PROCEEDINGS OF

The Institute of Radio Engineers

Volume 14 DECEMBER, 1926 Number 6

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GENERAL INFORMATION

The PROCEEDINGS of the Institute are published every two months and contain the papers and the discussions thereon as presented at the meetings and at the Sections in the several cities listed on the following page.

Payment of the annual dues by a member entitles him to one copy of each number of the PROCEEDINGS issued during the period of his membership.

Subscriptions to the PROCEEDINGS are received from non-members at the rate of $1.50 per copy or $9.00 per year. To foreign countries the rates are $1.60 per copy or $9.60 per year. A discount of 25 per cent is allowed to libraries and booksellers.

It is understood that the statements and opinions given in the PROCEEDINGS are the views of the individual members to whom they are credited, and are not binding on the membership of the Institute as a whole.

PUBLISHED BY

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INSTITUTE ACTIVITIES

Lloyd P. Smith

Mr. Lloyd P. Smith, the author of the paper entitled "Theory of Detection in a High Vacuum Thermionic Tube," which appeared in the October, 1926, issue of the PROCEEDINGS is connected with the Research Department of the General Electric Company, at Schenectady, New York.

Membership Committee

The Membership Committee, H. F. Dart, Chairman, held a meeting at Institute headquarters on the evening of November 9th. The committee has completed plans looking to a considerable increase in the membership throughout the midwestern states.

Sections Committee

The Sections Committee, David H. Gage, Chairman, held a meeting at Institute headquarters on the afternoon of November 4th. The committee has been making a thorough study of the entire Sections situation with a view to strengthening the ties between the Sections and Institute headquarters and with the object of rendering all assistance possible to Section officers in carrying on the work.

Chicago Section

The Chicago Section held a meeting on the evening of October 29th, in the rooms of the Western Society of Engineers, Chicago. A paper was delivered by Lieut. Fred H. Schnell on the subject "Transmission and Reception on Short Waves." The paper dealt with the experiences of Lieut. Schnell while in charge of the Short Wave Station of the U. S. Navy during a cruise across the Pacific to Australia. The talk was illustrated with lantern slides.

At this meeting a Membership Committee was appointed, made up of J. H. Miller, F. J. Marco, and G. S. Turner.

Washington Section

The Washington Section held a meeting on the evening of November 10th in the Conference Room, 8th floor, Department of Commerce Building, 19th and Pennsylvania Avenue, Washington. A talk was given by Dr. A. Hoyt Taylor on the subject "Recent Developments in High Frequency."

Dinner Precedes New York Meetings

Members of the Institute and their engineer guests who attend the regular meetings in New York, have been foregathering at The Fraternities Club, Madison Avenue and Thirty-seventh Street, for dinner. Dinner is served at 6:30 P. M., at $1.25 per plate.

The attendance at dinner ranges from sixty to eighty-five members.

The meetings are held on the first Wednesday of each month, excepting July and August. Also, the January meeting each year is held simultaneously with the Annual Convention.

October Meeting in New York

At the October 6th meeting held in the Engineering Societies' Building, New York, a paper was presented by Dr. Alfred N. Goldsmith, on the subject "Reduction in Interference in Broadcast Reception." The paper was illustrated by lantern slides.

About two hundred and fifty members were present.

Canadian Section

The Canadian Section, Toronto, held a meeting at the University of Toronto on September 24th, jointly with the Toronto Section of the A. I. E. E.

A paper was presented by Professor T. R. Rosebrugh, entitled: "A-c.—d-c. Rectification for Radio Uses," and one by Professor H. W. Price entitled: "Elementary Mathematical Consideration of Flter Circuits."

Oscillographic demonstrations supplemented by loud speaker reproductions were given by Professor Price.

The Section held a meeting on October 6th, at which Mr. F. K. Dalton, of the Hydro-Electric Power Commission gave a talk on: "Radio Applications of the Hydro-Electric Power Commission."

Discussion was participated in by C. L. Richardson, Dr. Lucas, G. F. Pipe and others.

