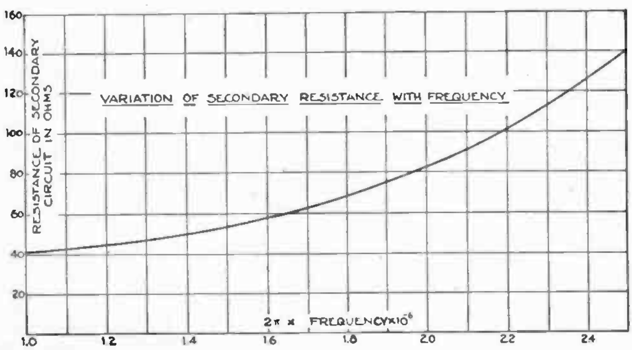

Fig. 6—Variation of Secondary Resistance with Frequency.

TABLE II

SAMPLE TEST DATA

Freq.	R_2 ohms	L_2 micro-henries	R_1 ohms	μ	M micro-henries	L_1 micro-henries	C_o $\mu\mu f$	Stage voltage amplification
290 kc per sec.	70	1900	18000	6	0	0	0	0
					200	103	8.1	5.05
					400	289	11.5	7.90
					600	514	14.2	8.65
					800	748	16.3	8.90
					1000	1000	18.2	8.80
					1092	1265	20.0	8.45

The manner of variation of stage voltage gain with the frequency is indicated in Fig. 5. Curve *A* is plotted from computations based on the general equations in which the effect of capacitive coupling is considered; curve *B* from computations based on the simpler equations resulting when $C_o = 0$, and curve *C* from actual measured results. Here, again, the agreement between computed and experimental values is better when the effect of capacitive coupling is not neglected. Fig. 6 shows how the resistance of the transformer secondary varies with frequency. This curve is essential in the computation of the curves of Figs. 5 and 7.

In conclusion, it is interesting to note that the equivalent primary impedance of the transformer is materially altered from that predicted by the simpler theory. According to the usual

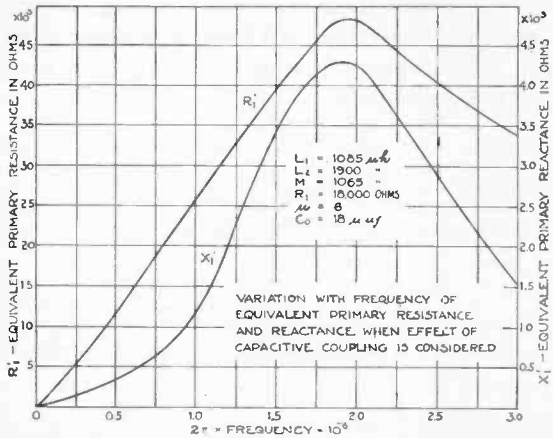

Fig. 7—Variation with Frequency of Equivalent Primary Resistance and Reactance When Effect of Capacitive Coupling Is Considered.

analysis, curves showing the variation of R_1^1 and X_1^1 with frequency are similar to those for a parallel resonance circuit. Actually, the variation indicated in Fig. 7 obtains, these curves being computed from (7). Within the useful frequency range of the transformer, there is no transition point at which X_1^1 changes from an inductive to a capacitive reactance, as is usually assumed.

Volume 16, Number 9 *September, 1928*

RADIO BEACONS FOR TRANSPACIFIC FLIGHTS*

By

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Summary—*This paper deals with the radio beacon and its practical application in connection with long distance flights over water. It describes briefly the operation of the equi-signal radio-beacon system as developed by the Air Corps and Signal Corps Aircraft Radio Laboratories at Dayton, Ohio, during the past few years.*[1]

The use of radio beacons as an aid to aerial navigation was considered necessary by the Army Air Corps in the plans for the flight from San Francisco to Hawaii by Lieutenant Hegenberger and Lieutenant Maitland. The Signal Corps was then requested to establish a radio-beacon station at each of the above points. The equipment for these installations was assembled and tested at the Signal Corps Aircraft Radio Laboratory and then shipped. One station was installed at Crissy Field, San Francisco and the other one was installed on the island of Maui, Territory of Hawaii. Several tests were made by these stations prior to the flight on June 28, 1927 during which the signals from each station were heard over the entire distance of twenty-four hundred miles.

The Army flight is described and the log kept by each station is shown. The beacon signals assisted materially in the problem of navigation during this flight, but unfortunately were not followed the entire distance due to difficulties with the receiving equipment. The next flight, over the same course, in which the radio beacons were used was that made by Messrs. Smith and Bronte. Here again trouble was experienced with the receiving equipment aboard the airplane which prevented the flyers from utilizing the beacon service continuously.

The Honolulu Chapter of the National Aeronautical Association requested the Army to provide radio-beacon service for the Dole Flight from San Francisco to Hawaii which was scheduled to start on August 12. This request was acceded to as it was desired to assist the participants as much as possible and further tests of the radio beacon were also desired. This flight was by far the most successful from a radio viewpoint, as the beacon signals were followed continuously by the winners of the Dole Flight. Photographs of the equipment are shown together with maps and the log kept by each station.

After the Dole Flight the beacon station on the Island of Maui was removed and permanently installed at Wheeler Field near Honolulu, where it is to be used in connection with local and inter-island flying by Air Corps personnel.

Since that time several improvements have been made in beacon equipment at the Signal Corps Aircraft Radio Laboratory which render it much more useful and reliable.

* Original Manuscript Received by the Institute, June 13, 1928.

[1] Captain W. H. Murphy and Lieut. L. M. Wolfe, "The Stationary and Rotating Equi-signal Radio Beacons" *Journal* of Automotive Engineers, 19, September 1926.

DURING the last year a keen interest in aviation has been aroused through the medium of long spectacular flights such as that of Lindbergh from New York to Paris, the Army flight from San Francisco to Hawaii by Lieutenant Hegenberger and Lieutenant Maitland, the Dole Derby from San Francisco to Hawaii, the Round-the-World flight by Brock and Schlee, and several others, some of which ended in disaster. The flight of the *Southern Cross* from San Francisco to Australia is perhaps the most vivid in the minds of the general public.

The airplanes used on these spectacular flights represented the last work in airplane design and equipment. Despite this, but few of the airplanes participating were equipped with radio apparatus of any kind. The omission of this seemingly important adjunct to navigation and safety, especially on any long flight over water, lies in the desire to carry a maximum fuel load, limiting all accessories to an absolute minimum. This attitude is quite natural, for it is impossible to calculate exactly how much fuel will be necessary for a flight, due to such factors as adverse weather conditions and other unforeseen reasons. With very few exceptions, if any, at the conclusion of these flights the pilots and navigators have expressed a belief that radio communication was essential and should be provided in future flights.

The preparations for the Army flight to Hawaii, made by Lieutenant Hegenberger and Lieutenant Maitland in a three-motored Fokker monoplane, did not include radio equipment until a few weeks before the proposed date of departure. Lieutenant Hegenberger, an expert aerial navigator and pilot, had made previous flights making use of the equi-signal radio beacon during its development at McCook Field, Dayton, Ohio, and realized its possibilities as an aid to aerial navigation, especially since the beacon equi-signal zone followed a Great Circle course. It was, therefore, recommended that a suitable radio-beacon station be installed at the starting point and also at the destination of the flight. The advisability of this plan was concurred in by the Chief of Air Corps, and the Chief Signal Officer was requested to have two radio-beacon installations made available for this project. The preparations for this project were carried out secretly so as to avoid any publicity before the proposed date of departure from San Francisco.

At this point a brief description of the equi-signal radio beacon will be given for those who are not familiar with the system. It is essentially a Bellini-Tosi system used for transmitting signals which are so arranged that they interlock and form a single dash along the bisector of the projected angle of the two inner coils, or primary, of the goniometer. The antenna consists of two triangular loops 80 feet in height and 300 feet along the base. These two loops must be very accurately laid out at right angles to each other and constructed so as to be identical in frequency and radio-frequency resistance. The goniometer is then connected at the base of the loops and equal values of capacity and inductance are

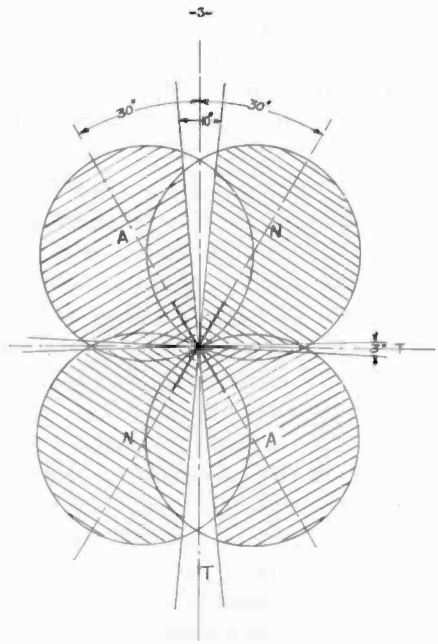

Fig. 1—Equi-Signal or *T* Zones of the Radio Beacon.

added in each leg of the loops so that the entire system is electrically balanced. The rotor coils of the goniometer are spaced 60 degrees apart, as this was found to be a fair compromise for obtaining a reasonable transmission range with minimum equi-signal zones narrow enough to allow one to follow the predetermined course with accuracy. See Fig. 1.

The primary coils of the goniometer are alternately connected to the output of the transmitter by means of an automatic relay that is actuated by letter *N* and *A* cams which are driven by a suitable electric motor. Thus, the letters *N* (– ·) and

A (· –) in Morse code are used as a medium for breaking up the continuous dash obtained when the key of the transmitter is closed. The degree of coupling between these two primary coils and the loop coupling coils, or secondary, of the goniometer governs the current induced into each loop so that the letters *N* and *A* are radiated with varying intensity at different settings of the goniometer. When a receiver is so located as to pick up signals from these two loops with equal intensity the *N* and *A* signals interlock so as to form a single dash or *T*. This is equivalent to rotating two large loops with 60 degree displacement. Now, if the receiving set were located to one side or the other of the bisector of this projected angle then the signals would no longer be of equal intensity and the letter *N* or *A* would be heard, depending upon which side of the bisector the receiver was located.

In applying the above principles in practice the goniometer is set to permit an equi-signal or *T* to be transmitted along a predetermined course which is the line of flight along the Great Circle. As long as the airplane continues along this course the letter *T* is heard when the simple receiving set is tuned to the frequency of the beacon transmitter. If the airplane goes off the course slightly the *T* signal becomes broken, since the letter *N* is heard more loudly than the letter *A*. This has the effect of an *N* superimposed on a slightly weaker *A*. However, as the airplane gets further off the course in this direction the letter *N* becomes more distinct with the background character entirely lacking. Should the airplane get off the course to the left the letter *A* will be heard in a like manner.

In air navigation, as in marine navigation, it is necessary for the pilot to correct his course for drift due to side winds. This is accomplished by noting the position of ground objects through a drift indicator which is attached to the side of the airplane and then altering the course so as to compensate for the drift component. However, in flying above clouds or over water where no land marks are available the problem of correcting for wind drift becomes more difficult. In the transoceanic flights fixed ground objects were replaced by white-caps on the waves for reference in some cases, while in others smoke bombs were used. Any of these methods of checking the extent of wind drift and making the necessary changes in the compass course, whether of the magnetic or earth inductor type, require considerable skill and good judgment on the part of the navigator.

The equi-signal zone of the radio beacon, by virtue of its following the Great Circle course, automatically compensates for any directional error due to cross wind or to personal errors in making changes in the compass course in following the Great Circle. Thus, it will be seen that as long as the letter *T* is heard by the pilot or navigator the airplane is being held on the correct course, regardless of the wind drift. Whenever letter *T* becomes broken up so that a letter *N* is heard this indicates that the airplane is getting off the course to the right and when the letter *A* is heard it is an indication that the airplane is veering to the left of the course. This method, therefore, not only permits the pilot to keep a correct course, but also shows to a certain extent the amount of deviation from the course when the letter *N* or *A* is heard superimposed upon the background character. While the radio beacon indicates the desired course it is advisable to use the customary and time-honored compass so that the two methods may be used as a check against each other. In this case the radio-beacon signals need not be listened to continuously but periodically to check the compass course. In addition to the automatically-keyed range sign transmitted it is also possible to broadcast important meteorological data with the beacon transmitter.

The Army Flight

The plans for the use of the radio beacon for the Army flight from San Francisco to Hawaii called for an installation at Crissy Field, Presidio of San Francisco and a similar installation in the Hawaiian Islands. The advisability of this plan will be readily seen when it is shown that the entire Hawaiian Island group subtends but an angle of 7 deg. with San Francisco taken as the point of origin. This shows the necessity for setting and following a very accurate course toward the center of the island group, as an error of but 3½ deg. from this course would result in an airplane flying right on past the islands. With one beacon station located at San Francisco the initial course would be accurately established, but due to the widening of the equi-signal zone when going away from the station the accuracy of the course would be decreased. With a similar beacon located at the destination, however, the equi-signal zone would converge upon approaching the Hawaiian Islands, thus increasing the accuracy of the bearing sufficiently to bring the airplane directly towards the beacon station.

When the Signal Corps Aircraft Radio Laboratory was instructed during the latter part of March to install two beacons for the San Francisco-Hawaii flight a rather difficult problem was presented. The only beacon apparatus available was installed in the experimental station at Wilbur Wright Field. This equipment consisted of an obsolete 5 kw quenched spark transmitter and two experimental goniometers together with the necessary auxiliary apparatus for one beacon installation. The tentative date of the proposed Army flight was set as June 15, which

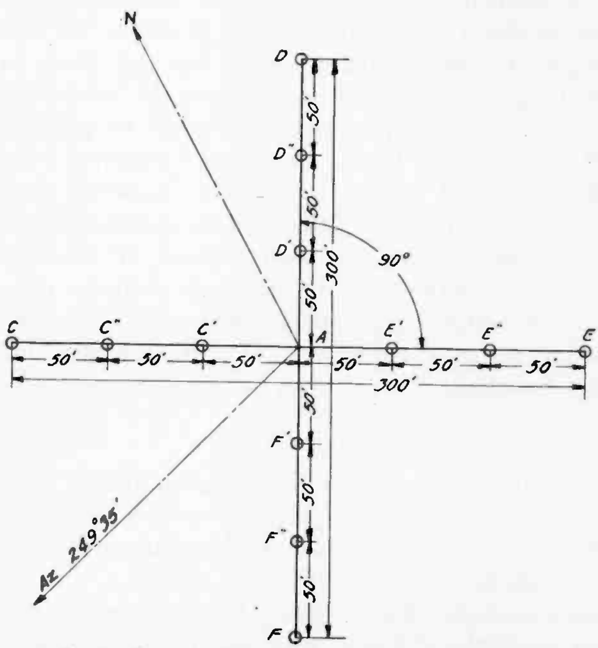

Fig. 2—Radio-Beacon Loop System, Crissy Field, California.

allowed less than three months in which to obtain transmitting sets, construct and test additional apparatus, pack and make shipment to San Francisco and Hawaii, and then to install the apparatus at each place.

Attempts to purchase and get delivery on two 5-kw tube transmitters in this short period of time were futile, so it became necessary to modify existing 5-kw spark transmitters into tube transmitters. These sets utilized two 1-kw air-cooled tubes, type UV-851, in a full-wave self-rectified circuit with 500-cycle plate supply and operated on a frequency of 290 kc. The power equipment consisted of the 500-cycle motor generator sets which were previously used with the old quenched spark sets. Current for operating these machines was to be obtained from a standard Signal Corps d. c. generator driven by a gasoline engine. Complete equipment for the two radio-beacon installations was shipped by express to San Francisco on May 6, arriving in time for the equipment, consigned to Hawaii, to be loaded in an Army transport which sailed a week later.

Lieutenant Hegenberger, co-pilot and navigator of the proposed flight, having been previously stationed in the Territory of Hawaii, was familiar with the location and topography of the

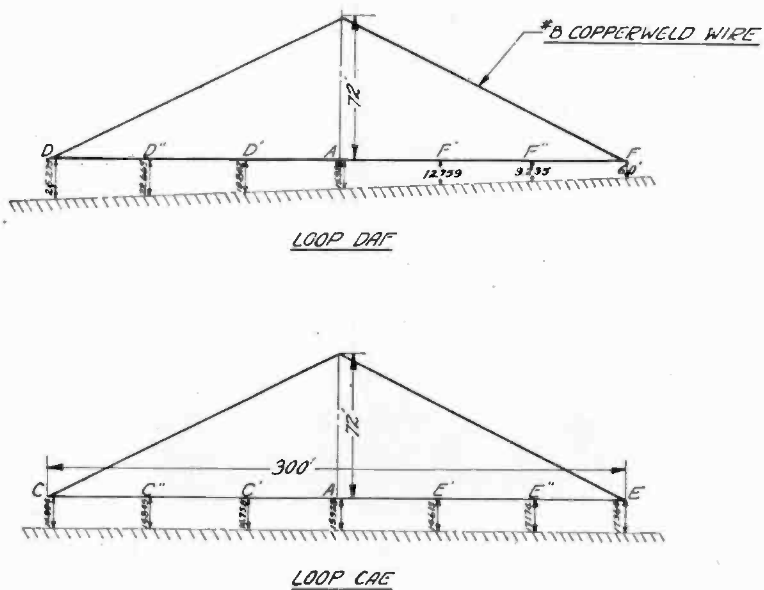

Fig. 3—Radio-Beacon Loop System, Crissy Field, California.

various islands, and upon his recommendation it was decided to locate the Hawaiian beacon station at Halawa Point on the eastern tip of the island of Molokai, or in the vicinity of Kahului, on the island of Maui. These locations come very close to the center of the Hawaiian island group. Since but a small variation in the course from San Francisco to Hawaii was permissible, it was considered advisable for the course to be set from San Francisco to the center of the group of islands and then, after sighting the islands, to change the course of the airplane to the island of Oahu, on which Wheeler Field is located.

The author arrived in San Francisco on May 12 and reported to the Signal Officer, Ninth Corps Area, for temporary duty. A suitable site for the San Francisco beacon was selected on the top of a hill at Crissy Field. The services of personnel of Company E, 5th Engineers, stationed at Ft. Scott, were made available for surveying and laying out the loop system. Credit is given this organization for the efficient and expeditious manner in which this work was carried out. The loop layout is shown in Figs. 2

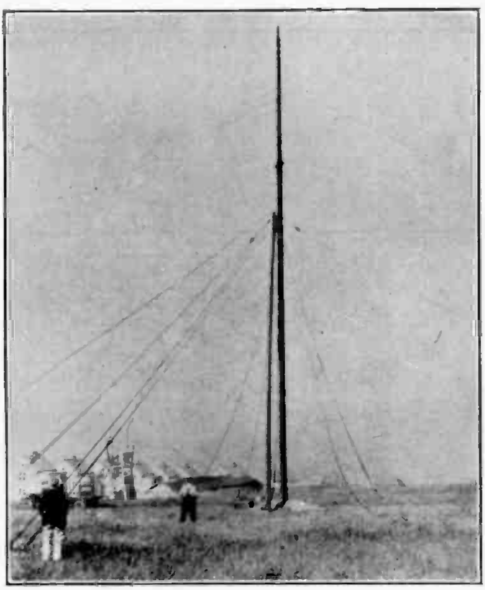

Fig. 4—Location of Radio-Beacon Station at Crissy Field; Pole in Position.

and 3. A 90-foot pole for supporting the loops was purchased locally and arrangements made to have it set in place, and also to erect a temporary building in which to install the beacon equipment. A representative of the Signal Corps Aircraft Radio Laboratory arrived at Crissy Field on May 13, 1927 for duty in connection with the establishment of this beacon station and tests therewith.[2] Fig. 4 shows location of beacon station. Fig. 5 shows the interior of this station.

On May 18 the author proceeded via commercial liner to Honolulu, arriving on the morning of the 25th and reported to

[2] Mr. L. A. Hendricks.

the Hawaiian Department for temporary duty in connection with the establishment and test of the radio beacon station in Hawaii.