Membership Committee

The Membership Committee held a meeting at Institute headquarters on the evening of October 4th. Those present were: H. F. Dart, Chairman, R. S. Kruse, W. G. H. Finch, M. Berger and President McNicol, ex-officio. The committee has done excellent work this year as is reflected by the fact that there has been a net gain of thirty per cent in members for the year.

Section Facilities

Members of the Institute should make note of the names and addresses of Section officers so that when opportunity presents, on visits to the cities where Sections are organized, contacts may be formed which should benefit the members and the Institute.

October Board Meeting

At the October 6th meeting of the Board of Direction the following were present: D. McNicol, President, R. Bown, Vice-president, A. N. Goldsmith, Secretary; W. F. Hubley, Treasurer; J. H. Dellinger, Past President and L. A. Hazeltine, L. E. Whittemore, L. Espenschied, R. H. Marriott, Melville Eastham, Managers.

The Board approved the election of 78 Associates and 3 Juniors.

The report of the Admissions Committee was approved passing for transfer to Member grade; F. H. Schnell, J. F. Andrews, B. E. Shackleford, E. W. Lovejoy, E. W. Dunton, L. J. N. Du Treil, K. S. Van Dyke. Also direct election to Member grade; E. H. Ullrich, Dr. George Seibt and F. G. Wright.

Annual Convention

The personnel of the Convention Committee which will arrange for the annual meeting and convention to be held about the middle of January is: Douglas Rigney, Chairman, and Meade Brunet, L. M. Clement, Q. A. Brackett, P. H. Boucheron, J. H. Dellinger, D. G. Casem, J. D. R. Freed, H. F. Dart, O. E. Dunlap, Keith Henney, W. E. Harkness, W. G. H. Finch, I. K. Rodman, M. C. Rypinski, W. A. Winterbottom, U. B. Ross, and F. E. Eldredge.

Committee on Drafting Room Practice

At the invitation of the American Engineering Standards

Committee, the Institute has appointed a representative on a Committee which will undertake the task of setting up Standards for Drawing and Drafting Room Practice. Mr. L. E. Whittemore will serve as the Institute's representative.

Los Angeles Section

The Los Angeles Section held a meeting in classrooms of the Y.M.C.A., Los Angeles, on the evening of September 20th. A paper was presented by Mr. H. Pratt on the subject "Problems of The Radio Engineer."

Philadelphia Section

The Philadelphia Section held a meeting on September 17th for the purpose of electing new officers for the coming year. Forty-five members were present. The result of the election was that J. C. Van Horn was elected chairman and David P. Gullette Secretary-treasurer. At this meeting a paper was presented by Mr. T. R. Kennedy on the subject of "Radio Compass Installation."

A meeting of the Section was held on October 22nd at which Mr. Halborg read a paper on the subject of "Short Wave Communication." The meetings of the Section are held in the Bartol Laboratories, Philadelphia.

Committee on Broadcast Engineering

As announced in the October PROCEEDINGS, the Board of Direction approved the appointment of a Committee on Broadcast Engineering. The members of this committee are R. H. Marriott, Chairman, and Messrs. L. Espenschied, L. A. Hazeltine, Frank Conrad and John H. Miller. It will be noted that three members of the committee are also members of the Board of Direction.

The purpose of the Institute's Committee is to establish an authority to which technical questions relating to broadcasting may be referred for report. The Institute's non-commercial position and prestige are such that it is the only body equipped to render accurate and unbiased decisions on radio engineering subjects.

Sectional Committee on Radio, A.E.S.C.

This Committee, organized some time ago, with Professor J. H. Morecroft as chairman and Dr. A. N. Goldsmith as secretary, is at work on the various important problems involved in planning standards for radio manufacture and installation.

Entrance Fee

On page 15 of the 1926 Year Book, Article IV, Dues, the entrance fee payable on admission to the Institute, covering each grade is given. During the past three or four years the entrance fee has been waived, but is to be restored on January 1, 1927, as stated in Article IV. Those who join the Institute, any grade, after January 1, 1927, shall be required to pay the proper entrance fee, as well as the annual dues, as soon as they are notified of their election to membership.