The Department Air Officer was requested to authorize a reconnaissance flight over the Island of Molokai and Maui for the

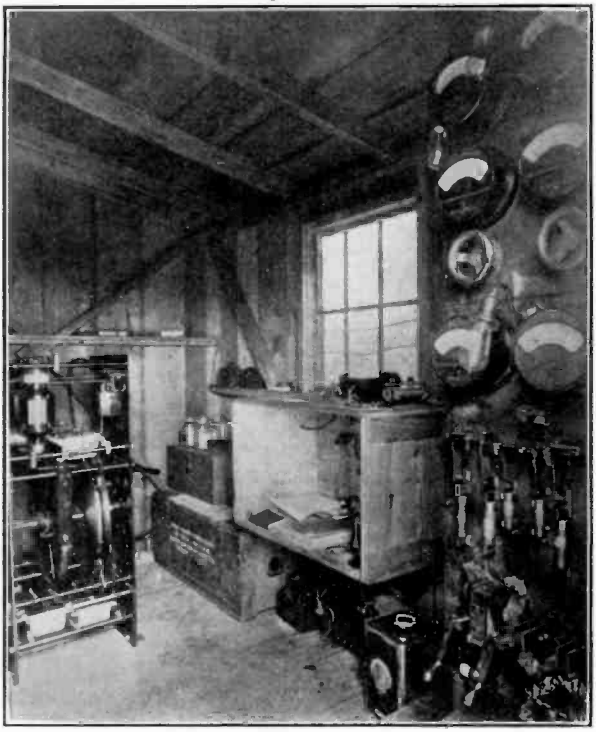

Fig. 5—Interior of Radio Beacon Station at Crissy Field.

purpose of selecting a suitable site for the establishment of the radio-beacon station. This flight, in which three planes took part, was made on May 27, 1927.[3] We flew over the Leper Colony on Molokai and over Halawa at a low altitude to learn as much as possible of its topography. It took but a short time to decide

[3] Due to the hazard of inter-island flying with land type airplanes Army orders require that not less than three airplanes will participate in an inter-island flight. One of the airplanes is equipped with a radio transmitter and receiver and carries an expert radio operator who transmits the position of the airplanes to Headquarters every 5 minutes. In case of a forced landing in the water one of the airplanes goes back to Luke Field, near Honolulu, for assistance while the other circles above the disabled airplane.

against this place as a site for the beacon station due to its close proximity to rugged mountains and lack of docking facilities for unloading supplies and equipment. The shore line is extremely broken and edged with coral reefs, making it practically impossible to land even a small boat. We then proceeded across the channel toward Kahului on the Island of Maui. The windward side of this island appeared well-suited for a beacon location and we attempted to land at Kahului to look over the ground more carefully. The landing field at Kahului, however, was

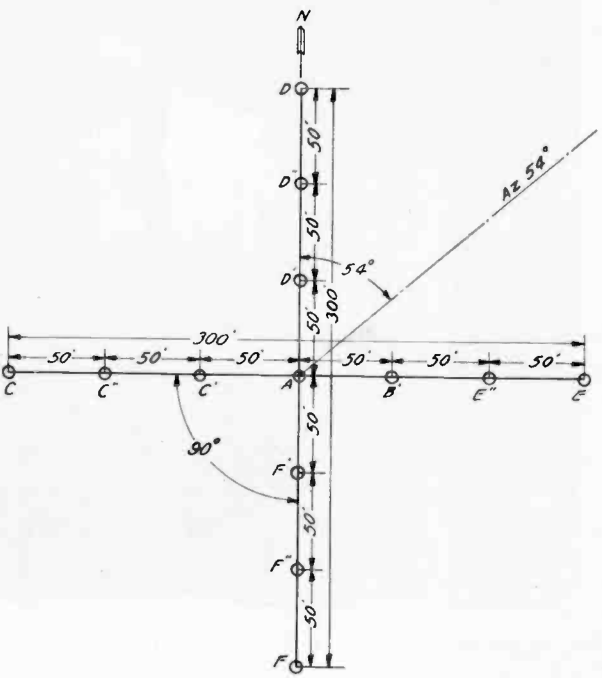

Fig. 6—Radio-Beacon Loop System, Hamakuapoko, Maui, T.H Lat. 20 deg. 55 min. N., Long. 156 deg. 20 min. W.

partially covered with water, making a landing difficult, so we proceeded to the Island of Lanai where the airplanes were refueled with Government gasoline and oil, held there for such contingencies, before the return to Luke Field, Oahu.

The following day orders were issued for me to proceed to Kahului, Maui, via steamer for temporary duty in connection with the selection of a site for the radio-beacon station. The small inter-island steamer left Honolulu Sunday evening and arrived at Lahaina on the south side of Maui at 4 o'clock on the following morning. Getting ashore was accomplished by means of one of the life boats, as docking facilities were not available. A 20-mile automobile trip was then necessary to reach the town of Wailuku, where hotel accommodations were available. Here a local map was obtained and a "Drive Yourself" car hired for the day. The road along the shore from Kahului to Huelo was followed and a careful search made for an open and fairly level location. The terrain in this direction was found to be very rugged and, therefore, unsuitable, except on the edge of the cliff near Maliko. This location, however, was undesirable,

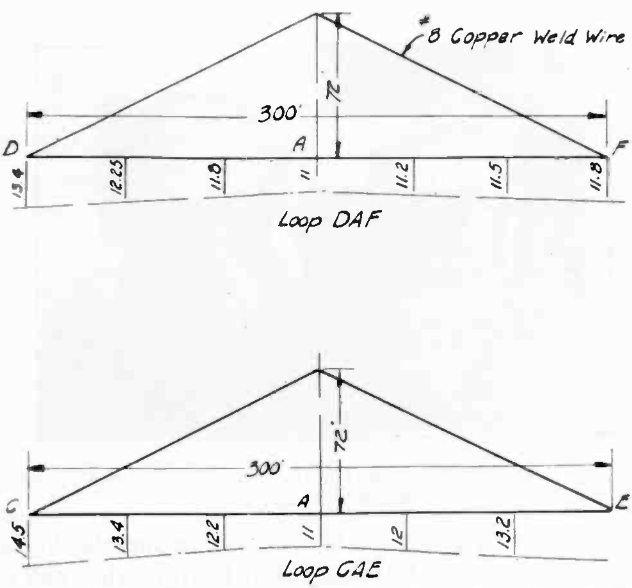

Fig. 7—Radio-Beacon Loop System, Hamakuapoko, T. H.

as it was too far from Kahului where the equipment would be unloaded. A reconnaissance was then made inland between Haiku and Paia, where there are many sugar cane and pineapple fields, and towards noon a very desirable field was located at Hamakuapoko. Permission to establish the radio-beacon station temporarily was obtained from the owners. Upon returning to the hotel that evening I was fortunate in meeting a territorial civil engineer who was familiar with the location of triangulation stations in the vicinity of Hamakuopoko. The next day this engineer was engaged to survey and lay out the loop system.

The position of the loops was carefully laid out and marked with stakes, as shown in Figs. 6 and 7.

Upon arrival at Fort Shafter the following morning a radiogram was received advising that the Crissy Field beacon would be operated for test from 11:00 P.M. to 1:30 A.M. (P. T.) or 8:30 P.M. to 11:30 P.M. (Hu. T.). We listened during this period but could not hear the Crissy Field beacon signals at Fort Shafter. Naturally we were disappointed with the results, but not altogether discouraged, as receiving conditions in that locality were considered very poor. The remainder of the week was spent in gathering additional supplies and arranging for enlisted personnel to assist in the construction of the beacon station on the

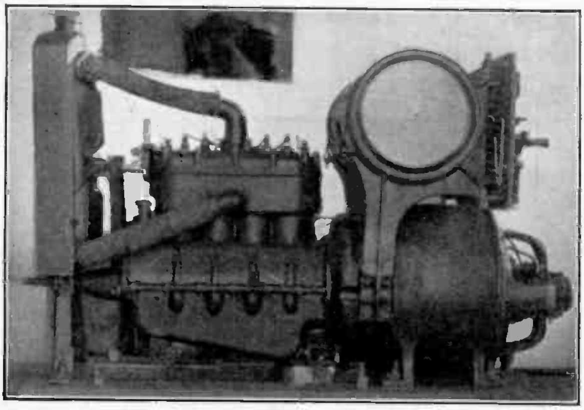

Fig. 8—Power Equipment Type PE-40. Gasoline-Engine-Driven 5 kw Direct-current Generator.

Island of Maui. A pole suitable for supporting the loops was obtained from the Navy Department at Pearl Harbor and towed to the inter-island wharf at Honolulu.

On June 7, 1927, accompanied by a detachment of four enlisted men from Luke Field, the writer left Honolulu for Kahului on the SS *Mauna Kea*. All of the equipment and supplies were on board, including the 93-foot pole which was lashed to the rail. We arrived on the following morning and quarters were obtained on the plantation of the Maui Agricultural Company. Work on the construction of the loops and of a building was started immediately.

On the following day a temporary radio station was established for communication with the Department Signal Officer at Fort Shafter, Honolulu. An airplane radio transmitter type BC-114[4] (SCR-134 set) was used for transmitting and a receiver type SE-1420, with two stages of audio amplification, was used for receiving. The radio station at Fort Shafter (FX-2) transmitted on a wavelength of 1600 meters. The Maui station (EH-9) transmitted on a wavelength of 450 meters, or 750 meters, depending upon receiving conditions at Fort Shafter. The distance between Fort Shafter and Hamakuopoko, Maui, is approximately 90 miles, and reliable communication was maintained on regular schedules daily.

During the week of June 7 the Crissy Field beacon carried on regular tests with the SS *Manoa* of the Matson line, sailing between San Francisco and Honolulu, which were very success-

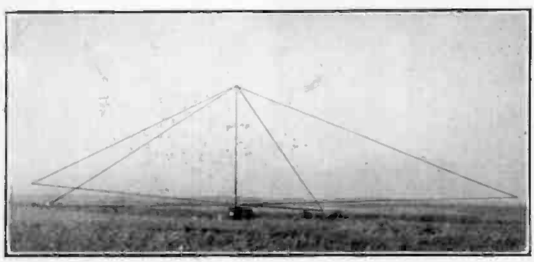

Fig. 9—Exterior of Radio Beacon, Maui, T. H. Mt. Haleakala in Background.

ful. The Crissy Field beacon was heard at Hamakuopoko, Maui, on an SE-1420 receiver using two stages of amplification, with a signal strength of R-4 to R-5 during the hours of darkness. The letter *N* was quite pronounced, superimposed on the background character, indicating that the bearing of the equisignal zone being transmitted from Crissy Field was slightly to the south of the correct course. It had been arranged previously that each station would be so adjusted that the *N* signals would be heard in an airplane when it was north of the correct course and the *A* signals when south of the course. This was the first time that the Crissy Field beacon had been heard in the Hawaiian Islands, and the results were most gratifying, as they not only showed that the modified transmitter had a much greater range than the old-type spark sets, but also made it pos-

[4] This transmitter is designed for telephone, C. W. and tone telegraph. It consists of three 50-watt tubes: master oscillator power amplifier and modulator; also, one 5-watt speech amplifier. Range: telephone—30 miles; C. W. telegraph—100 miles.

sible to adjust readily the transmitted goniometer bearing upon the advice of the listener at the opposite end of the course. In other words, the goniometer bearing could be shifted so as to establish a bracket on the receiving station at the opposite end of the course in order that the average of these readings could be used in the final setting of the goniometer.

The Crissy Field beacon was again operated on the night of June 14th from 10:30 P.M. to 11:40 P.M. (P. T.). The signals were barely audible from 8:30 to 8:40 P.M. and then disappeared

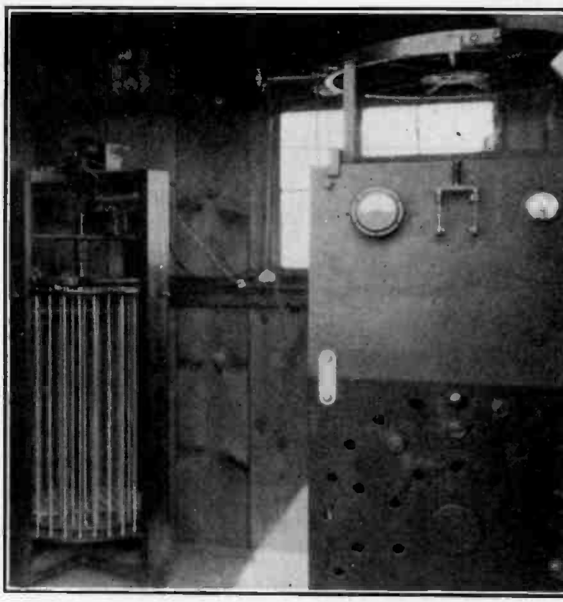

Fig. 10—Interior of Radio-Beacon Station at Hamakuapoko, Maui, T. H

entirely during an eclipse of the moon. On the following night this station was again operated on the same schedule with the goniometer set on 240 deg. The results of this test indicated that the bearing was still slightly south of the true course and that the keying was rather slow with poor interlocking. The signals occurred at about seven-second intervals with a signal strength of R-4.

Further tests were carried on, and on the night of June 21 the bearing was increased to 241 deg.[5] During this test, and a

[5] Considerable distortion caused by a stray coupling within the goniometer was observed at the Crissy Field Station. This accounts for the fact that the bearing as indicated on the goniometer scale did not coincide with the computed bearing.

similar one on the following night, a broken dash, which might be described as a letter X, was received, which showed the bearing of 241 deg. to be correct. The interlocking, however, was slightly defective, probably due to adjustment of the automatic key or relay. At this time a standard superheterodyne receiver type BC-115–116 was also used for comparison with the SE-1420 receiver. Prior to the beacon tests broadcasting stations on the Coast were heard with very good volume. However, this set was much less sensitive on high wavelengths, (1035 meters) and the beacon signals could not be heard with it, although they came in R-4 to R-5 with the SE-1420 receiver, with regeneration just below the point of oscillation. The operator at Crissy Field was

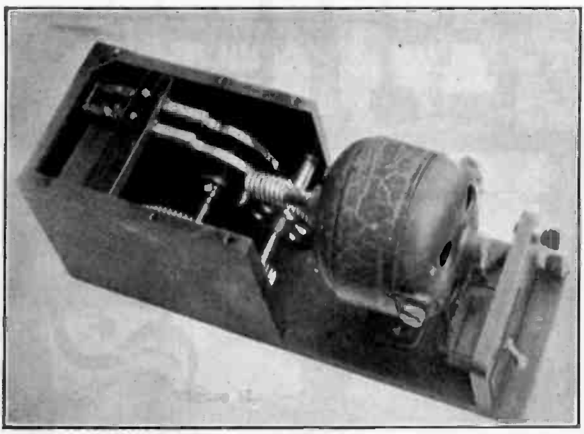

Fig. 11—Automatic Keys for Radio Beacon.

then advised that the bearing was correct from Crissy Field to Hamakuopoko, Maui. It was also advised that the BC-115–116 receiver was not suitable for long flights with the radio beacon.

The installation of the Maui radio beacon was completed on June 21st and preliminary test showed it to be well-balanced and ready for operation. Fig. 9 shows the exterior of this station with Mt. Haleakala in the background. Fig. 10 shows the interior with goniometer. The goniometer was set on the computed bearing of 52 deg. 31 min. for the preliminary tests. Both stations were tested on the night of June 23rd. The observer at the San Francisco station reported the Maui beacon signals were heard with signal strength R-3 on an SE-1420 receiver through static and some interference. The letter A predominated during this test, which indicated that the bearing being transmitted by the

Maui Beacon Station was too far north and had to be increased from the present setting of 52 deg. 31 min. Signals from Crissy Field were received with signal strength R-4 on the bearing of 241 deg., which had been previously found correct. There was considerable static, but messages keyed on the loops, giving a report of the test, were readable. The interlocking of the Maui beacon did not remain perfect during this test and further adjustment had to be made. Figs. 11 and 12 show automatic key and switching relay which are instrumental in obtaining

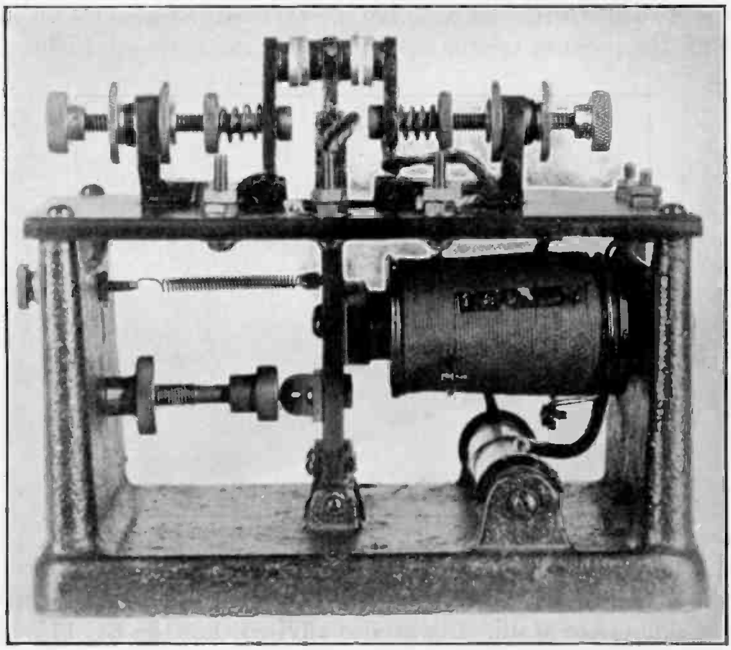

Fig. 12—Radio-Beacon Switching Relay Used in Transpacific Flights.

correct interlocking of signals. After minor adjustments had been completed a perfect dash was obtained along the designated course. Further tests were made with the goniometer set on 54 deg., which proved to be the correct setting. The Chief Signal Officer was then advised that both beacon stations were operating in a satisfactory manner and that the bearing transmitted by each station was correct.

The Fokker monoplane, type C-2, shown in Fig. 13, was equipped with a radio set type SCR-134, shown in Fig. 14, before leaving McCook Field, Dayton, Ohio enroute to San Francisco via Chicago, Fort Sill, San Antonio, El Paso and San Diego. The Crissy Field beacon was used during the flight from San Diego to San Francisco in order that the pilot and

Fig. 13—Fokker Monoplane Type C-2, Used by Lieutenant Hegenberger and Lieutenant Maitland in Flight from San Francisco to Hawaii, June 28 and 29, 1927.

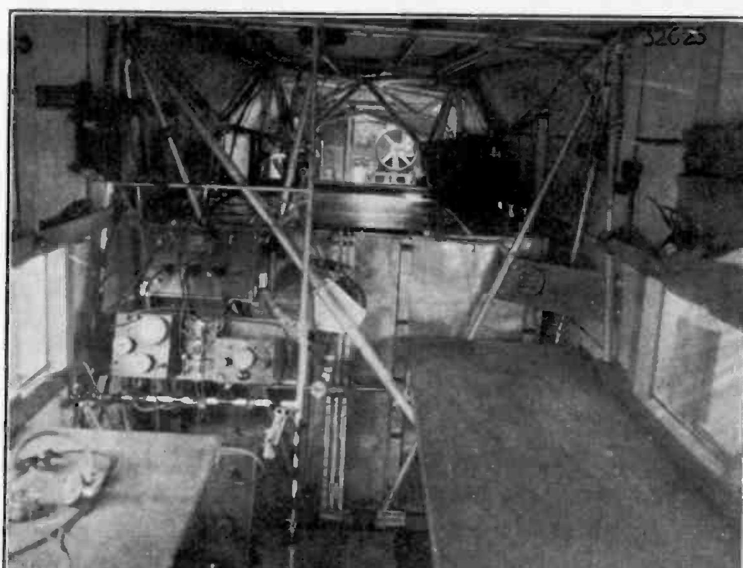

Fig. 14—Interior of Airplane Type C-2 Used by Lieutenant Hegenberger and Lieutenant Maitland in Flight from San Francisco to Hawaii. The SCR-134 Radio Telephone and Telegraph Set Is Shown Mounted in Special Framework on Left Side of the Cabin. The Table on the Right Was Used As A Chart Table for the Navigator.

navigator of the airplane might become familiar with the use of their radio equipment and the radio-beacon signals before setting out on their long flight to Hawaii. After the arrival of the C-2 airplane at Crissy Field a modified receiver type BC-137[6] was installed as an additional receiver.

On the morning of June 28, 1927 at 7:10 A.M. the Fokker airplane, of which Lieutenant Albert F. Hegenberger was navigator-pilot and Lieutenant Lester J. Maitland pilot, took off from Oakland Airport enroute to Honolulu, T. H. The Crissy Field radio beacon was placed in operation immediately with the

Fig. 15—Wreck of Smith-Bronte Plane *City of Oakland* at Molokai, T. H.

goniometer set on 241 deg. The transmitted course and quality of interlocking was checked locally during the flight so that any errors might be noticed immediately and corrected.

The Crissy Field beacon operated continuously during the flight except for a short period about two hours after the start of the flight when the gasoline engine stopped due to a stoppage in the fuel line. This was quickly repaired, however, and the set was again in operation in ten minutes. During the flight re-

[6] One-stage tuned r.f., regenerative detector and two stages of audio amplification.

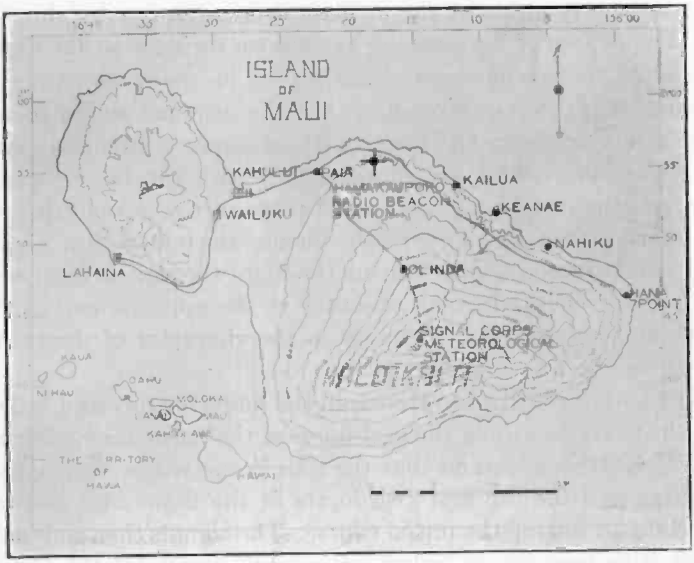

Fig. 16—Chart of Island of Maui Showing Location of Radio Beacon Station and Meteorological Station on Mt. Haleakala.

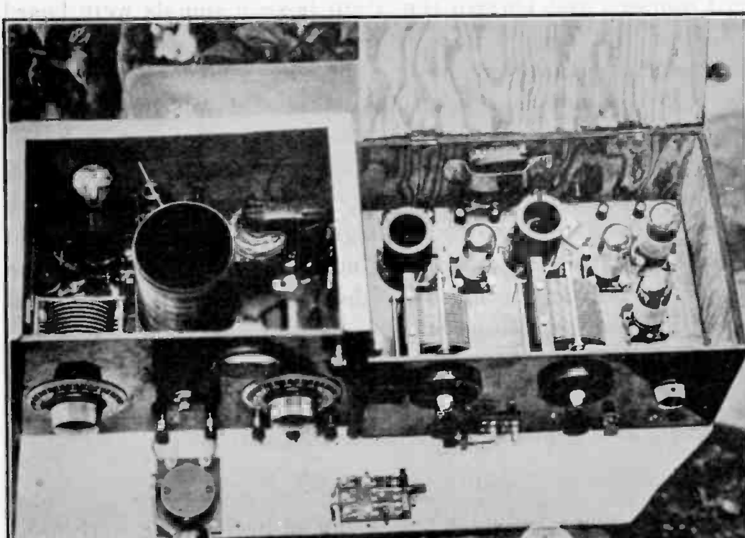

Fig. 17—Fort Shafter, T. H. August 19, 1927. Radio Set Used by Goebel in the Plane *Woolaroc*, Which Flew from San Francisco to Wheeler Field. T. H.

ports on the progress of the airplane were sent out by ships so that the position of the airplane was known throughout the flight.

The Maui beacon station was placed in operation at 5 P.M. on June 28, as it was estimated that the airplane would be approximately half way to Hawaii at that time. Starting at midnight weather reports were transmitted with the beacon every hour by substituting a hand key in place of the automatic key. The station functioned perfectly during the entire run of approximately fifteen hours. During the flight the signals from each station were checked by an observer at the opposite end of the course and no appreciable change in the character of the transmitted signals was noticed.

The author returned to Honolulu the following day and talked with the flyers regarding the usefulness of the radio beacon during the flight. It was learned that the San Francisco beacon signals were followed for the first two hours of the flight and assisted materially in setting the initial course. The signals then suddenly ceased (this was due to failure of gasoline engine at the Crissy Field beacon station) and were then picked up intermittently during the remainder of the flight. When about midway between San Francisco and Hawaii the Maui beacon signals were heard by Lieutenant Hegenberger who estimated the width of the *T* signal zone to be approximately eight miles. The beacon signals, however, were not heard continuously and it was believed that something was defective with the receiving equipment on board the airplane. A test flight made subsequent to the airplane's arrival at Wheeler Field, however, did not reveal any defects in the receiving equipment. It is regrettable that an expert radio operator could not have been included in the crew so that the radio equipment and reception of the signals could have received the entire attention of one man.

Part B

The Smith-Bronte Flight

July 14–15, 1927

The next flight in which the Army radio beacons were used was that made by Mr. Ernest Smith, pilot, and Mr. Emory Bronte, navigator in a single-motored "Travel Air" monoplane. The radio equipment installed in this airplane was made up hastily at San Francisco and is described below:

Transmitter. Hartley Circuit using one 50-watt tube and tuned to 600 meters for use in communication with ship stations.

Plate and filament supplied from a 900-cycle wind-driven generator, type GN-4.

Weight of transmitter complete approximately 50 pounds.

Receiver. One-stage tuned radio-frequency and regenerative detector with two stages of audio amplification. Plug-in coils to cover wave band from 500 to 1100 meters. Regeneration controlled by detector filament rheostat. Type DV-3 tubes, with dry cells for filament supply were provided. Weight of receiver approximately 15 pounds.

The above equipment was installed in the fuselage in back of the navigator's cockpit. The ignition system of the single Wright Whirlwind engine was not shielded, but the receiver was far enough away from the engine so that comparatively little ignition interference was present. The call letters of this airplane were WLO.

On July 14, 1927, the take-off was made from Oakland Airport at 10:40 A.M. with Honolulu as the destination. The log of the Crissy Field radio-beacon station for this flight is shown below:

July 14	
10:30 P.M.	Started beacon.
11:10 A.M.	Smith's plane passed over beacon station.
1:00 P.M.	Airplane reports beacon signals received O.K.
1:10 P.M.	Airplane reports still foggy—Beacon coming in fine.
2:00 P.M.	Still hearing beacon signals.
3:25 P.M.	Bronte reports signals not heard since 2:24 P.M. Thinks receiver out of order.
July 15	Bulletins came in during night but no report of beacon signals.
3:00 A.M.	Beacon shut down. Signals from Maui received at Crissy Field about R-2.
7:45 A.M.	Plane reported landing in sea 600 miles from Honolulu. Out of gas.
12:16 P.M.	Plane reported landing on Molokai—wrecked.

The Maui beacon station started transmitting when the airplane was estimated to be about half-way between San Francisco and Hawaii. In accordance with previous arrangements this station suspended its regular transmission of bearing for the first ten minutes of each hour to enable the operator to listen for the signals from the Crissy Field beacon. At every hour, on the half hour, the Maui beacon again suspended its regular beacon transmission while meteorological data was transmitted on one of the loops.

The log of the Maui radio-beacon station is shown below:

July 14.

3:45 P.M.	(H.T.)	Started beacon 4.5 kw input.
3:45 P.M.	"	Message relayed from plane—Lat. 36.32 N. Long. 123.33 W. Still foggy have not heard beacon for last hour.
8:10 P.M.	"	Position of plane at 6:00 P.M. (P.T.) Lat. 35.08 N. Long. 130.46 W. Going fine.
9:00 P.M.	"	Crissy Field beacon heard R-4 heavy QRM.
11:00 P.M.	"	Crissy Field beacon heard R-4 heavy QRM.
11:55 P.M.	"	Crissy Field beacon heard R-4 heavy QRM.

July 15.

12:15 A.M.	"	Received from Presidio S. F. "Maui beacon received here very good."
1:30 A.M.	"	Crissy Field beacon not heard. U.S.A.T. *Kenowis* reported through KHK (Honolulu) that he heard plane, WLO, send out a QST but was unable to copy due to QRM. (12:30 A.M. (Hu. T.)) (*Kenowis* about 700 miles from Honolulu).
2:00 A.M.	"	SS *Wilhelmina* (WMO) reported to Honolulu (KH) at 1:57 A.M. (H.T.) that plane's position report at 4:05 A.M. (P.T.) was Lat. 28.58 N. Long. 144.36 W.
2:15 A.M.	"	From Presidio WVY "Think Crissy Field beacon station closed now as unable to reach them by phone."
3:00 A.M.	"	Intercept direct from plane. Long. 145.45 W. All well aboard pretty tired too.
3:10 A.M.	"	Received relayed message from plane "We are out of gas."
3:24 A.M.	"	Intercept "Can you make it to Honolulu" WYAD working WLO.
4:00 A.M.	"	Received QST direct from plane (WLO) "Rush help to WLO making forced landing in water NE of Paia, Maui."
5:06 A.M.	"	Received QST direct from Plane (WLO) "500 miles north east Paia all out of gas, send help, planes, boats."
5:15 A.M.	"	Received direct from plane (WLO) "Landing in sea, have rubber life boat but send help."
5:49 A.M.	"	Received QST from plane (WLO) "Please send help to WLO coming down no gas."

6:20 A.M. (H.T.) Sent QST on beacon "Smith plane (WLO) probably been using radio beacons from Coast to Hawaii stop Letter *T* indicates course stop Letter *N* indicates north of course stop Letter *A* indicates south of course stop Wavelength ten thirty five meters.

7:25 A.M. " S.S. *Wilhelmina* (WMO) reported position about 75 miles from plane at 6:35 A.M. and proceeding to plane's position.

7:35 A.M. " Repeated QST sent out at 6:20 to assist rescue ship in proceeding to disabled plane.

7:55 A.M. " QST "Will resume transmitting beacon signals on San Francisco to Maui bearing at 9:00 A.M."

8:00 A.M. " Sent message to Signal Officer Ft. Shafter "Suggest following be broadcast on 600 meters 'Smith airplane was following radio beacon signals on ten thirty five meters from Coast enroute Honolulu stop Letter *T* indicates course stop letter *N* indicates north of course stop Letter *A* indicates south of course.'"

9:15 A.M. " At approximately 9:15 A.M. Smith's Plane was sighted over coast of Maui and headed towards Paia. When nearly over the receiving station at Hamakuopoko he turned towards Molokai and disappeared in the clouds. At about 11:00 A.M. a radiogram broadcast by a small privately-owned radio station on the island of Molokai advised that the airplane *City of Oakland* had landed in Kiawi trees on the south-eastern shore of Molokai out of gasoline. Smith and Bronte unhurt.

A flight of Army airplanes from Luke Field, Oahu landed at an emergency field on the island of Molokai and took Messrs. Smith and Bronte to Honolulu. The wrecked airplane *City of Oakland* (Fig. 15) was salvaged by naval personnel and taken to the Naval Air Station at Pearl Harbor. A copy of a letter written by Mr. Bronte commenting upon the use of the radio beacon is shown below.

San Francisco, August 8, 1927.

MR. P. HENDRICKS,
CRISSY FIELD,
PRESIDIO, SAN FRANCISCO.

DEAR SIR:

It gives me great pleasure at this time to thank you for the splendid cooperation given Mr. Ernest Smith and myself on our recent flight from the Oakland Air Port to the Hawaiian island in the monoplane *City of Oakland*. It is to be regretted that our headphones went out of commission when we were approximately

200 miles at sea because up to that time the radio beacon had functioned perfectly and we were desirous of using it on the entire flight.

I might say at this time that it was the San Francisco radio beacon which set us on our course from the coast, for, as you know, we left on the morning of July 14th in a dense fog and after climbing through the fog, found ourselves quite a bit to the northward over Marin County. At that time the beacon signal *N* was coming in very strongly and we headed due south until the signal *T* was heard most distinctly. We then set the plane on our course for the Hawaiian groups keeping the *T* signal tuned in meanwhile.

Personally I believe the radio beacon to be the greatest aid to long distance aerial navigation that is known today.

Thanking you again for your kind cooperation before and during the flight, I am

Sincerely yours,
(signed) E. B. Bronte

EBB/RC

Part C

The Dole Flight

August 16–17, 1927

The Honolulu Chapter of the National Aeronautic Association requested the War Department to authorize the use of the Army radio-beacon station at Crissy Field, San Francisco, and at Hamakuopoko, Maui, T. H., during the Dole Flight which was scheduled to start from San Francisco at noon August 12, 1927 with Wheeler Field, Honolulu, as the destination. As soon as the Hawaiian Department was notified that the above request had been granted preparations were made whereby the greatest service possible would be rendered by the radio-beacon system.

During the Army flight by Lieutenant Maitland and Lieutenant Hegenberger, as well as the Smith-Bronte flight from San Francisco to Hawaii, the radio beacons were used as an aid to aerial navigation by sending out signals to indicate the Great Circle course from Crissy Field to Hamakuopoko, Maui. This service was interrupted at intervals to transmit meteorological data which was obtained locally. However, due to trouble with the receiving apparatus in the airplanes on these flights, the aviators were not able to utilize to the fullest degree the assistance which was offered.

The Signal Officer, Hawaiian Department, realizing the possibilities of the radio beacon, not only as a guide along the correct course, but as a means of furnishing the aviators with reliable meteorological data, ordered a meteorological detachment to the summit of Mt. Haleakala on the island of Maui, shown in Fig. 16. The information obtained for several days prior to the Dole Flight was forwarded to the Weather Bureau at Honolulu and at San Francisco to assist in forecasting the weather during the flight. Telephone communication was established between the meteorological station on Haleakala and the radio-beacon station at Hamakuopoko.

Owing to the fact that only a very few of the entrants for the flight were ready for the start at noon of August 12, 1927, the start of the Dole flight was postponed until noon of August 16. The lineup of the planes entered on that date was as follows:

Plane No.	Call Letters	Frequency of Transmitter Kilocycles	Power Watts	Beacon Receiver	Type Plane	Name of Plane	Pilot	Navigator
1.	KDE	500		Yes	Monoplane	*Oklahoma*	Griffin	Henley
2.	KNK	500	100	No	Monoplane	*El Canto*	Goddard	Lt. K. C. Hawkins, U.S.N.
3.	KGGA	9050	50	No	Monoplane	*Pabco*	Maj. Irving	None
4.	KW5	None		Yes	Monoplane	*Golden Eagle*	Frost	Scott
5.	None	None		No	Biplane	*Miss Doran*	Pedlar	Knope
6.	None	None		No	Monoplane	*City of Peoria*	Parkhurst	Lowes
7.	KGGI	493	50	Yes	Monoplane	*Woolaroc*	Goebel	Lt. Wm. V. Davis, U.S.N.
8.	None	None		No	Monoplane	*Spirit of Dallas*	Erwin	Eichwaldt
9.	None	None		No	Monoplane	*Aloha*	Jensen	Schlueter

The first airplane took off at Oakland Airport at 12:30 P.M. (P. T.). Several of the planes had trouble after getting into the air, forcing them to return, while others were unsuccessful in getting off the ground. Only four of the nine airplanes entered for the race actually started out. They were numbers 4, 5, 7, and 9. Two of these, No. 4 and No. 7 were equipped with beacon receivers and No. 7 also carried a transmitting set. The radio equipment installed in the *Golden Eagle*, entrant No. 4, was essentially the same as that of the *Woolaroc* which will be described below. The transmitter, however, was removed before the flight to decrease the weight of the airplane.

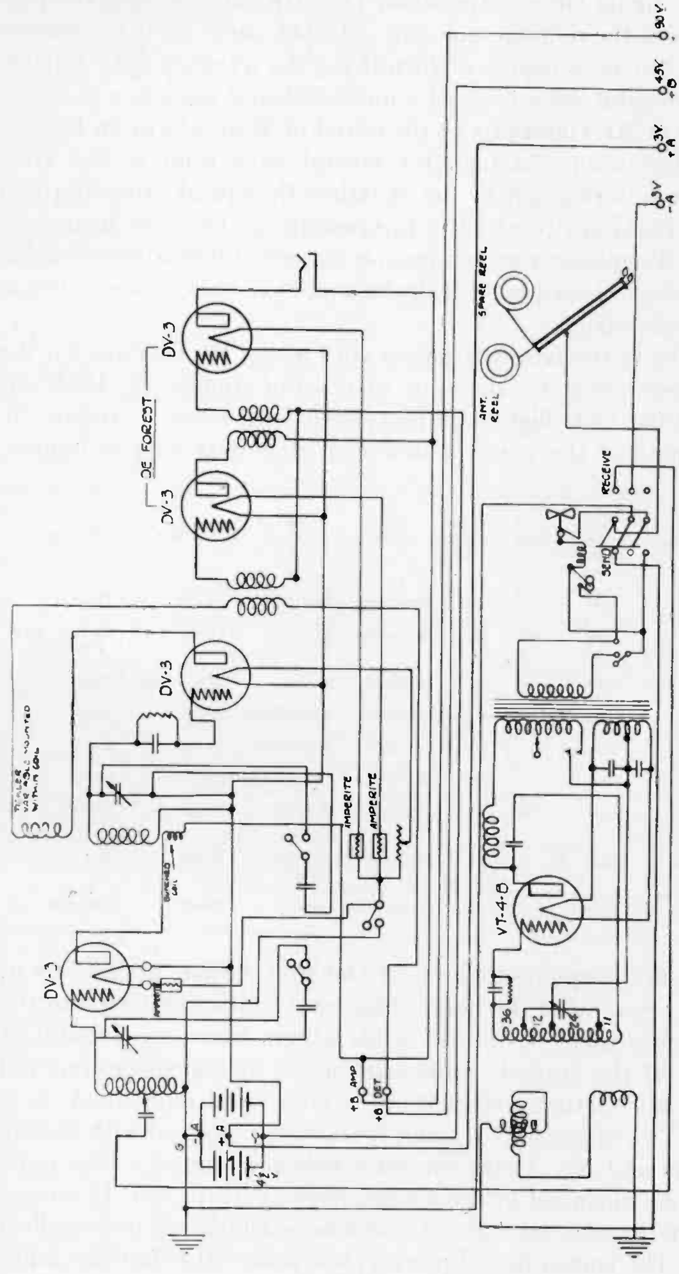

Fig. 18—Radio Installation on Airplane *Woolaroc*, Used Successfully in Transpacific Flight, August 16–17, 1927.

The radio equipment installed in the *Woolaroc,* entrant No. 7, consisted of:

Receiver. One-stage tuned radio frequency, regenerative detector and two stages of audio amplification. This was the same receiver that was previously used in the Smith-Bronte flight to Honolulu.

Transmitter. Same one used in Smith-Bronte flight to Honolulu. 600-meter ACW Hartley Circuit using 50-watt tube. Filament and plate supplied from 900-cycle wind-driven generator, type GN-4.

Note: A dual-antenna installation was made so that if one was lost another could be used. Fig. 17 shows transmitting and receiving sets and Fig. 18 shows the schematic wiring of the complete installation.

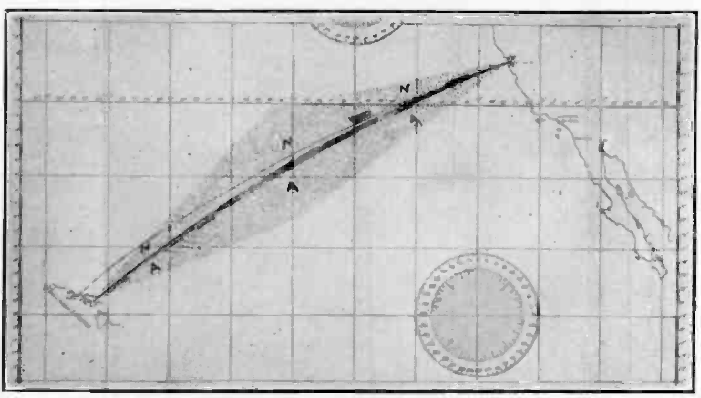

Fig. 19—Radio Beacon Chart—Dole Flight. Chart Showing Great Circle Course Transmitted by Radio Beacons between San Francisco and Maui, T. H. The Width of the Equi-Signal Zone at Approximately Half-Way between These Two Points Was Estimated to be about Eight Miles from Observations Made During Flight and on Surface Vessels.

The Crissy Field beacon was placed in operation at 12 o'clock noon of August 16th and continued in operation until 11:00 A.M. August 17th. No trouble of any kind was experienced with this set during the entire period of twenty-three hours.

The Maui beacon was placed in operation at 7:30 P.M. (Hu. T.) or approximately ten hours after the start of the flight, as it was assumed that the San Francisco beacon would operate during the first twelve hours of the flight which would make a two-hour overlap in transmission. This station functioned perfectly with full power during the entire night and starting at daybreak, meteorological data consisting of wind direction and velocity, cloud density, cloud ceiling, cloud summit, and direction and velocity of wind drift component was transmitted during the first ten minutes of each hour.

Position reports from the *Woolaroc*, which were received at frequent intervals, indicated that this airplane was following a direct course from San Francisco to Hamakuopoko, Maui, T. H. as shown in Fig. 19. It was also reported that signals from both of the beacon stations were heard and that the *T* signals were being followed continuously.

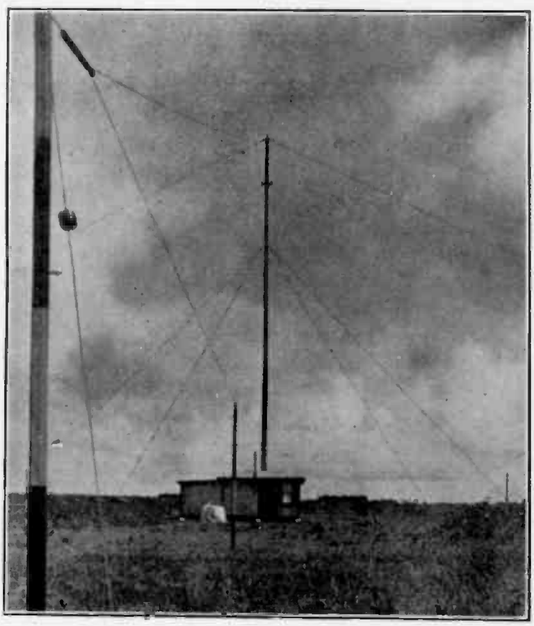

Fig. 20—Radio-Beacon Station at Wheeler Field, Oahu, T. H. The Airplane Hangars May Be Seen in the Background.

The *Woolaroc* landed at Wheeler Field at 12:24 P.M. (Honolulu time) thereby winning the first prize of $25,000.00. Messrs. Goebel and Davis were taken into Honolulu immediately, where each gave a short talk on their flight from a local broadcasting station. A copy of a letter written by Lieutenant Davis commenting upon the flight is shown below.

San Francisco, California,
1 Sept. 1927.

SIGNAL OFFICER,
9TH CORPS AREA HEADQUARTERS,
SAN FRANCISCO, CALIF.

DEAR SIR:

I wish to express my appreciation of the Army courtesies to Art Goebel and myself in conjunction with the Dole Flight. The Army was of great assistance in many ways and I cannot tell you how we appreciated it. In particular, the radio beacon was an unqualified success, and rendered the navigational problem a very simple one. The signals were clear and distinct and were held practically the entire way. At one time I was able to hear both the San Francisco and Maui beacons at the same time, our position at the time being about midway between Honolulu and San Francisco.

I will write a detailed report of the flight upon my return to duty and will be glad to forward a copy to you, if it would be of interest.

Thanking you again, I remain

Respectfully yours,
(Signed) WILLIAM V. DAVIS
Lieut. (j.g.) U.S.N.

Naval Air Station
San Diego, Cal.

On August 24 the author returned to Honolulu and had the opportunity of talking with Mr. Goebel and Lieutenant Davis, pilot and navigator respectively of the *Woolaroc*. Both of these gentlemen were very enthusiastic in their praise of the radio beacons which had so greatly simplified their navigation problems. Lieutenant Davis said that the San Francisco beacon signals faded out for about two hours before sunset, but the Maui signals were picked up immediately when started at 7:30 P.M. (Hu. T.). After sunset the San Francisco beacon signals were again heard and for a period both beacon stations were heard simultaneously. The position of the *Woolaroc* at that time was about midway between San Francisco and Honolulu and the width of the *T* zone was estimated to be about 8 miles. The islands were sighted when about 40 miles from the coast of Maui and the beacon course was then abandoned and a new course was set towards Wheeler Field on the island of Oahu. Towards the latter part of the flight a connection in one of the receiver tube sockets became crystallized and broke off. Lieutenant Davis located the trouble, made a temporary repair connection and then held the tube in place for about two hours, when the islands were sighted and the course changed. Lieutenant Davis also said that in obtaining his position at various times he calculated the distance from San Francisco along the beacon path by dead reckoning and then obtained the latitude by sighting on Polaris. This latitude line when projected to intersect the Great Circle beacon course gave the longitude of the airplane at that time.

The second prize of $10,000.00 was won by Martin Jensen, pilot of the *Aloha*. The two remaining airplanes which started in the Dole Derby were lost, and nothing has since been heard of either of them. The *Spirit of Dallas* with Wm. Erwin, pilot, and

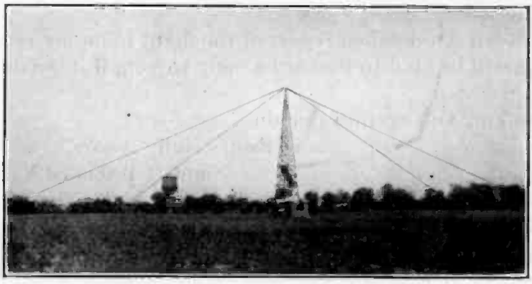

Fig. 21—Radio Beacon, Wright Field. Building, Tower, and Loop System.

Eichwaldt, navigator, left San Francisco enroute to Honolulu on August 18th. This airplane carried a short-wave transmitter. The last report heard of this airplane was when it was in a tail spin about six hundred miles from San Francisco.

In the final analysis of the data which was obtained during these tests the following conclusions are set forth.

(1) That the equi-signal radio beacon is already developed to the point where it is capable of furnishing important assistance in aerial navigation.

(2) That reception aboard the airplane is the weakest part of the beacon system.

(3) That with the best transmitting and receiving apparatus adequate personnel training is necessary, as it was demonstrated in these flights that in one case excellent training of the radio operator made up for deficiencies in apparatus while in another case with adequate apparatus a comparatively untrained operator utilized the beacon only part of the time.

Part D

Radio Beacon Installation at Wheeler Field, Oahu, T. H.

Shortly after the Dole Flight the radio-beacon station at Hamakuopoko, Maui was dismantled and shipped to Wheeler Field near Honolulu, where it was permanently installed, (Fig. 20). The computed Great Circle course from Wheeler Field, T. H. to Crissy Field, San Francisco is approximately 54 de-

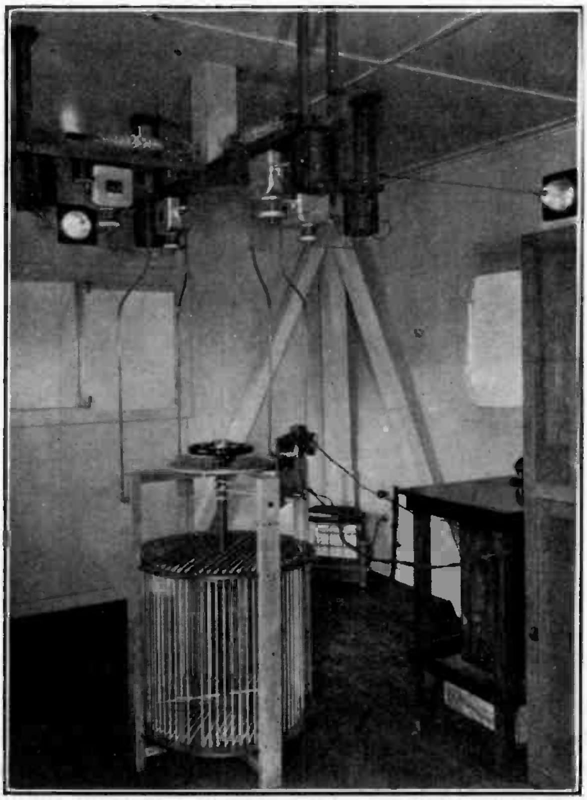

Fig. 22—Radio Beacon, Wright Field. Interior, Showing Goniometer and Loop Loading with Details of Interior Construction and Method of Mounting Loop Loading Coils and Condensers.

grees. Signals and bearing transmitted by the Wheeler Field station were checked by the writer during his return to San Francisco by steamer. At this time the width of the equi-signal zone was conservatively estimated to be approximately 5 miles when about 1100 nautical miles from Hawaii, which checks rather closely with the estimates made by Hegenberger and Davis on their respective flights.

Improvements in the Radio Beacon

During the past year several improvements have been made in the radio beacon by the Signal Corps Aircraft Radio Laboratory at Dayton, Ohio. It has been observed that the average pilot has more or less difficulty in differentiating between the *N* and *A* signals when the airplane gets slightly off the course. To overcome this difficulty, the letters *N* and *A* have been super-

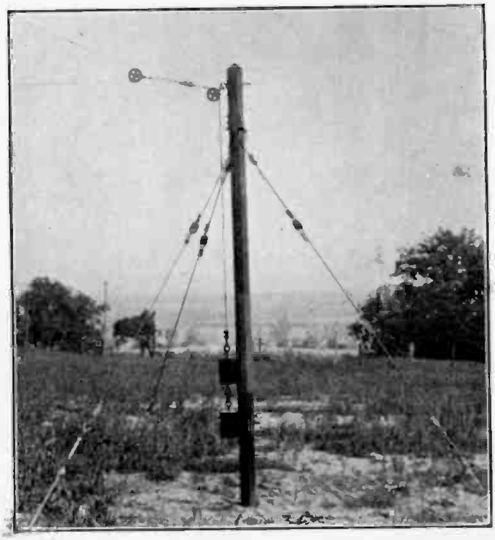

Fig. 23—Radio Beacon, Wright Field. Detail of End of Loop.

seded by groups of dots and dashes. These signals interlock as before and the pilot hears a continuous 1000-cycle note when on the course. A series of dots or dashes is heard when the airplane gets off the correct course. This system has been found to be superior in that the zone of interlocked signals is made narrower eud to a more rapid change in the quality of the signals.

The automatic key and switching relay in the rotor circuit of the goniometer has also been improved so that both are much more simple to adjust and are rugged enough to maintain their adjustments. A complete new installation has been made at Wright Field as shown in Figs. 21 and 22. Fig. 23 shows methods of holding loops in position. A master oscillator and neutralized power-amplifier circuit is used to obtain a more constant frequency, as it was observed that there was a tendency for the frequency to shift when the goniometer was coupled directly to the oscillator. In the new installation the transmitter is entirely shielded to prevent any stray coupling between it and the goniometer or loop circuits. The results obtained during test flights have been very satisfactory. Recently flights have been made from Dayton to Buffalo, Cleveland, Detroit, Uniontown, and St. Louis. During these flights the equi-signal zone appeared to be approximately 1 deg. in width.

Volume 16, Number 9 *September, 1928*

EFFECTIVE HEIGHTS OF THE KENNELLY-HEAVISIDE LAYER IN DECEMBER, 1927 AND JANUARY, 1928*

By

G. Breit, M. A. Tuve, and O. Dahl

(Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.)

Summary—*Effective heights of the Kennelly-Heaviside layer have been measured from December 19, 1927 to January 16, 1928. It is found, with the improved conditions, that the heights of successive reflections are approximately in the ratios 1, 2, 4.*

THIS is a brief report on the results obtained by the echo-method. The transmission used for this has been improved so as to obtain sharp peaks. The details of the method have been described by M. A. Tuve and O. Dahl.[1] The sharpness of the peaks obtainable and the large spacing between them make the identification of the ground-wave and the reflected wave much more certain. The accuracy with which the time of arrival

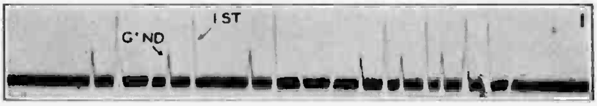

Fig. 1—Specimen Test Records; Test 88 during $9^h\ 50^m$ to $10^h\ 15^m$, December 29, 1927.

of the two waves can be measured is increased as well. There are two reasons for this: (1) The graphical accuracy of locating the peaks is higher, and (2) the interference between the successive waves is completely eliminated and hence no correction for relative phases of interfering waves has to be made.

As in our previous experiments the transmission took place from the Naval Research Laboratory located at Bellevue, Anacostia, D. C. The signals were received at the laboratory of the Department of Terrestrial Magnetism about 7 miles northwest from the transmitter. The frequency used was 4015 kilocycles.

Some representative wave-forms are shown in Figs. 1, 2, 3, and 4, for all of which the time-scale is increasing from left to

* Original Manuscript Received by the Institute, May 23, 1928. Communication from the International Union of Scientific Radiotelegraphy.

[1] Proc. I. R. E., 16, p. 794; June, 1928.

right. In Fig. 1 a case of single reflection is shown. The approximate effective height is 140 miles. The smaller hump is due to the ground, the larger to the reflection. In Fig. 2 a case of double reflection is shown. The strong reflection gives a height of 140

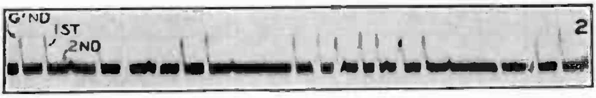

Fig. 2—Specimen Test Records; Test 88 during $9^h\ 50^m$ to $10^h\ 15^m$, December 29, 1927.

miles; the weak one corresponds to 280 miles. These wave-forms represent the usual conditions during the period discussed.

Under exceptional conditions triple reflections are observed. Examples are shown in Figs. 3 and 4. The wave-forms were obtained on January 14 during a period of severe short-distance

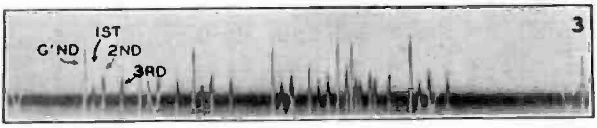

Fig. 3—Specimen Test Records; Test 109 during $9^h\ 30^m$ to $9^h\ 45^m$, January 14, 1928.

fading. The three reflections correspond to heights of 67, 140, and 280 miles. As in most cases the amplitudes of the reflections are different in the two cases while the strength of the ground-wave remained constant.

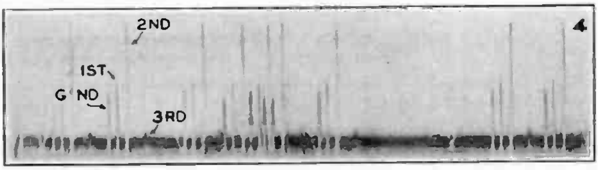

Fig. 4—Specimen Test Records; Test 109 during $9^h\ 30^m$ to $9^h\ 45^m$, January 14, 1928.

We have not observed such multiplicities in our previous tests. We had cases of multiple reflections, but the retardations were not different from each other by factors of two as they are here. Heising[2] observed retardations having integral ratios for considerably larger total time-differences. This is presumably due to the fact that our older tests did not resolve the reflections

[2] PROC. I. R. E., 16. p. 75, January, 1928.

TABLE I

EFFECTIVE HEIGHTS OF LAYER AND RELATIVE INTENSITIES OF REFLECTIONS AT WASHINGTON, DECEMBER 1927 TO JANUARY 1928

Test No.	Date	75° west M.M.T. From	75° west M.M.T. To	Heights First	Heights Second	Heights Third	Intensities Ground	Intensities Reflection First	Intensities Reflection Second	Intensities Reflection Third
	1927	h m	h m	miles	miles	miles				
74	Dec. 19	9 30	10 00	135	285	—	—	—	—	—
				135	270	—	—	—	—	—
				135	—	—	—	—	—	—
75	Dec. 19	14 25	15 05	140	—	—	—	—	—	—
				140	—	—	—	—	—	—
				145	—	—	—	—	—	—
				145	—	—	—	—	—	—
76	Dec. 20	9 30	10 00	145[a]	285[a]	—	4	5	0.5	—
				135[a]	—	—	3.5	4	0	—
				135[b]	—	—	7	1.5	—	—
				135[b]	—	—	7	1.5	—	—
78	Dec. 21	9 30	9 55	140	—	—	5	4	—	—
				140	—	—	3	1.5	—	—
				140	—	—	3	2	—	—
79	Dec. 21	14 30	15 00	140[c]	—	—	—	—	—	—
80	Dec. 22	9 30	10 00	134	272	—	—	—	—	—
81, 82	Dec. 22	14 30	15 00	46?	93?	140	5	—	—	2
86, 87	Dec. 28	9 30	9 55	75	140	—	5	3	2.5	—
				140	—	—	4	4	—	—
		14 30	14 50	140	—	—	3.5	1.4	—	—
				140	—	—	5.0	3.0	—	—
				140	—	—	4.4	4.3	—	—
88	Dec. 29	9 50	10 15	140	280	—	3.2	6	0.5	—
				135	—	—	3.5	8	0	—
				140	280	—	3.5	4.0	0.5	—
				135	—	—	3.2	3.2	—	—
				135	—	—	3.9	1.0	—	—
89, 90	Dec. 29	14 30	14 45	145	—	—	3.2	8.5	—	—
91	Dec. 30	14 30	15 00	145	—	—	6.0	0.8	—	—
				140	—	—	7.5	0.5	—	—
	1928									
92	Jan. 3	14 30	14 50	142	—	—	7	3	—	—
93	Jan. 4	9 30	9 50	132	—	—	3.5	2.8	—	—
				132	—	—	4.3	5.0	—	—

Test No.	Date	75° west M.M.T. From	75° west M.M.T. To	Heights First	Heights Second	Heights Third	Intensities Ground	Intensities Reflection First	Intensities Reflection Second	Intensities Reflection Third
	1928	h m	h m	miles	miles	miles				
94	Jan. 4	14 30	14 50	140	—	—	5	3	—	—
95	Jan. 5	9 30	9 45	145	—	—	6.5	12.5	—	—
				140	285	—	6.5	10.6	1.0	—
97	Jan. 6	9 30	9 50	140	—	—	2.0	5.5	—	—
98	Jan. 7	9 30	9 50	135	—	—	5	11	—	—
				140	280	—	5	11	1	—
100	Jan. 9	9 30	9 45	140	280	—	9	8	0.5	—
101	Jan. 9	14 30	14 50	145	—	—	9	3.5	—	—
102	Jan. 10	9 30	9 50	140	280	—	10	9	1	—
				140	280	—	10	15	1	—
				140	280	—	9	3	2	—
103	Jan. 11	9 30	9 50	140	—	—	10	12	—	—
104	Jan. 11	14 30	14 50	140	—	—	7	11	—	—
105	Jan. 12	9 30	9 45	75	150	—	8	10	14	—
				75	150	300	8	10	14	3
				75	150	—	8	6	13	—
106	Jan. 12	14 30	14 45	140	300	—	5	3	2	—
				140	300	—	5	5	0.5	—
107	Jan. 13	9 30	9 40	140	290	—	9	9	2	—
				140	—	—	9	13	0	—
				140	—	—	9	23	—	—
				140	280	—	9	3	2	—
				140	280	—	9	21	2	—
108	Jan. 13	14 30	14 45	140	280	—	3	8	1	—
				140	—	—	3	13	0	—
				140	—	—	3	5	0	—
				140	—	—	3	7	0	—
109	Jan. 14	9 30	9 45	65	140	280	9	12	11	1
				65	140	280	9	7	1	1
				70	140	280	9	2	3.5	3
				70	140	280	9	11	18	2
				70	140	280	9	9	19	1
110	Jan. 16	9 30	9 45	140	280	—	6	19	2	—
				140	280	—	6	2	1	—

[a] Loop. [b] Antenna. [c] Questionable 93-mile reflection.

completely. The interference between overlapping waves must have produced misleading effects.

Table I gives the measured effective heights and also rough estimates of intensities of the waves recorded.

The authors should like to express again their gratitude to Messrs. A. H. Taylor, M. H. Schrenk, and L. A. Gebhard for the possibility of using the *NKF* transmitter in these tests.

Volume, Number 9 *September, 1928*

CONSIDERATIONS AFFECTING THE LICENSING OF HIGH-FREQUENCY STATIONS*

By

S. C. Hooper, U.S.N.†

(Captain U. S. Navy; Director of Naval Communications, Navy Department, Washington, D. C.)

Advent of the use of high frequency in commercial fields puts us face to face with new problems of regulation, not entirely paralleled in previous radio situations, due to (1) the great economic value of these frequencies because of the comparatively low cost for long distance communication, and (2) because of the fact that a large share of these frequencies require, generally speaking, a world-wide clear channel. The following considerations appear to me pertinent in the allocation of frequencies between 6,000 and 23,000 kilocycles.

(1) Generally speaking, these frequencies must be considered as interfering around the world. Attention is called to the recognition of the long-distance value of these frequencies in the International Radio Convention Regulations with recommendation that they be reserved for long-distance communication in services between fixed points.

For this reason, frequencies assigned by one nation must not be later assigned by another nation unless it be demonstrated that, due to geographical separation and difference in day and night conditions, this is practicable without interference.

The distances which high frequencies carry may be summed up (roughly) in Table I:[1]

TABLE I

		Average Distance	
		Day-Miles	Night-Miles
1500–2000	kc	100	250
2000–2250	"	125	300
2250–2750	"	150	500
2750–2850	"	150	550
2850–3500	"	250	600
3500–4000	"	300	1000
4000–5500	"	450	2500
5500–5700	"	500	3500
5700–6000	"	550	4000
6000–6150	"	600	5000 +
6150–6675	"	800	"
6675–7300	"	1000	"
7300–8550	"	1200	"
8550–8950	"	1500	"
8950–9500	"	1800	"

* Original Manuscript Received by the Institute, April 24, 1928. Revised Manuscript Received May 31, 1928.

† Technical Advisor to Federal Radio Commission.

[1] Author's Note: The distances are by no means fixed or constant, and only generally represent the situation, being dependent upon various factors such as different geographical locations.

9500–11000 "	2500	"
11000–11700 "	3500	"
11700–12300 "	4000	"
12300–12825 "	5000	"
12825–14000 "	5500	"
14000–23000 "	7000	Not useful at night

Frequencies above 6,000 kc have a silent zone due to the "skipping" of the wave, at distances varying up to hundreds of miles in the daytime and even thousands of miles at night, depending on the frequency from the transmitting station. This table is subject to deviation due to summer and winter, day and night, because of differences in the height of the Heaviside layer. Fig. 1 illustrates this.

The curves shown in Fig. 1 are plotted from the data received from the following sources: (a) American Telephone and Telegraph Company, (b) Radio Corporation of America, (c) General Electric Company, (d) U. S. Army, (d) Naval Research Laboratory, (f) actual operating data in the U. S. Navy. These curves

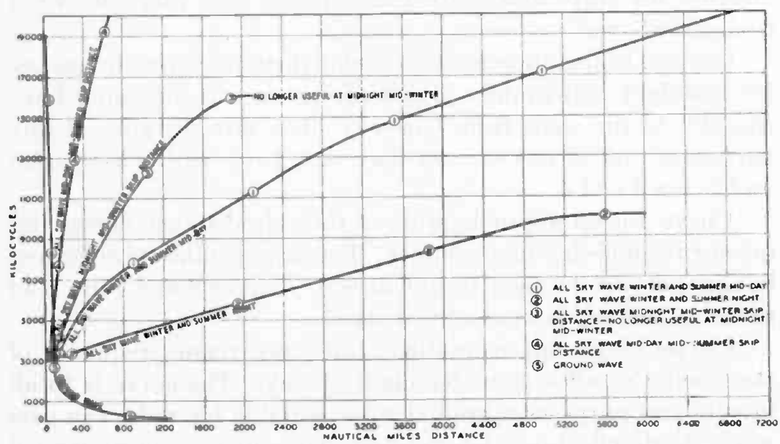

Fig. 1

are an approximation of the effective mid-day sky wave for all seasons, a night sky wave for all seasons, a skip distance curve for summer mid-day and winter midnight, and an all season ground wave for night and day. The curves are based on 1 kw in the antenna, CW telegraphy, using moderately sensitive receivers. Curve 1 shows the approximate distance versus frequency for an all season mid-day sky wave. Example: Given a distance 2200 miles find the frequency to produce a good readable signal at the receiving station. Vertically up from 2200 miles to Curve 1 and horizontally to the left read 11,400 kc. Given a certain frequency the distance will be found by the reverse process. The frequency is probably accurate to ±500 kc and the distance to ±200 miles, when in an east-west direction. The frequency and distance for north and south transmission may vary greatly from the above.

Curve 2 shows the approximate distance versus frequency for the night sky wave at all seasons. The curve is read in the same manner as explained above. To produce a good readable signal at a receiving station 2200 miles away when both the receiving and transmitting stations are in darkness, it is found that approximately 6000 kc will suffice. Also it is probable that any frequency between Curve 1 and Curve 2 at 2200 miles will suffice and the choice of frequency depends upon the experiment and the time of day. Greater distances are covered by the lower frequencies at night as shown by this curve. The frequency and distance for north and south transmission may vary somewhat from the above.

Curve 3 is an approximation of skip distance versus frequency for midnight mid-winter. The skip distance is measured horizontally to the right from Curve 5. The skip distance at any particular time of day or year may vary between the horizontal on Curves 3 and 4.

Curve 4 is an approximation of the skip distance versus frequency for mid-day mid-summer. The skip distance is measured horizontally to the right from Curve 5. Curves 3 and 4 are read in the same manner as described above.

Curve 5 is an approximation of distance versus frequency of the ground at all seasons for night or day. The curve is to all intents and purposes a ground wave suitable for radio compass work. Night effect may be expected. This curve as shown is good for approximate day and night transmission. An increase of power may be required of the lower frequencies for the required distance.

(2) In order to have a well-built structure on which to base allocations, not only for the present, but with a view to taking advantage of future advances in the science of radio, it is desirable that the frequency separation be considered from an international standpoint, and that the same constant of separation, together with the same midpoint for the first channel in each service band, be used by all nations. It would be a simple matter for the United States to allocate the high-frequency channels to

meet national requirements and conditions, but if we must dovetail in with the high-frequency channels of all nations we must use a system common to that of all other nations. What should the separation of the world's high-frequency channels be, and where should we locate the carrier wave for the first channel in each service band?

In most of the governmental services we can today require a 0.1 per cent channel separation for telegraphy, restricting the maximum permissible deviation of frequency from the fundamental to 0.05 per cent of the frequency used, insofar as it applies to apparatus now in use. For a small amount of apparatus under construction we can restrict the deviation to 0.03 per cent, which will permit of a channel separation of 0.06 per cent; and in our Naval Laboratory at Bellevue, D. C., there is a set in operation which has maintained its frequency within 0.01 per cent stability for several months. A few commercial stations in the United States can do as well, if not better.

But it will be several years before even the Navy will be able to equip its many stations with apparatus capable of 0.01 per cent stability, and at least two years before we will be equipped even to use 0.05 per cent separation. A parallel situation exists in the most up-to-date commercial organizations. The average of the less up-to-date commercial stations are not equipped to maintain a frequency stabilization of even 0.1 per cent today, and it will require at least a year before such stations can obtain, install, and learn to operate within an accuracy of 0.05 per cent, or within a 0.1 per cent channel.

The same is true in other countries. All nations, in the International Radio Convention, bound themselves to use modern equipment, but a reasonable time must be allowed to comply with this agreement. Some will be prompt in complying, others will be slow. If one nation uses a 0.2 per cent separation and another 0.5 per cent separation, on adjacent channels, the signals will interfere and business will be interrupted. Consequently, we must build a world-wide allocation structure, and all nations build together.

Exchange of correspondence between various leading technical experts of the world indicates that perhaps 0.2 per cent separation is the best we can hope for for a year or two, and that we may then divide each channel into two, making two channels where one formerly existed; still later on as nations use more accurate control we may again expect that a further halving will become possible. 0.1 per cent separation of channels after a year or two, with allocation of alternate channels for the present, appears a simple and logical solution. For telegraphy it should be practicable to allocate all the 0.1 per cent channels within a year or so. For telephony and facsimile transmission it may not be possible to fill in the alternate channels, at least for some years. Whatever we do, we must play safe, and not build up a structure which will permit us to drift into a situation parallel to the present broadcast situation, where too many stations have been licensed.

(3) The rules for separation and stability of frequency must be capable of enforcement. Otherwise interference will result. Even though stations might be equipped within a few weeks to maintain a frequency stability of 0.05 per cent, what guarantee is there that this will be maintained? The only assurance is through proper inspection by duly constituted authority. The Radio Inspectors do not yet have the necessary modern equipment, nor have they adequate personnel, to cope with such a refined separation, and it will take at least a year before the necessary facilities are available. And this will be equally true in all nations. The traffic police must be procured, must be trained, and must be equipped for the proper performance of their duties.

(4) Assuming that the world is, at the present moment, capable of using channels spaced 0.2 per cent apart without serious interference, an endeavor to bring about an agreement between nations on this point must be sought. This will take time, but it is hoped that this can be done, and that we have sufficient expectation of such agreement that we will be able to license stations without waiting for such agreement. If we take this chance in advance of international agreement, those that are licensed must risk a change in frequency later, if not the loss of such frequency.

(5) It seems desirable that each channel width assigned be the per cent separation multiplied by some mean frequency of a considerable band, rather than the per cent separation multiplied by the exact frequency of the individual channel. The former is simpler, and avoids fractions. I accordingly propose herewith certain rounded values of channel width throughout the high-frequency spectrum, for approximately 0.1 per cent separation. The channel widths for approximately 0.2 per cent separation would be twice the values given.

TABLE II

Frequencies (kc)	Channel width (kc)	Number of Channels	Maximum width (per cent)	Minimum width (per cent)
1500–2198	2	350	0.133	0.091
2200–3313	3	372	0.136	0.091
3316–4400	4	272	0.121	0.091
4405–5490	5	218	0.114	0.091
5495–8202.5	7.5	362	0.136	0.091
8210–10980	10	278	0.122	0.091
10990–16405	15	362	0.136	0.091
16420–21960	20	278	0.122	0.091
21980–23000 (on to 32810)	30	35	0.136	0.130

The frequencies given in Table II are the first and last assignable channel in each of the ranges of frequency. The plan is so arranged that the channel widths progress numerically throughout the entire spectrum without break or skip. With Table II the whole system of assignable frequencies can be built up by anyone, without the necessity for charts or further details.

(6) An analysis of the frequency bands specified in the International Radio Convention is desirable. As Table II shows, there are 2527 channels of the widths given (approximately 0.1 per cent) between 1500 and 23,000 kc. These are divided as follows:

Below 6000 kc,	568	channels in mobile, amateur and broadcast bands
	711	channels in fixed and shared fixed-mobile bands.
Total,	1279	
Above 6000 kc,	368	channels in mobile, amateur and broadcast bands
	880	channels in fixed and shared fixed-mobile bands.
Total,	1248	

Consider the bands assigned to fixed services. We have the following:

1715–2000	Shared with mobile and amateur services. Nothing available for fixed, as amateurs have priority after mobile services.
2000–2250	Shared with mobile services. Of national value for short distance (100 miles) work.
2750–2850	Fixed services.
2850–3500	Shared mobile and fixed services.
3500–4000	Shared mobile, fixed, and amateur. Nothing available to fixed services.
4000–5500	Shared mobile and fixed services.
5700–6000	Fixed services.
6675–7000	Fixed services.
7300–8200	Fixed services.
8550–8900	Shared mobile and fixed services.
8900–9500	Fixed services.
9600–11000	Fixed services.
11400–11700	Fixed services.
11900–12300	Fixed services.
12825–13350	Shared mobile and fixed services.
13350–14000	Fixed services.
14400–15100	Fixed services.
15350–16400	Fixed services.
17100–17750	Shared mobile and fixed services.
17800–21450	Fixed services.
22300–23000	Shared mobile and fixed services.

As shown above, there are a total of 880 channels of the widths given (approximately 0.1 per cent) above 6000 kc in the fixed and shared fixed-mobile bands. Over half of these channels are already in use; between 200 and 250 remain for assignment by all nations. For a basis of approximately 0.2 per cent wide channels, these figures would be cut in two.

The bands assigned to mobile services are the shared bands shown above plus the following:

1500–1715	Mobile services
2250–2750	" "
5500–5700	" "
6150–6675	" "
8200–8550	" "
11000–11400	" "
12300–12825	" "
16400–17100	" "
21550–22300	" "

There is a total of 398 channels available for mobile services at 0.1 per cent separation (alternate channels), of which more than 200 remaining channels are still available in the mobile bands, and only about 30 applications for mobile channels by United States interests, so there will be a little difficulty in finding channels for the applicants. Each mobile station will require at least a day channel and a night channel. From two to ten channels will have to be reserved for each of certain types of mobile services in these bands, for example: short-range portable stations for mining and oil-well investigations, for detecting criminals, for railway services, in the 2250–2750 kc band, and three or four radio-telephone channels for maritime uses with a similar number for use between aircraft and ground stations in each of various bands.

Broadcast Bands. These are as follows:

6000–6150
9500–9600
11700–11900
15100–15350
17750–17800
21450–21550

On the basis of 0.2 per cent separation there are 40 channels, of which 20 channels are available, to be divided between all nations. These bands were allotted by the International Radio Conference primarily for relay telephone broadcasting, or for broadcasting beyond the range of national broadcast networks. It will undoubtedly be more difficult, if at all possible, to increase the number of channels in these bands by lessening the separation in later years, because they will be used mostly for radio telephony.

It may be desirable to adopt a different channelling system for these bands, the 10 kc broadcast channel standard, or a multiple thereof, say 40 kc channels for the present. Owing to the limited number of channels available, these will probably have to be restricted to stations of maximum power, say 5 kw, (or greater), stations which can guarantee reception of high-class programs in foreign countries.

Amateur bands. These are as follows (plus shared bands shown under fixed service list):

7000–7300 kc	
14000–14400	
28000–30000	Amateurs and experimental
56000–60000	Amateurs and experimental

It is expected that the amateur and unreserved bands above 23,000 kilocycles will permit of pioneer experimental work by the amateurs, that they may develop the unknown. Possibly the amateurs will desire to experiment with television and picture transmission in one of their bands. The 1715–2000 band is allocated to mobile, fixed, and amateur service. It is believed desirable to allocate this band to the amateurs.

(7) First attention should be given to the mobile bands, as ships depend on radio and deserve first consideration. Fortunately, priority does not need to be considered within these bands now, as there are plenty of channels. For ships using frequency, one thing must be settled and that is, what should be the common calling frequency? Ships far apart, belonging to the same company, will undoubtedly use their working wave for inter-communication, but those of different companies will often wish to establish schedules, and it must be known in advance what will be the calling channel. There is a mobile band 5500–5700 which is just below the day skip-distance point. This seems a logical band to choose a tentative calling frequency from, and its second or third harmonic can be used when very long distance communication is desired.

High frequency will enable ships of the world to maintain a constant touch with headquarters, at reasonable cost, and this will reduce considerably the overhead expense of shipping.

(8) After the mobile bands, attention should be given to the fixed service bands. The channels, frequency less than 6000 kc, can wait for thorough consideration, as these will not interfere across the seas, and we can easily arrange with our neighboring

North American nations with regard to these channels. Perhaps we can require narrower channels rather earlier for these frequencies.

The channels above 6000 should be assigned without delay, so we can occupy our share of world channels, and have these duly registered in the International Bureau at an early date. The United States should occupy only a certain percentage of the total high-frequency channels, as these channels are for use by all nations. If we appropriated more than our reasonable share it would not make for good feeling between nations.

The channels above 6000 should first be allocated as clear channels, assigning adjacent channels to the same organizations when practicable. By so doing provision is made for later permitting the use of the "band" system, and it may become possible to permit some organizations to fill in the vacant alternate channels, and later again subdivide, sooner than other agencies which are not so progressive. And later, additional stations might be permitted to use some of the same channels on divided time basis and otherwise share frequencies as conditions make this possible. It will be practicable to use some of the high frequencies for day uses not possible at night, and to make special double uses of the so-called summer and winter day frequencies, to considerable advantage.

Also, what about keeping certain bands in harmonic relation? It will be an economic advantage to those who must pay for equipment, if the day and night channels they are to use are in harmonic relation. But this is not always practicable, owing to the fact that the bands are not all in equal harmonic relation. It can be done in most cases.

(9) The question of priority among applicants is most important in the fixed service bands. The following is one suggestion:

Fixed Service Bands.

1. Government—national defense (including coast guard).
2. Government—civil airways.
3. Emergency communication systems, for emergency use only (including provision for necessary testing).
4. Systems for communicating where landwire service impracticable or cannot be secured and maintained without *prohibitive* expense.
5. Trans-oceanic and intercontinental radio service communication systems open to general public service.

6. Certain important experimental and development work.
7. Private trans-oceanic and intercontinental radio communication for very important purposes of national interest, not well served by public service radio companies. (Certain of these may be considered of such importance as to take priority over some under priority No. 5 if no channels remain for allocation to priority No. 5.)
8. National (within the U. S.) radio communication, by radio companies, for public service in competition with wire lines.
9. National (within the U. S.) radio communication by non-radio public service companies, for limited uses by special interests, which could be handled by wire or by public service radio companies.

Another suggestion is to follow the above list, except that Priority No. 8 should be moved up to a place between Priorities No. 5 and No. 6; still another suggestion is to place the press agencies, handling news for all the public, ahead of Priority No. 5. Both suggestions have great merit, and are worthy of serious consideration.

One guiding principle should be that the channels above 6000 kc should be assigned for those who require them to work long distances (international) rather than short distances (national). For example, circuit New York to Japan should be given choice of frequency as compared with the circuit New York to London, whereas the latter should take priority ahead of New York to San Francisco. Considering this rule, together with the fact that there are not enough channels remaining to be allocated, it will be seen that most of those desiring circuits between cities within the United States will have to be satisfied with frequencies below 6000 kc.

It appears likely that there will not be enough channels to accommodate even all of the immediate requirements of the public service radio companies under Priority No. 5; therefore, there will be *considerable opposition* to suggested priority due to the desires of those in Priority No. 7 to obtain channels. The argument then becomes a question of whether the public service common carrier systems should have priority over certain very important private interests not in the public service business. There is much to be said on both sides.

Those who are in the public radio service communication business will say that they have risked their money in pioneering the establishment of radio systems, building up patents through expensive research, training their personnel, arranging their traffic agreements, all for use by the general public, and that if insufficient channels are available all should be assigned to the radio companies as they operate in the service of all the public. Some private interests (such as the press newsgathering organizations) will say that they have not been able to get the radio companies to provide for their needs, and that they will operate in the public interest just as much as the radio companies, if not more so, even though not open to general public service traffic, so they want to maintain their own radio services. The radio companies will reply that they have been so busily engaged in applying their rapid developments that they have not yet had time to satisfy everyone. Personally, I feel sympathetic with all interests, and believe as long as there is going to be competition between at least two great public service communication concerns, the best thing to do (considering that there are far too few channels available) may be to give these companies a large share of the channels in trust, if they demonstrate themselves to be in position to provide adequate service, let competition be their spur, and if the rates are not satisfactory, it may become a matter for regulation by the Interstate Commerce Commission. Or if the service is not adequate and satisfactory, the channels can be taken away from the radio companies and given over to special interests. However, it is a little too early to form a definite conclusion on this subject, and it will be seen that it requires serious consideration. There are, of course, exceptions to all rules, and it may be to the public interest to assign certain of the channels in Priority No. 5 to private interests operating for the benefit of all the public.

(10) Places must be found in the spectrum for other uses of radio. For example, where in the spectrum will television be assigned? For television, channels between 80 and 500 kc width will be required. How soon will television be so reasonably obtainable that the public will demand clear channels for the service? If the time is near at hand, should we not reserve a large space in the spectrum for television development work?

What is to become of the experimenters if all the channels are to be assigned for traffic? Most of the applications from "short-wave" experimenters are for a "broad band," 5000–20000 kc, or something similar. If a station is licensed to use a certain channel it is the duty of the Government to keep others clear of that channel during the term of his license, yet this would be impracticable if experimentation were permitted without restriction. For this reason, experimenters in the future will ordinarily have to be content with a few (not over six) channels, about equal distances apart in the spectrum, and get along as best they can in these bands. Of course, there are exceptions to all cases, and if the experimental work in new fields by suitably equipped experimenters is sufficiently important special experimental channels must be arranged for.

(11) The International Convention requires that modern apparatus be used. "Modern apparatus" must be construed to include limitation of harmonics from all (including broadcast) transmitters, otherwise traffic on high-frequency channels will be interrupted. The rules concerning specifications for apparatus must therefore be decided upon.

In conclusion, the problem of licensing stations to use high-frequency channels is a most difficult one, and the Federal Radio Commission will have much difficulty in building a satisfactory allocation structure to insure the best interest of the public.

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LONG-WAVE RADIO RECEIVING MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1927*

By

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THE monthly averages of the daylight signal intensities of a number of stations and the strength of the atmospheric disturbances, as measured in Washington, are shown in the following tables. Some of the transatlantic stations of the Radio Corporation of America situated at moderate distances from Washington, 250–700 km, have been added to the long-

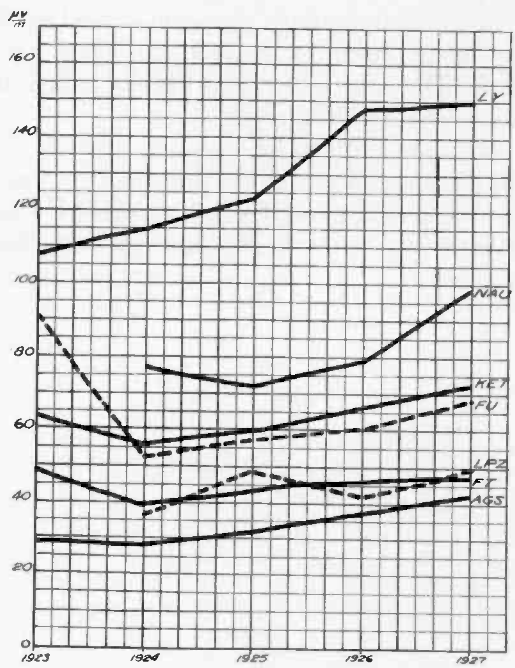

Fig. 1—Annual Average Signal, 10 A.M.

distance stations covered in former reports, since it has been found that signals from stations at such distances are especially useful for comparison with meteorological, solar and magnetic

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phenomena. The signals marked A.M. in the tables are received in Washington between 10 and 11 o'clock in the forenoon (E.S.T.) and represent transmission under daylight conditions along the whole wave path except in the case of the two stations, AGS and AGW, near Berlin, where for a period of about six weeks near the end of the year the sun sets slightly before 10 A.M. (E.S.T.). The P.M. signals of the tables, received in Washington between 3:00 and 4:00 o'clock in the afternoon, represent all

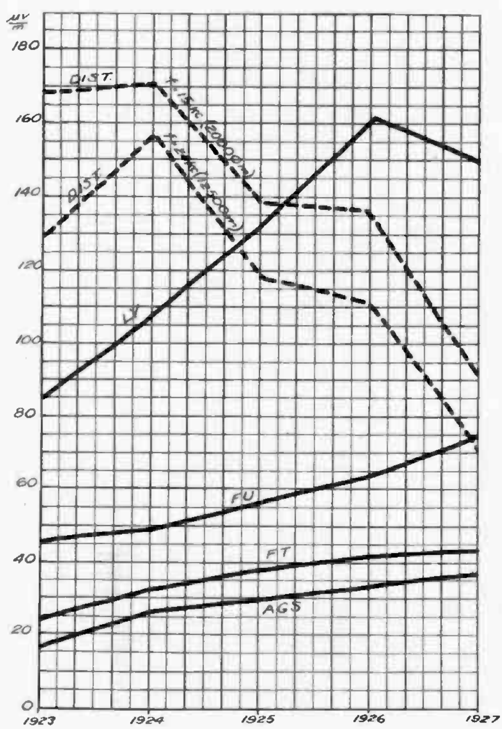

Fig. 2—Annual Average Signal and Atmospheric Disturbances, 3 P.M.

daylight transmission paths for the southern and western stations measured, and paths partly in darkness and partly in daylight for the European stations except for GBR (Rugby) and GBL (Leafield), which give all daylight transmission during the longest days of summer.

In examining the tables it will be noticed that despite the fact that from January to May 1927 the intensities of the distant stations fell for the most part below the 1926 values, the averages for the year of all stations except Bordeaux (LY) were above those for 1926. During June, signals were stronger than for any preceding June since regular measurements have been made at this Laboratory. The October values were also very high, the intensity of the signals received at about 10 A.M. from Nauen (AGS) being 67 per cent higher than in the same month of the preceding year. On October 14 the strongest daylight European signals ever measured in Washington were observed. Bordeaux

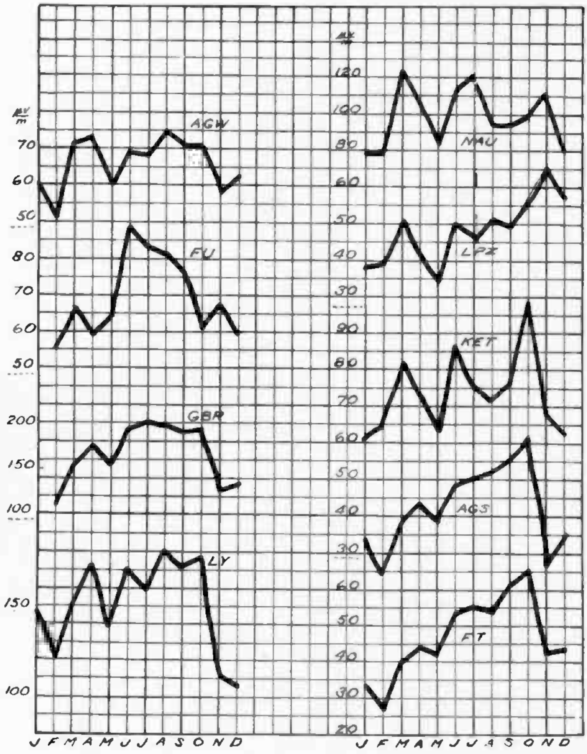

Fig. 3—Seasonal Variations, 1927, 10 A.M.

gave an increase of 227 per cent above the monthly average, Rugby (GBR) and Nauen (AGW) were both approximately 200 per cent above the average, while nearly all other stations both in the east-west and north-south directions were of unusual strength on this day. These extraordinary signals occurred two days after the very severe magnetic storm of October 12.

The atmospheric disturbances for the year have been very weak. During June the intensity of the afternoon disturbances was less than one half of the 1926 value. The weak disturbances of the summer were undoubtedly connected with the large number of cool days and small number of thunderstorms. There is also a very possible connection between the disturbance weakness and the present high solar activity.

In the figures, the curves of the annual values of signal intensity and atmospherics since 1923 which have been given in the more recent annual reports of the laboratory have been continued to include 1927.

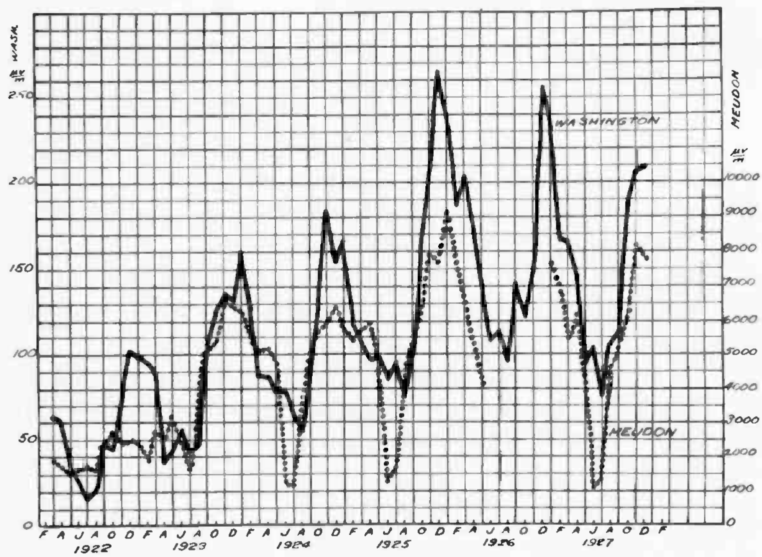

Fig. 4—Lafayette (LY) Average Signal at Washington and Meudon, 3 P.M.

Figs. 1 and 2 show the course of the annual averages of signals from a number of stations as received in Washington in the morning and in the afternoon since 1923. If we except Buenos Aires (LPZ)—and Cayey (NAU), which have been irregular, possibly on account of changes in transmitting current or antenna arrangement, and Bordeaux (LY) in 1927, all signals have increased regularly in intensity from 1924 to 1927 inclusive. The morning signals of Bordeaux have nearly the same observed strength in 1927 as in 1926, while the afternoon signals which have a transmission path partly in darkness have dropped perceptibly in 1927. This behavior of Bordeaux is perhaps due to the fact that the sunspot curve may have now reached its maximum which in the present cycle appears to be less sharp than the maximum in 1917. It now appears from the observations thus far taken in 1928 that the other long-wave stations are following the lead of Bordeaux and are also beginning to fall in strength.

The curves of the atmospheric disturbances in Fig. 2 show, in contrast with the increase in signal, a steady drop until in 1927 the average disturbance strength is only approximately half as great as in 1924.

Fig. 3 gives the seasonal signal variations of various stations for 1927. The autumn maxima usually shown in September by many stations are less definite than in 1926 and in some cases are shifted to October or November.

Fig. 4 continues the comparison of the monthly averages of the U.R.S.I. signals sent out by Bordeaux at 19:55 (7:55 P.M.) G.M.T. as received at Meudon near Paris and at Washington. The figure shows a marked drop in the December signal strength of 1927 from the high values of 1925 and 1926.[1]

The work on the relation of solar activity to radio transmission described in the report for 1926 has been continued and has been printed in another paper.[2]

The signal intensity recorder[3] and the atmospheric direction recorder mentioned in the last report are now in operation and some of the results obtained from them will be published in the near future.

TABLE I
TRANSMISSION DATA, 1927.

	Frequency f	Wavelength λ	Antenna Current I	Effective height h	Distances d km
LY,[4] Bordeaux	15.9	18,900	540	180	6160
FU, Ste. Assise, Paris	15.0	20,000	475	180	6200
FT, Ste. Assise, Paris	20.8	14,400	340	180	6200
AGW,[4] Nauen, Berlin	16.5	18,100	442	170	6650
AGS,[4] Nauen, Berlin	23.4	12,800	389	130	6650
GBR,[4] Rugby	16.1	18,600	600	185	5930
GBL,[4] Leafield	24.4	12,300	195	75	5900
LPZ, Monte Grande, Buenos Aires.	23.6	12,700	600	143	8300
LPV, Monte Grande, Buenos Aires.	17.0	17,600	585	143	8300
SPR, Rio de Janeiro	13.8	22,000	780	150	7800
KET,[4] Bolinas, San Francisco	22.9	13,100	640	51	3920
ICC, Coltano, Pisa	19.9	15,000	380	150	7100
NAU, Cayey, Porto Rico	33.8	8,870	150	120	2490

[4] Daily antenna current reported. Other antenna currents more or less uncertain.

[1] Author's note: Measurements were discontinued at Meudon during a part of 1926.

[2] PROC. I. R. E., 16, p. 166; 1928.

[3] PROC. I. R. E., 16, p. 666; 1928.

TABLE II

AVERAGE SIGNAL INTENSITY AND ATMOSPHERIC DISTURBANCES FOR LAFAYETTE (LY), RUGBY (GBR), STE. ASSISE (FU), NAUEN (AGW), MONTE GRANDE (LPV) AND RIO DE JANEIRO (SPR), IN MICROVOLTS PER METER.

	A.M.							P.M.					
1927	LY	GBR	FU	AGW	LPV	SPR	Dist.	LY	GBR	FU	AGW	SPR	Dist.
Jan.	147	—	—	60	34	46	26	231	297	97	82	31	37
Feb.	120	110	55	51	45	32	44	163	226	94	63	22	59
Mar.	150	152	66	71	43	34	37	162	182	76	72	27	53
Apr.	171	178	59	73	32	27	47	147	166	72	59	14	67
May	140	154	64	60	26	27	44	95	121	52	42	15	113
June	170	194	89	79	35	37	38	102	117	54	47	19	68
July	160	200	83	78	39	35	50	76	75	46	38	—	310
Aug.	180	198	82	75	34	32	44	105	128	56	51	—	173
Sept.	171	194	76	72	30	30	39	112	138	54	54	—	124
Oct.	174	197	61	72	36	—	31	188	204	89	74	—	44
Nov.	111	128	67	58	—	29	27	207	203	96	81	15	37
Dec.	109	136	60	62	—	32	25	208	230	109	91	—	26
Ave.	150	168	69	68	35	33	38	150	174	75	63	20	93

TABLE III

AVERAGE SIGNAL INTENSITY AND ATMOSPHERIC DISTURBANCES FOR COLTANO (ICC), STE. ASSISE (FT), BOLINAS (KET), NAUEN (AGS), MONTE GRANDE (LPZ) AND LEAFIELD (GBL) IN MICROVOLTS PER METER.

	A.M.							P.M.						
1927	ICC	FT	AGS	KET	LPZ	GBL	Dist.	ICC	FT	AGS	KET	LPZ	GBL	Dist.
Jan.	26	34	33	61	38	16	19	40	49	46	66	31	16	28
Feb.	27	27	25	64	39	10	32	35	35	31	54	29	12	44
Mar.	40	40	38	82	51	19	28	38	46	39	69	42	16	43
Apr.	42	44	43	72	41	21	35	24	33	28	50	25	11	47
May	38	43	39	63	34	21	36	20	25	22	47	17	15	90
June	51	54	48	86	50	24	30	23	28	23	54	24	14	56
July	51	55	50	75	46	26	43	—	24	26	43	26	13	230
Aug.	—	54	52	72	51	29	34	—	33	26	48	23	22	130
Sept.	—	62	55	76	50	28	30	—	39	32	54	—	—	93
Oct.	—	65	62	98	56	36	24	—	58	52	76	—	23	41
Nov.	—	42	26	68	66	22	20	—	64	45	75	—	20	30
Dec.	—	44	35	63	57	19	19	—	73	58	85	—	26	20
Ave.		47	42	73	48	23	29		42	36	60	27	17	71

TABLE IV

AVERAGE SIGNAL INTENSITY AND ATMOSPHERIC DISTURBANCES FOR CAYEY (NAU) IN MICROVOLTS PER METER.

	A.M.		P.M.	
1927	NAU	Dist.	NAU	Dist.
Jan.	79	12	63	15
Feb.	79	15	59	20
Mar.	124	15	88	21
Apr.	107	20	73	47
May	82	23	66	45
June	113	18	85	39
July	120	26	—	109
Aug.	94	18	61	85
Sept.	95	22	75	64
Oct.	97	14	97	24
Nov.	111	13	94	19
Dec.	80	13	79	12
Ave.	98	17	76	42

TABLE V

AVERAGE SIGNAL INTENSITY FOR ROCKY POINT, L. I. (WSS), MARION, MASS. (WSO), NEW BRUNSWICK, N. J. (WII) AND (WRT), IN MILLIVOLTS PER METER.

	A.M.				P.M.			
1927	WSS	WSO	WII	WRT	WSS	WSO	WII	WRT
Jan.	4.1	1.0	4.0	—	3.6	0.9	3.4	—
Feb.	3.5	—	3.1	—	3.4	—	3.1	—
Mar.	3.1	1.2	2.8	—	3.2	1.1	3.0	—
Apr.	3.1	1.1	2.3	—	3.1	1.0	2.6	—
May	2.7	0.9	2.2	—	2.8	0.9	2.4	—
June	3.0	1.1	2.5	2.9	3.1	1.0	2.6	2.9
July	2.6	1.1	2.3	2.5	2.5	0.9	2.2	2.4
Aug.	2.7	1.1	2.6	2.6	2.7	0.9	2.5	2.6
Sept.	2.7	1.2	2.4	2.9	2.7	1.1	2.7	3.0
Oct.	3.1	1.3	3.0	3.2	3.0	1.4	3.4	3.4
Nov.	3.9	—	4.2	4.0	3.5	1.4	3.8	3.8
Dec.	2.9	—	3.4	3.3	3.0	1.2	3.3	3.2
Ave.	3.1	1.1	2.9		3.1	1.1	2.9	

MONTHLY LIST OF REFERENCES TO CURRENT RADIO LITERATURE*

THIS is a monthly list of references prepared by the Bureau of Standards and is intended to cover the more important papers of interest to professional radio engineers which have recently appeared in periodicals, books, etc. The number at the left of each reference classifies the reference by subject, in accordance with the scheme presented in "A Decimal Classification of Radio Subjects—An Extension of the Dewey System," Bureau of Standards Circular No. 138, a copy of which may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C. The various articles listed below are not obtainable from the Government. The various periodicals can be secured from their publishers and can be consulted at large public libraries.

R000. Radio Communication

R007 Lemoine, S. Allocation of European broadcast wavelengths. *Experimental Wireless* (London), 5, pp. 386–96; July, 1928.

(Discusses basis of reallocation of frequencies to conform with Washington Conference.)

R100. Radio Principles

R113 Barfield, R. H. Woods and wireless. *Nature* (London), **121**, p. 908; June 9, 1928.

(Absorption of wireless waves by trees.)

R113 Hankey, H. A. Empire broadcasting—Results of the recent range tests conducted by the Wireless League. *Wireless World and Radio Rev.*, **22**, pp. 695–96; June 27, 1928.

(Observations made on 5SW broadcasts during a voyage to the Antipodes via So. Africa. Results showed good reception of this station on 24 meters.)

R113.4 Tuve, M. A. and Dahl, O. A transmitter modulating device for the study of the Kennelly-Heaviside layer by the echo method. Proc. I. R. E., **16**, pp. 794–98; June, 1928.

(A method of modulating a transmitting set by sudden pulses of plate current which occur in an unbalanced multivibrator circuit is described.)

R113.5 Pickard, G. W. Some correlations of radio reception with atmospheric temperature and pressure. Proc. I. R. E., **16**, pp. 765–72; June, 1928.

(Night reception and temperature at receiving station found to be directly related, maximum reception being associated with maximum temperatures. Temperature effect is local to the receiver. Correlation between night reception and pressure found.)

R113.7 Espenschied, L. Technical considerations involved in the allocation of short waves; frequencies between 1.5 and 30 megacycles. Proc. I. R. E., **16**, pp. 773–777; June, 1928.

(Chart given which shows approximate relation of optimum frequency to distance in short-wave radio transmission and the number of available channels based on present practice.)

* Original Manuscript Received by the Institute, July 14, 1928.

R120 Wilmotte, R. M. The distribution of current in a transmitting antenna. *Jnl.* I. E. E. (London), **66**, pp. 617–627; June, 1928.

(Investigation conducted to ascertain whether assumption usually made regarding distribution of current in antenna is an approximation to conditions obtained in practice. Current distribution of straight vertical antenna found by placing ammeters at various points along antenna. Ammeters placed in inside of cage type of antenna to determine effect of ammeters. Comparison of experimental and theoretical curves showed good agreement over range of 15 to 800 meters.)

R125.6 Chireix, M. Un systeme Francais d'emission a ondes courtes projetees. (A French system of the transmission of projected short waves.) *L'Onde Electrique*, **7**, pp. 169–195; May, 1928.

(Short-wave beam system installed by French government for communication with the colonies is described.)

R125.6 Yagi, H. Beam transmission of ultra short waves. Proc. I. R. E., **16**, pp. 715–41; June, 1928.

(Describes experiments at frequencies above 1500 kc. Curves given which show effect of ground and various types of antennas. Describes the use of the magnetron for the production of 12 cm waves. Circuit arrangements used with these tubes given.)

R127 The equivalent inductance and capacity of an aerial with inserted tuning coil or condenser. *Experimental Wireless* (London), **5**, pp. 357–60; July, 1928.

(Editorial pointing out error in treatment of subject by Palmer in "Wireless Principles and Practice." Mathematical discussion of the conditions.)

R134 Nelson, J. R. Detection with the four-electrode tube. Proc. I. R. E., **16**, pp. 822–39; June, 1928.

(Mathematical analysis of plate rectification and results applied to screen-grid tubes.)

R134.45 David, P. La super-reactions. (On Super-regeneration.) *L'Onde Electrique*, **7**, pp. 217–260; June, 1928.

(Principles of super-regeneration explained. Circuits given. Short bibliography included.)

R141 Bird, L. T. Reactance and admittance curves applied to tuned circuits with and without resistance. *Experimental Wireless* (London), **6**, pp. 371–377; July, 1928.

(Continuation of paper in June issue. Use of vector diagrams in study of circuits.)

R200. Radio Measurements and Standardization

R210 Worrall, R. H. and Owens, R. B. The Navy's primary frequency standard. Proc. I. R. E., **16**, pp. 778–793; June, 1928.

(Describes the method used to determine the fundamental frequency in terms of Naval observatory time to an accuracy of one part in 100,000.)

R214 Van Dyke, K. S. The piezo-electric resonator and its equivalent network. Proc. I. R. E., **16**, pp. 742–64; June, 1928.

(Theory of piezo-electric and mechanical behavior of quartz resonators. Rods which are excited lengthwise through transverse piezo-electric effects and those excited through longitudinal piezo-electric effects are described and equivalent circuits of these are given.)

R261 Turner, H. M. A compensated electron-tube voltmeter. Proc. I. R. E., **16**, pp. 799–801; June, 1928.

(Method described which eliminates source of error in use of electron-tube voltmeter due to changes in filament. The grid bias changes with filament current so the plate current is practically independent of filament current.)

R300. Radio Apparatus and Equipment

R330 Oatley, C. W. The use of a.c. for heating valve filaments. *Experimental Wireless* (London), **5**, pp. 380–384; July, 1928.

(Discusses problem of direct and indirect heating of electron-tube cathode by a.c., concludes that tubes with indirectly heated cathodes have definite place in detector stage but have no obvious advantages in amplifier stages.)

R342 Kirke, H. L. Microphone amplifiers and transformers. *Experimental Wireless* (London), 5, pp. 361–370; July, 1928.

(Design of microphone amplifiers and transformers for use in a broadcast transmitting system.)

R400. Radio Communication Systems

R431 Tubbs, E. A. System of combatting effects of static. *Experimental Wireless* (London), 5, pp. 378–379; July, 1928.

(Device used by Federal Telegraph Co. of California to increase reliability of service. McCaa system used.)

R500. Applications of Radio

R522 Kaufman, J. Radio's part in the *Southern Cross* flight. *Radio* (San Francisco), 10, pp. 18–20; July, 1928.

(Description of short-wave transmitting equipment used by the *Southern Cross* on its flight from San Francisco to Australia.)

R526.1 Gunn, R. Aircraft radio and navigation. *Jnl.* Franklin Institute, 205, pp. 849–63; June, 1928.

(Engineering features of aircraft radio and associated difficulties are discussed. Heterodyne beacon system described.)

R526.1 New radio beacon guides planes. *Science and Invention*, 16, p. 338; August, 1928.

(Work of Bureau of Standards on visual type of indicator, and beacon transmitting set at College Park, Md.)

Review of Current Literature*

Prepared by

STUART BALLANTINE

Boonton - - - - - - New Jersey

THE CHIREIX-MESNY DIRECTIVE ANTENNA FOR SHORT WAVES

UNDER this caption may be reviewed some interesting and novel developments which have lately been carried out in France in the field of directive radiation and reception at short wavelengths. Among the contributors to these developments the names of H. Chireix, Chief Engineer of the Societé Francaise Radioelectrique, and René Mesny, Professor of Hydrography in the French Navy, are conspicuous. I am indebted to conversations with Prof. Mesny for an account of this work and to the publications of Mesny and Chireix cited below.[1]

1. Fundamental Types of Directive Antenna Arrays. Fig. 1 illustrates an array which will be designated as of Type 1. Along the x axis is arranged a uniform series of vertical wires, regularly

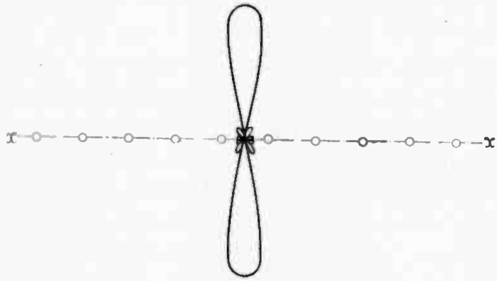

Fig. 1—Directivity Characteristic of Alignment of Type 1; Currents in Phase.

* Original Manuscript Received by the Institute, July 31, 1928.

[1] René Mesny: "Les Ondes Electriques Courtes," p. 76, (Paris, 1927); *L'Onde Electrique*, **6**, 181, 1927; *Compte rendu Académie des Sciences*, Report of Meeting of May 2, 1927, **1**, 1047; *Tejd. van Het. Neder Radiogenootschap*, **3**, Feb. 1927.

H. Chireix: *Radio-Electricité* (Sup. Tech.), **5**, 65, 1924; *L'Onde Electrique*, **5**, 237, 1926; **7**, 169, 1928; French Patent No. 216,757, filed Mar. 10, 1926.

spaced a distance of less than one wavelength, and carrying currents in the same phase. The radiation from this array is principally concentrated in two symmetrical beams along the y axis; and the acuity of these beams increases with the horizontal length of the array. The whole arrangement is equivalent to a hyperbolic reflector of infinite focus. If n represents the number of wires, and d their separation, the electric field intensity at a distant point may be expressed as

$$E = \text{Const.} \frac{\sin \dfrac{n\pi d}{\lambda} \sin \varphi}{\dfrac{n\pi d}{\lambda} \sin \varphi} \tag{1}$$

This has a grand maximum when $\varphi = \pi/2$ and other maxima of negligible importance. As to these small maxima it is perhaps of academic interest to note that Bellini has shown that they may be completely eliminated by making the currents in the separate wires proportional to the Binomial Coefficients; Mesny has also suggested that the most important of them may be reduced from 1/22 to 1/225 of the intensity of the principal maximum by graduating the currents according to the law: $\cos \pi x/2$.

As a second fundamental type of assembly consider Fig. 2. Here the antennas are situated along the y axis and their several currents are dephased by a constant angle corresponding to their angular separation d; viz. $\phi = 2\pi d/\lambda$. Thus if the separation is a quarter-wavelength the currents in adjacent wires will be in quadrature ($\phi = \pi/2$). When the separation is $\lambda/4$ the beam is directed along the y axis and has the remarkable property of being asymmetrical. For a given number of wires and total horizontal length of the alignment the Type 2 beam is broader than Type 1. One recognizes here immediately the close identity in the operation of this system and the "wave directors" of Uda and Yagi.[2]

Types 1 and 2 may be combined in a general two-dimensional array and it can be shown mathematically that the resulting directional characteristic is the product of the characteristics of the separate ranks and columns regarded as Type 1 and Type 2 systems. The outstanding property of curtains of Type 1 is the acuity of the beam; the outstanding property of Type 2 is the

[2] H. Yagi and S. Uda: *Proc.* Imp. Acad. 2, No. 2, 1926. Proc. I. R. E., 16, 715; June, 1928.

possibility of undirectional, or at least asymmetrical, radiation. In practice these types are combined to secure both results. A sufficient asymmetry of the beam is obtained by employing but two of the Type 2 elements, so that the antenna takes the form of two curtains of Type 1 separated by a fraction of a wavelength. The separation which secures the greatest asymmetry is $\lambda/4$,

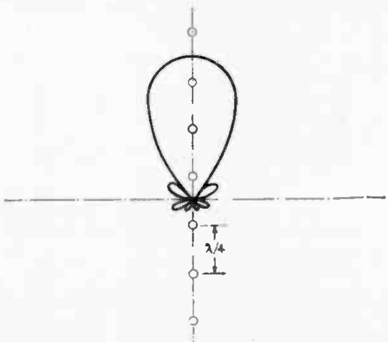

Fig. 2—Directivity of Alignment of Type 2; Currents in Adjacent Wires in Quadrature; Separation of Wires $=\lambda/4$.

the phase difference between the curtains being then adjusted to $\pi/2$. To secure an acute beam the horizontal dimensions of the curtains are made as large as possible, since the acuity has been shown by Mesny to be proportional to the ratio of this dimension to the wavelength. This applies to the normal or principal beam.

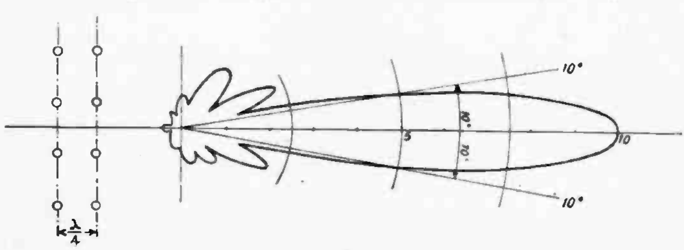

Fig. 3—Directivity of Franklin Projector of Eight Elements As Determined Experimentally at Short Distances (after Mesny).

The amplitude of the other maxima, which may be properly called "diffraction fringes," decreases as the number of vertical wires increases for a given total horizontal length.

2. Franklin System. Such a double curtain system as devised by C. S. Franklin of the English Marconi Company is shown in Fig. 3 together with its directivity characteristic.

3. Mesny's Arrangement in the Grecian Key-Pattern. To avoid some of the difficulties of the rather delicate adjustment of current amplitudes and phases in the wires of the preceding antennas and to simplify the problem of supplying power to them, Mesny has proposed a rather ingenious antenna arrangement comprising one wire bent into the form of the Grecian key-pattern. (Fig. 4.) The current distribution is

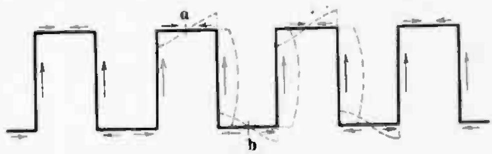

Fig. 4—Directive Antenna Arrangement of Mesny in the Grecian Key-pattern; Current Distribution Shown by Dotted Lines, Directions by Arrows. Distance $ab = \lambda/2$.

indicated by the dotted lines and the directions of the currents by the arrows. It will be noted that in the vertical sections the currents are all in the same direction. An important advantage which Mesny claims for this system is the uniformity of the flow of power, there being no significant reflection points throughout the length of the wire. The radiation in a vertical direction is negligible at large distances because the currents in each of the horizontal elements are in phase opposition and their effects cancel. The Grecian curtain may be excited in the middle or at the ends by means of separate generators, the currents of which

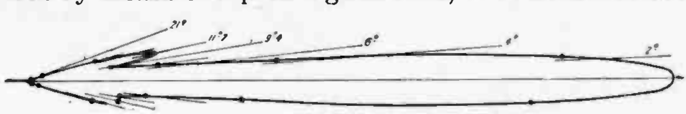

Fig. 5—Directivity of Grecian Curtain (Fig. 4) $\lambda = 5.87$ m. Symmetrical Left-hand Lobe of the Curve Has Been Omitted.

are automatically synchronized by taking advantage of the interlocking action of two oscillators. To secure an undirectional beam two Greek curtains may be mounted with a separation of $\lambda/4$ as in the Franklin system; one of these then acts as a "reflector."[3] The distribution of energy in a horizontal plane about such a Grecian antenna has been investigated experimentally by Mesny and is shown in Fig. 5.

[3] O. B. Blackwell (*Bell Tech. Journal*, April 1928, p. 179) has recently described a short-wave antenna used at Cliffwood, N. J. for trans-Atlantic telephony which appears to [me] to be precisely of this Grecian pattern type of Mesny, although it is not specifically ascribed to him.

4. Arrangement of Chireix. Another arrangement devised by H. Chireix and based upon the preceding is shown in Fig. 6. The wire is here arranged *en zig-zag* and the distribution of cur-

Fig. 6—Zig-zag Directive Arrangement of Chireix, a Modification of Fig. 4.

rent is shown by the dotted lines and the directions are indicated by the arrows. Each branch will be seen to comprise a half-wave element. The wire offers no change in characteristic impedance and the energy is readily propagated from one end to the other. The distribution diagram resembles in a general way that obtained with the Grecian curtain, but the amplitudes of the higher order maxima are advantageously smaller. The polarization of the electric field on the horizon is vertical.

A practical form of this antenna is shown in Fig. 7. This is obtained by a double reproduction of Fig. 6. Power is supplied by means of the wires *n m*. It will be observed that the wires *aa' bb' constitute effectively half-wave elements of the same sign in series,* thus increasing the radiated energy in the zenithal plane. The curtain may be extended vertically by repetitions of this structure, yielding the Chireix-Mesny (C. M.) antenna system illus-

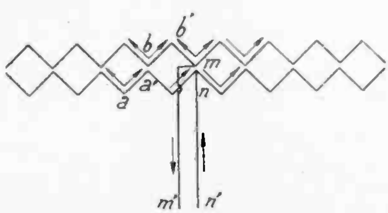

Fig. 7—Practical Form of the Chireix Antenna.

trated in Fig. 8, which comprises a total of 32 half-wave elements. In the complete antenna a similar curtain is usually employed as a reflector to render the beam asymmetrical. The total length of the curtain is 5 or 6 wavelengths and the beam obtained is less than 20 deg. in breadth. Power is supplied to the middle of each bay by the lines *nn* and *mm*, which are terminated in coupling impedances designed to minimize reflection.

It may be added that, according to Chireix, the adjustment of the system is not critical, but a variation of 200 kc, plus or minus, is tolerable at a wavelength of the order of 25 meters. This is more than sufficient to permit the simultaneous use of several frequencies with the same antenna.

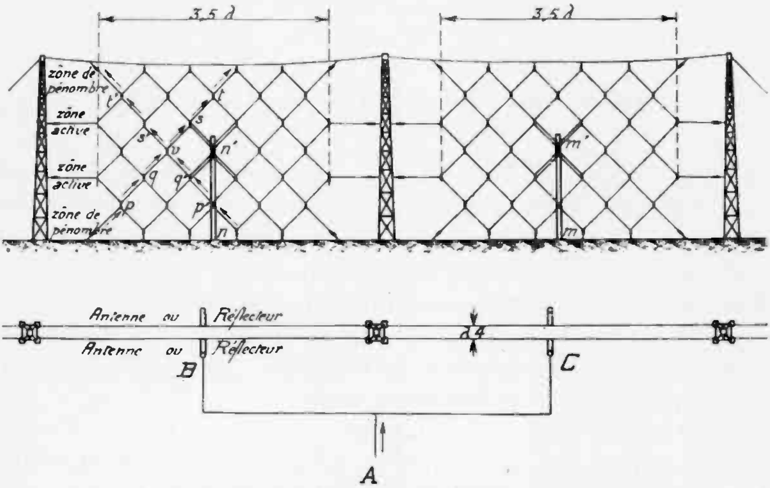

Fig. 8—Design for Complete Chireix-Mesny (C. M.) Projector of Two Bays Comprising 32 Half-wave Elements.

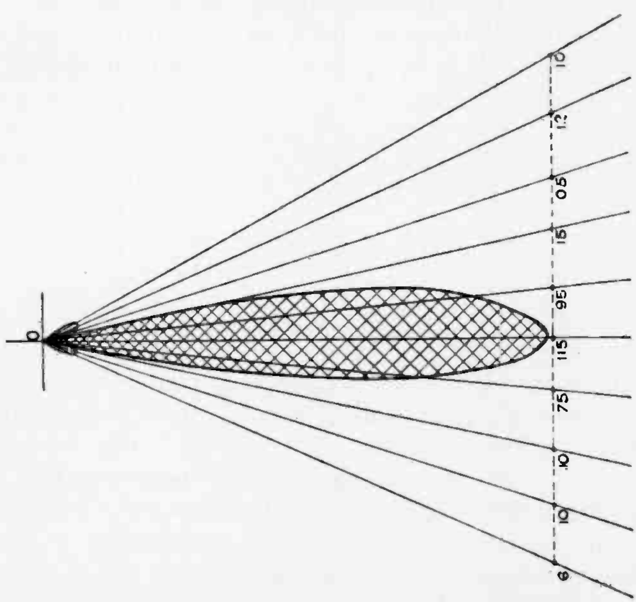

Fig. 9—Directivity of A Single Bay of the C. M. Projector Shown in Fig. 8, As Determined Experimentally at Short Distances (Chireix).

The directivity of a single bay of the C. M. antenna is shown in Fig. 9, which is an experimental curve obtained at *short* distances. The angular width of the beam is about 20 deg. With a reflector the two beams are in the ratio of 1.8 (at short distances). The direction of the beam may be reversed by exciting one or the other of the two antennas. This is an enormous advantage in practice in avoiding multiple ghost-signals due to complete transmission around the earth.

The C. M. antenna is also used for reception and is said to augment the power of the received signal 4 or 5 times over the reception with an ordinary antenna.

5. Installation of the C. M. Projector at Sainte-Assise, France. An installation of the C. M. antenna has been made by the Societé Francaise Radioelectrique in the short-wave station recently constructed by the Companie Radio-France for the French government. This apparently represents the first full-scale test of this system. A single bay of the antenna, as installed at Sainte-Assise, is shown in Fig. 10. This station (FW3) is in

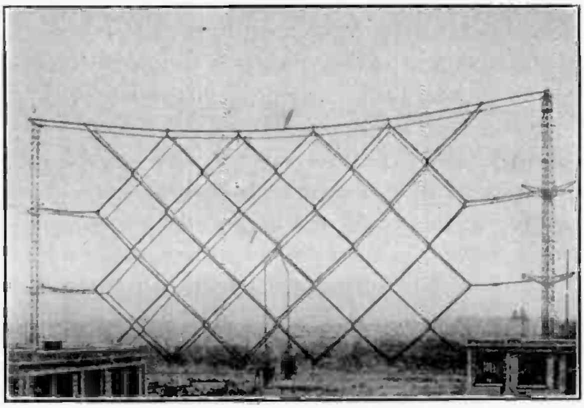

Fig. 10—View of Installation of a Single Bay C. M. Projector at Sainte-Assise, France.

regular communication with the Argentine and the Marconi beam station in Brazil. At the wavelength employed (15.5 m), operation with Buenos Aires is possible from 7 A.M. to 10 P.M. The results are considerably better than those obtained with ordinary non-directional systems and compare favorably with those of other beam systems.

BOOK REVIEWS

Wireless Principles and Practice, By L. S. Palmer. Published by Longmans, Green & Co., Ltd., London, 1928. 492 pages, 307 illustrations. Price $7.00.

This book in a very thorough manner deals with the apparatus and theory of present day radio. After a consideration of radio circuits and their calculation, the theory of the vacuum tube and its many applications are discussed. Chapters on Wireless Telephony and Directional Wireless close the book.

The completeness of the bibliographies at the end of each chapter make it highly desirable as a reference book to the technical man.

C. R. Hanna †

National Physical Laboratory Report for 1927. Issued by H. M. Stationery Office, Astral House, London W. C. 2. 264 pages paper bound. 7s. 6d.

A report of this nature, when prepared by so extensive a research organization as the National Physical Laboratory of England, in the form of a broad summary of the work undertaken by the Laboratory during 1927, can hardly be reviewed satisfactorily in a brief form. Many fields are covered, such as physics, electricity, metallurgy, aerodynamics, and several of the engineering fields; but in nearly all cases the technical details and other data concerning the various problems under advisement are omitted. In many cases, however, these facts can be obtained by referring to the official and other authorized papers which are listed, that have appeared during the year prepared by various members of the Laboratory staff.

A few sections of interest to radio engineers will be referred to; such as Sound, in which research on the acoustics of buildings, effect of partitions, the measurement of the absorbing power of various materials, the absolute measurement of sound intensity, and other acoustical determinations are outlined.

The international comparison of Radio Frequency Standards during the year by means of piezo oscillators (transported to England by the Bureau of Standards) is mentioned. An interest-

† Research Laboratory, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

ing method is outlined which was developed for the investigation of modes of vibration of flat quartz crystals, utilizing the principle of optical interference. The upper electrode is made somewhat transparent by utilizing a fine copper gauze which has been flattened and partially dissolved in acid. Above this a plate of glass (optically plane) is supported, the spacing being carefully regulated to produce interference bands when viewed with the proper light, when the crystal is not excited. When oscillating the spacing of course varies and the bands become blurred or disappear.

The radio section outlines the research being carried out on propagation of waves, directional wireless, interference from transmitting stations, solar eclipse of June 29, 1927, and rotating beacons. For the results of the very extensive tests on errors in direction finding the reader is referred to special report No. 5–1927, by R. L. Smith-Rose.

A cathode-ray oscillograph circuit for measuring wave form at radio frequencies and for other routine tests has been developed, details of which are included in the report. Measurements on a double detection receiver, the circuit for a long-wave time receiver, and the study of current distribution in antenna systems, and details of a short-wave transmitter complete this section. The latter item has a power of 200 watts and covers a range of from 5 to 30 meters. The photograph and circuit details indicate that the push-pull type of circuit, familiar in longer wave oscillators, can be adapted to the 5-meter band. A novel method of modulating this system is shown, in which the plate circuit of a modulator tube is coupled inductively to a coil in the high-voltage supply lead of the oscillator tubes. The modulated note is derived by audio-frequency tuning in the grid circuit, with keying accomplished by shorting out a small inductance coupled to the grid coil (presumably of the modulator circuit).

This review necessarily must omit many items referred to, many of which often consist of but a few sentences.

R. R. Batcher†

† Decatur Manufacturing Co., Inc., Brooklyn, New York.

APPLICATIONS FOR MEMBERSHIP

Applications for transfer or election to the various grades of membership have been received from the persons listed below, and have been acted upon by the Committee on Admissions. Members objecting to transfer or election of any of these applicants should communicate with the Secretary on or before September 31, 1928. These applications will be considered by the Board of Direction of the Institute at its October 3rd meeting.

For Transfer to the Fellow grade

Dist. of Columbia	Washington, Navy Department	Hooper, S. C.
Massachusetts	Cambridge, Harvard University	Kennelly, Arthur E.
New York	Schenectady	Rice, Chester W.

For Election to the Fellow grade

Dist. of Columbia	Anacostia, Naval Research Labs	Wheeler, Lynde P.

For Transfer to the Member grade

New Jersey	New Brunswick, P. O. Box 392	Cumming, Kenneth N.
New York	Hollis, 100-23 198 St.	Hotopp, Alfred H., Jr.

For Election to the Member grade

Illinois	Chicago, 623 S. Wabash Ave.	Smith, K. R.
Maryland	Chevy Chase, 6619 Summit Ave.	Walls, H. J.

For Election to the Associate grade

California	Fullerton, 113 E. Commonwealth	Finseth, E. B.
	Los Angeles, 6019 S. Broadway	Newman, William H.
	Monterey Park, 1012 E. Columbia St.	Sanmann, Edgar J.
	San Diego, 4741 32nd St.	Wright, Robert E.
	San Francisco, 511 Matson Bldg.	Attmore, William B.
	San Francisco, 245 Market St.	Kellogg, Richard B.
	West Hollywood, 871 Hilldale St.	Threlkeld, Howard M.
Colorado	Hereford	Nichols, Fred A.
	Pueblo, 2409 Pine St.	Glasscock, Glen R.
Connecticut	Wilson, 8 Garden Street	Appleby, Bertie
Delaware	Wilmington, 2303 Franklin St.	Boylan, Brandt
Dist. of Columbia	Washington, Federal Radio Commission	Blackwell, G. C.
Georgia	Atlanta, 366 Augusta Ave.	Walker, Joseph R.
Illinois	Chicago, 2641 S. Michigan Ave.	Doyel, Lee C.
	Chicago, 3100 N. Harding Ave.	Kobberup, J.
	Chicago, 5042 W. Superior St.	Remde, J.
	Chicago, 3843 N. Ridgeway Ave.	Sorensen, Carl P.
	Downers Grove, 720 Maple Ave.	Johnson, Arthur R.
Massachusetts	Boston, 332 A Street	Baird, Hollis S.
	Chatham, Radio Marine Corp. of Amer.	Weik, Adolf L.
	Concord	Hall, Henry D.
	East Springfield, 26 Prentice St.	Hurff, Jos. L.
	Lowell, 31 Princeton St.	Morton, Clarence F.
	Springfield, 491 Wilbraham Rd.	Der Bedrossyan, Mark
Michigan	Lapeer, Drawer A.	Margraf, Frank J.
New Jersey	Camden, Victor Talking Machine Co.	Cooley, Elihu H.
	Hoboken, Cooper Hewitt Elec. Co.	Dana, David W.
	Hoboken, 624 Washington St.	Izzo, Anthony
	Netcong, P. O. Box 393	Mack, Paul
New York	Brooklyn, 1536 E. 54th St.	Abraham, Irving
	Brooklyn, Y. M. C. A. Hanson Place	Donner, Louis F.
	Brooklyn, 654 East 23rd St.	Stobbe, John A.
	Buffalo, 225 Massachusetts Ave.	Pfleegor, Carroll M.
	Buffalo, 572 Elmwood Ave.	Vanacore, Thomas
	New York City, 66 Broad St.	Beltz, Willis H.
	New York City, 237 W. 100th St.	Jones, Dramin D.
	New York City, 463 West Street	Koerner, Allan M.
	New York City, 1054 Grant Av. Bronx	Siegal, Jos A.
North Carolina	Charlotte, c/o Radio Sta. WBT	Callahan, Thomas G.
	Charlotte, c/o Radio Sta. WBT	Reid, Ralph J.
	Gastonia, c/o A. Kirby & Co.	Jenkins, Russell A.
	Gastonia, 413 Broad St.	Morris, Robert S.
Ohio	Cleveland, 15305 Huntmere Ave.	Melrose, James W.
Oregon	Portland, Reed College, Physics Dept.	O'Day, Marcus

Pennsylvania	Philadelphia, 1603 Ellsworth St.	Caporate, Peter
	Pittsburgh, 2012 Noble St.	Bricker, James O.
	Pittsburgh, 328 Stratford Ave.	Wallace, H. E.
	Wilkinsburg, 442 Franklin Ave.	Haller, G. L.
Tennessee	Athens, 12 Euclid Ave.	Knight, Gaylord A.
Chile	Valparaiso, 98th Tubildad St.	Basaure, Auro
China	Tientsin, 10 Recreation Rd.	Chen, Ying-Chien
England	Dorset, Long Crickel, Wienborne	Harris, R.
	Essex, 11 Argyll Rd. Westcliff-on-Sea	White, Thomas G.
	Gloucester, 29 Lannett Rd.	Myers, Geo. T.
Japan	Tokyo-Fu, Electro Technical Lab.	Iinuma, H.
	Tokyo, Electro Technical Lab.	Matsumura, Sadao
	Kumamotoshi, c/o Shimizu Hosojo	Shimayama, Tsurno
Scotland	Glasgow, 105 Douglas St.	Carnie, Ben

For Election to the Junior grade

Massachusetts	Marion, c/o R. C. A.	Carson, Jos.
Minnesota	Mapleton	Norgrant, Lawrence A.
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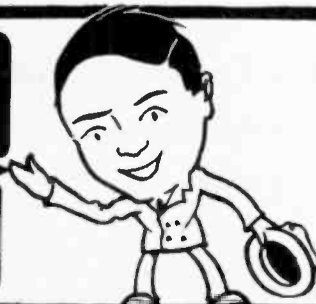
Pennsylvania	Philadelphia, 1533 Pine St.	Gilson, Walter E.
Texas	Amarillo, Route 3, Box 99-B	Reville, T. A., Jr.

CLEVELAND ACME OHIO



HERE THEY ARE

ACME'S SUPER-LINE OF RADIO PRODUCTS

as announced at the

R.M.A. Exposition

A great range of voltage is available with ACME'S Dry "B" Power Unit through the use of a 12,000 ohm voltage divider. It delivers voltage at 22½, 45, 67, 90, 135 and 180.

ACME's Dry "BC" Power Unit delivers both "B" and "C" current to meet the requirements of your set.

The ACME ABC-4 and ABC-5 convert A.C. operated sets to D.C. operation. Bring your old set up-to-date.

The Acme Universal Dry "A" Power Unit, takes raw A.C. current and delivers smooth D.C. Current at the proper voltage for your set. This unit will give you real satisfaction because its built right.

Send for Bulletin 99 on New ACME A.C. Receiver.

THE ACME ELECTRIC AND MFG. CO.

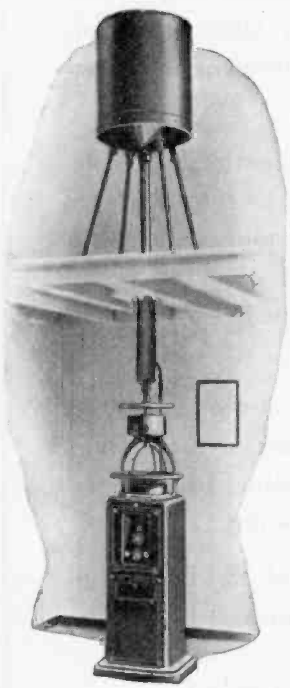
1439 Hamilton Avenue Cleveland, Ohio

Member R.M.A. Established 1917

Representatives in all principal cities.

The new Kolster Radio Compass provides

Greater Safety—
Visual Bearings—
Simple, Positive Operation



From its aluminum pedestal to the new enclosed loop, the new Kolster Radio Compass [Type AM-4490] embodies every improvement radio science has to offer. The insulated cylindrical housing of the loop affords complete protection against wind, ice, snow, and spray. A tiny lamp flashes the signals of nearby stations. While for long-distance bearings, a Kolster eight-tube receiver with a new circuit especially designed for radio compass work provides the maximum of selectivity and sensitiveness.

No knowledge of radio is necessary to operate the Kolster Radio Compass. It is built for the navigator. The positive unidirectional indicator gives instantaneous readings without guesswork or computation. A new and improved Kolster automatic compensator corrects all natural errors, and makes *direct* readings absolutely accurate.

Kolster Radio is also setting new standards of performance in broadcast receiving sets for the home.

KOLSTER RADIO CORPORATION

200 Mt. Pleasant Avenue
Newark, N. J.

FASTER PRODUCTION—
BETTER QUALITY—
LOWER COST—

Aluminum Die Cast Loud Speaker Case made for Farrand Manufacturing Company, Inc., Long Island City, N. Y.

Proven Uses for Aluminum Die Castings in the Radio Industry:

Cabinets and Loud Speaker Frames, Bases and Housings, Chasses, Condenser Frames and Cradles, Drum Dials, etc.

ADVANTAGES: Light Weight combined with Strength, Speed and Economy. A minimum cost for machining and assembling in your plant.

We urge you to call upon us for a Die Casting Specialist who can give you practical and engineering data along with helpful suggestions on your problems.

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DIE CASTINGS
For Strength, Lightness, Economy

TEMPLE

The name TEMPLE and its Compelling Significance

THE name TEMPLE is recognized wherever radio exists as perfection in speaker design and construction. And herein lies a tale of an organization that has earned the name of being "Leaders in Speaker Design." An exacting standard of measurement—an organization that is unequalled anywhere for its laboratory and manufacturing facilities, that is why TEMPLE is synonymous with quality.

The TEMPLE laboratory staff, headed by Prof. Paul G. Andres, consists of nine graduate engineers. These men are constantly at work developing reproducers worthy of the TEMPLE name. TEMPLE speakers, therefore, are not the result of mere ideas, but of careful and painstaking research in an electro-acoustical laboratory that is second to none in the country.

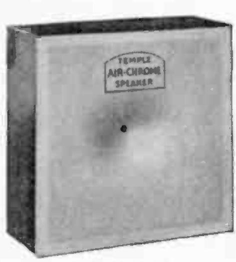
TEMPLE speakers are available to manufacturers in two types—the famous TEMPLE Air Column and the new and sensational TEMPLE Air Chrome. Both are outstanding for their faithful reproduction, response to all frequencies and ability for handling tremendous volume without distortion. They may be had in a variety of models that will meet every dimension and cabinet requirement for size.

Model 150
U. S. Pats. Pend.

Air Column Models

Model 150—The circular type has a center line air column length of 60". This is a correct mathematical exponential design making for maximum response and true brilliancy in the entire audible range. $11\frac{1}{2}$" diameter, $7\frac{1}{2}$" deep and weighs but $6\frac{1}{2}$ lbs. without unit.

Model 180—The larger circular model. Similar in design to Model 150, but larger. It has a center line air column length of 75", is 18" in diameter, $11\frac{1}{2}$" deep and weighs 36 lbs.



Model K
U. S. Pat. No. 1,672,796

Air Chrome Models

Model Z—A small rectangular model. Wonderful in tone—small in size. Size $9\frac{3}{4}$"x21", depth 5". Weight 4 lbs.

Model R—A small rectangular model. Size 9"x24". Weight 4 lbs.

Model S—A small rectangular model. Size $9\frac{5}{8}$"x$18\frac{5}{8}$". Weight 4 lbs.

Model F—The oblong model. May be installed either in an upright position or horizontally. Size 18"23", depth $8\frac{1}{2}$", weight 6 lbs.

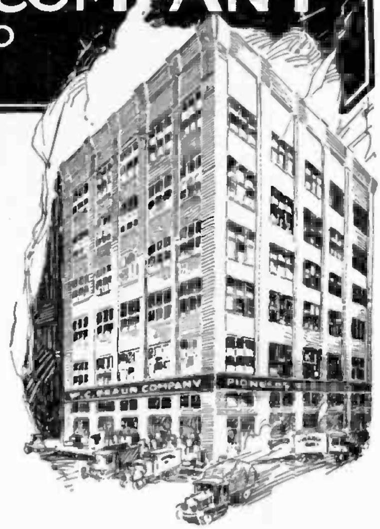
Model K—The small square model. Size 14"x14", depth 7", weight $4\frac{1}{2}$ lbs.

Write for complete information.

TEMPLE, *Incorporated*
1935 So. Western Ave. Chicago, U. S. A.

LEADERS IN SPEAKER DESIGN

W.C. BRAUN COMPANY
WHOLESALE RADIO HEADQUARTERS



Official Distributors for Leading Radio Products

AS the world's largest distributors, jobbers and wholesalers of a varied line of radio products, the W. C. Braun Co. offers to manufacturers, dealers and custom set builders, a most useful and necessary service.

For the dealer and custom set builder we furnish a quick, easy, convenient and economical means of securing any merchandise desired on instant notice by letter, wire or in person. To be able to secure such service, all under one roof, without going to the trouble of buying from a dozen or a hundred different sources, certainly is a service that is well worth while to the manufacturer as well as to the Radio Trade.

Selections—Variety—Service

The list of well-known radio lines represented by us includes practically all the famous names in the radio industry. Besides carrying large selections of varied lines of products of leading parts, equipment and accessory manufacturers, we distribute well-known lines of radio sets and co-operate with our dealers in advertising, window and store displays and in furnishing proper sales aids to insure successful business. In the small-town field as well as in larger radio centers, Braun service means much to the dealer and professional radio man.

Headquarters for Custom Set Builders

We are headquarters for the parts of the country's leading parts manufacturers' products, used in the leading circuits. Parts and supplies for any published radio circuit, whether short wave or broadcast, are immediately available from our stock.

Manufacturers desiring a distributing outlet furnishing world-wide service, are invited to take up their problems with us. Dealers, custom set builders and engineers will find here an organization keyed to fill their needs promptly and efficiently and a request on their letterhead will bring a copy of the Braun's Radio Buyers' Guide —the bible of the radio industry.

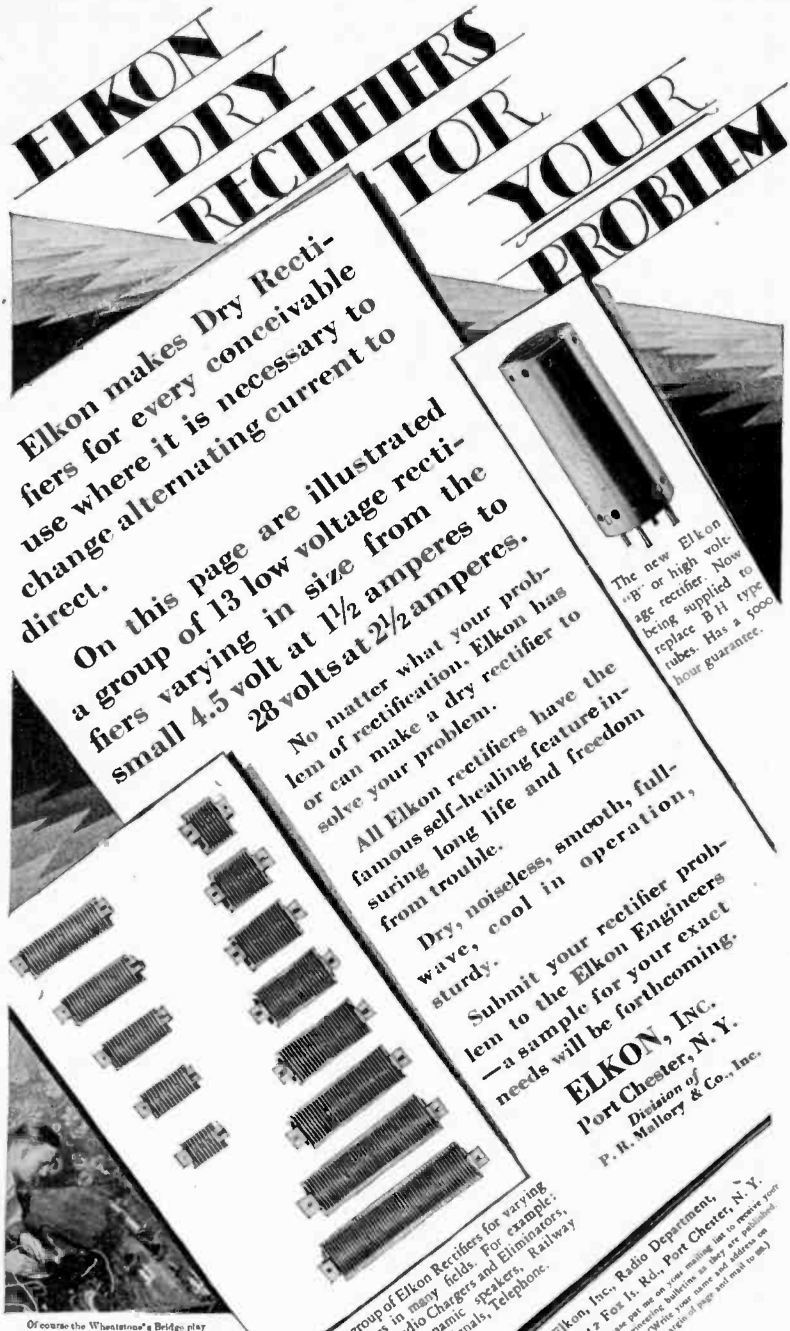
W. C. BRAUN COMPANY

Pioneers in Radio

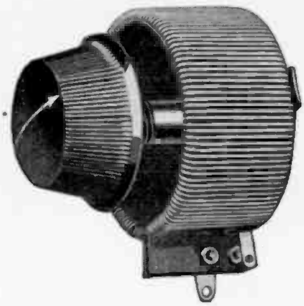
600 W. Randolph St.

CHICAGO

ILLINOIS


ELKON DRY RECTIFIERS FOR YOUR PROBLEM
Elkon makes Dry Recti- fiers for every conceivable use where it is necessary to change alternating current to direct.
On this page are illustrated a group of 13 low voltage recti- fiers varying in size from the small 4.5 volt at 1½ amperes to 28 volts at 2½ amperes.
No matter what your prob- lem of rectification, Elkon has or can make a dry rectifier to solve your problem.
All Elkon rectifiers have the famous self-healing feature in- suring long life and freedom from trouble.
Dry, noiseless, smooth, full- wave, cool in operation, sturdy.
Submit your rectifier prob- lem to the Elkon Engineers —a sample for your exact needs will be forthcoming.
ELKON, INC.
Port Chester, N. Y.
Division of
P. R. Mallory & Co., Inc.
The new Elkon "B" or high volt- age rectifier. Now being supplied to replace B H type tubes. Has a 5000 hour guarantee.
A group of Elkon Rectifiers for varying uses in many fields. For example: Radio Chargers and Eliminators, dynamic speakers, Railway Signals, Telephone.
Of course the Wheatstone's Bridge play its part in the Research Laboratory.
Elkon, Inc., Radio Department, 112 Fox Is. Rd., Port Chester, N. Y.
Please put me on your mailing list to receive your engineering bulletins as they are published. (Write your name and address on margin of page and mail to us.)

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*



Giant Power Rheostat

SMALL IN DIAMETER, but large in capacity, this rheostat will safely carry any power load of 70 watts. Constructed of heat proof materials throughout. There is no fibre to warp or burn out. Wire is wound on a steel core insulated with asbestos. Extra wide core assures large area for quick heat dissipation.

This unit is ideal for primary control of "AC" receivers or "A" Power Units. It will keep the line at a constant workable average, keeping the secondary output well within rated limits. These units connected in series across the output of a Rectifier and Filter system for "B" Power will provide all necessary voltage taps.

These units can be used in any power circuit position without any danger of burning out—the capacity is only limited by the capacity of the wire.

Manufactured with two or three terminals. Diameter 2″, depth 1¼″. Write for new booklet on "Volume Controls and Voltage Controls—their use."

Centralab

CRL

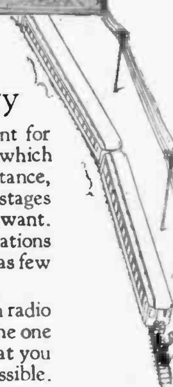
CENTRAL RADIO LABORATORIES

16 KEEFE AVENUE, MILWAUKEE

A CENTRALAB CONTROL IMPROVES THE SET

AmerTran Push-Pull Amplifier—complete 2 stage audio amplifier. First stage AmerTran Push-Pull for two power Tubes. Choice of standard amplifier or UX 227 AC for 1st stage and two 171 or two 210 power tubes for second stage. Price, east of Rockies-less tubes-**$60.00**

AmerTran ABC Hi-Power Box—500 volts DC plate voltage, current up to 110 ma; AC filament current for rectifier, power tubes and sufficient 226 and 227 AC Tubes for any set. Adjustable bias voltages for all tubes. Price, east of Rockies—less tubes—**$95.00**



The DeWitt Clinton would have a hard Job Pulling the 20th Century

HOW ridiculous it would be for the old wood burning De Witt Clinton to try to pull the 10 car sections of the 20th Century on its roaring route between New York and Chicago.

And to the experienced radio man it is just as ridiculous to continue to use antiquated amplifiers and power supplies.

The Companion units, The AmerTran ABC Hi-Power Box and Push-Pull Power Amplifier hooked on to your tuner will give you a set which is beyond compare in tone and one which most likely will be satisfactory as to station selection.

If you need a new tuner—build the tuner which will give you what you want for the particular locality in which you live. If you like distance, put in sufficient radio stages to give you what you want. If you like the local stations only build a tuner with as few tubes as possible.

Tone is everything in radio—the best radio set is the one which will give you what you want with the best possible.

Only a demonstration will do justice to what we believe is the finest development in audio amplification. Send the coupon today for further information about these remarkable units for perfect reproduction. No obligation, of course, but you owe it to yourself to hear what can be accomplished in tone quality, today.

AMERTRAN
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Transformer Manufacturers for over 28 years

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☐ Kindly send complete information on the AmerTran Push-Pull Amplifier and ABC Hi-Power Box.

Name..

Address..

City........................ State..................

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6.	The Inverted Vacuum Tube, A Voltage-Reducing Power Amplifier	F. E. Terman
8.	The Measurement of Choke Coil Inductance	C. A. Wright & F. T. Bowditch
9.	Radio Communication	Guglielmo Marconi
10.	On Round the World Signals	E. O. Hulburt
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JEWELL

Pattern No. 199 A.C.-D.C. Radio Set Analyzer

When it Comes to Service

When it comes to service it is quite likely that you will have to look a long time before finding a service instrument that so thoroughly fills the requirements for radio service equipment as does the Jewell Pattern No. 199 A.C.-D.C. Radio Set Analyzer.

This set was designed to take care of the service needs of the many new A.C. operated radio sets as well as those of the battery operated type. Features that have made it a favorite with experienced radio service men are given below:

Easily portable leather covered case with removable cover.
Five prong plug with four prong adapter.
Four reading A.C. Voltmeter 0-4-8-16-160 volts.
Six reading D.C. Volt-milliammeter 0-7.5-75-300-600 volts and 0-15-150 milliamperes.
Accurate tube test.
Positive, silver contact push button switches for taking readings.
New Cathode voltage test.
All ranges brought to binding posts for continuity tests.

These features are all described in descriptive circular No. 2002, which tells in detail all about this set analyzer. Write for a copy.

"28 Years Making Good Instruments"

Jewell Electrical Instrument Co.

1650 Walnut St., Chicago

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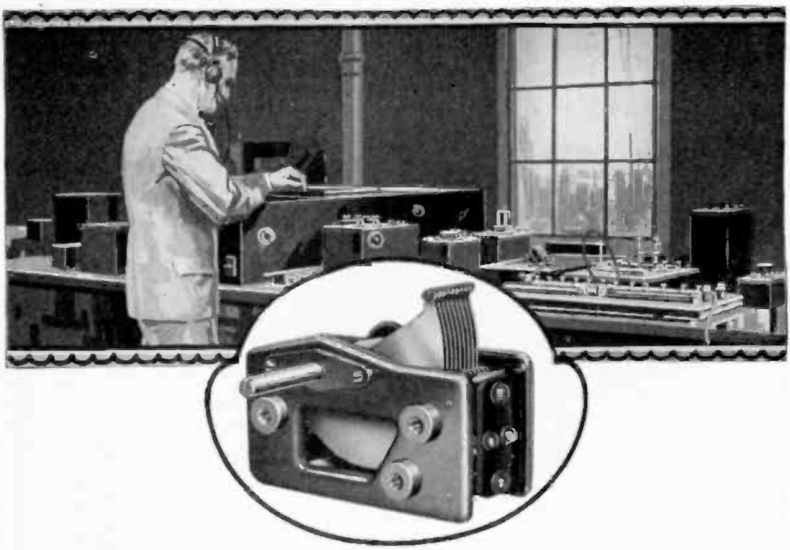
R A D I O   P A R T S



THOSE concerns who contract with Scovill for the manufacture of radio parts enjoy distinct advantages. Not only do they receive parts of superb quality and careful workmanship, but they have recourse to the valuable development work constantly being undertaken by the Scovill research department.

All Scovill condensers are made under the Scovill owned Lowenstein Patent No. 1,258,423, dated March 5, 1918. The following concerns have been licensed to manufacture under this patent.

HAMMARLUND MANUFACTURING COMPANY, *New York City*
GENERAL RADIO COMPANY, *Cambridge, Mass.*
THOMPSON-LEVERING COMPANY, *Philadelphia, Pa.*
PILOT ELECTRIC MFG. COMPANY, INC., *Brooklyn, N.Y.*
AMERICAN SPECIALTY COMPANY, *Bridgeport, Conn.*

Scovill means SERVICE to all who require parts or finished products of metal. Great factories equipped with the last word in laboratories, and modern machinery manned by skilled workmen, are at your disposal. Phone the nearest Scovill office.

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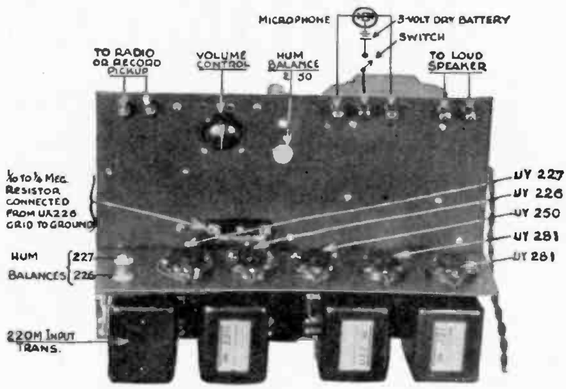
Member, Copper and Brass Research Association

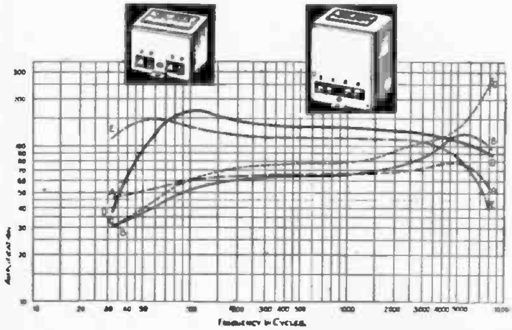
Public Address Amplification

Type 685 Public Address Unipac



The 685 Unipac is a high-grade 3-stage audio amplifier, operated from any 105 to 120 volt 60-cycle lighting socket. It employs 1-UY227, 1-UX226, 1-UX250 and 2-UX281 tubes. Used with up to twelve horns, it insures adequate coverage of crowds of 1,000 to 10,000 people. Suitable for microphone, radio receiver, or phonograph record input—an ideal, self-contained portable or permanent amplifier for conventions, theaters, churches, etc. A splendid opportunity is to be found here for the engineer in a position to make such installations. Full information is contained in S-M Data Sheet No. 2, sent on receipt of a two-cent stamp.

Type 685 Public Address Unipac is offered fully wired and tested at $160.00 list, or in complete kit form with metal case at $125.00.



New S-M Audios

The new S-M Clough System audio transformers give double the amplification of the best existing types, far better frequency characteristics and practical elimination of hysteretic distortion. Curve "D" is of S-M 255 and 256 transformers listing at $6.00 each as compared to three pairs of $8.00 to $10.00 transformers. Curve "E" is for a pair of S-M 225 and 226 transformers listing at $9.00 each. Note S-M superiority.

Write for S-M Catalog and Sample Copy of the S-M RADIOBUILDER.

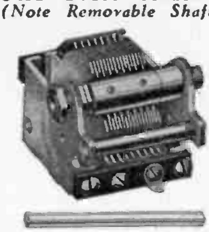
SILVER-MARSHALL, *Inc.*, 838 W. Jackson Blvd.
CHICAGO, U. S. A.

U·S·L CONDENSERS

Universal Precision Instruments Which Are Adaptable To Any Circuit and Can Be Mounted For All Sorts of Drives and Ganged In Any Number.

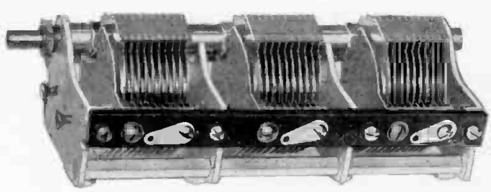
Let the USL Engineers co-operate with you in solving your condenser problems. We are always glad to quote on special specifications.

Universal Compact Type UXB Brass Condenser (Note Removable Shaft)



See Our Exhibit at the Radio World's Fair New York Booth 1 Section Z

Type UXB Three Gang Condenser



This fine job, which is small and compact is especially suited for shielded work. The popular type UXB Condensers are used. They can be had in either .005MF or .00035MF Capacities.

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