Philadelphia Section

The Philadelphia Section held a meeting on the evening of October 22nd in the rooms of the Bartol Laboratory, 127 North 19th Street, Philadelphia. A very interesting talk was given by Mr. H. E. Hallborg on the subject "High Power Transmitters at Wavelengths Varying from Fifteen to Ninety Meters." The Section plans to hold regular meetings during the winter months.

Proceedings to be Issued Monthly

The present plan is to begin monthly publication of the PROCEEDINGS, beginning with the January, 1927 issue. All members will receive the monthly issues as heretofore they have received the bi-monthly issues, without any additional dues payment. This increase in the number of copies of the PROCEEDINGS, which members receive annually, will be of very great advantage and value.

Hartford Section

An organization meeting was held at Hartford, Connecticut, on the evening of October 29th for the purpose of setting up a Section of the Institute to cover the State of Connecticut with headquarters at Hartford.

After the business meeting was concluded a highly interesting address was delivered by E. F. W. Alexanderson, consulting engineering, General Electric Company, and chief consulting engineer of the Radio Corporation of America. Mr. Alexanderson's talk was on the subject "Radio Photography." Motion pictures and lantern slides were used in illustration.

San Francisco Section

The San Francisco Section held a meeting on the evening of September 23d at the Engineers' Club, 57 Post Street, San Francisco. A talk was given by Dr. F. A. Kolster on the subject "Some Notes in the Design of Radio Receiving Equipment." A talk was also given by R. M. Heintz on the subject "Modern Short Wave Radio Equipment." These papers were discussed by Col. J. F. Dillon, A. H. Babcock, Major Bender, F. G. Roebuck. The Section also held a meeting on the evening of October 27th at which a paper was presented by Dr. L. F. Fuller on the subject "Carrier Current Communications Over High Tension Transmission Lines."

Rochester Section

The Rochester Section held a meeting on the evening of November 19th, Mr. Harold A. Wheeler from Johns Hopkins University spoke on the subject of "Applications of Electron Tube Amplifiers." A meeting to be held on December 3d will be addressed by Mr. W. A. McDonald of the Hazeltine Corporation on the subject "Importance of Laboratory Measurements in Radio Receiver Design." The meeting to be held on January 7th will be addressed by Mr. F. H. Engel, of the Radio Corporation of America, who will speak on "Vacuum Tubes."

The Section holds its meetings in the rooms of the Rochester Engineering Society, in the Sagamore Hotel.

November Meeting in New York

At the regular November meeting held in New York, a paper was presented by J. C. Warner and A. V. Loughren, on the subject "The Output Characteristics of Amplifier Tubes."

Admissions Committee

At the October 29th meeting of the Admissions Committee the following Associates were recommended for transfer to Member grade: W. K. Glasby, C. W. Richard, W. L. Holst, E. S. Farnsworth and W. J. Lee. For direct election to Member grade the following were recommended: H. D. Hineline, J. Svoboda and A. E. Thompson.

Seattle Section

The Seattle Section held a meeting on September 4th, in the club room of the Telephone Building. A paper was presented by Mr. Alex Hillman on the subject "Radio Conditions in The Orient." Also a paper by Mr. J. Tolmie on the subject "Two-Tube Bridge Oscillator." The discussion was participated in by John Greig, T. Libby and J. Tolmie.

A local Membership Committee was appointed consisting of R. B. Wilson, T. Libby, and J. Tolmie.

The Section held a meeting on the evening of October 2d at which Mr. Howard F. Mason gave a talk on the subject "Radio with the Detroit Expedition."

The meetings of the Section are attended by about thirty members.

Meetings and Papers Committee

The Meetings and Papers Committee, R. H. Marriott, Chairman, which arranges for all papers, meetings and the dinner at the Fraternity Club preceding the meetings, holds its meetings at those dinners beginning about one hour before the arrival of the other members. The speakers of the evening meet with this Committee. Occasionally members have come to these dinners alone and have not found any person they knew. Beginning with the December meeting the table used by this Committee will be placed near the door so that a member of the Committee will be able to meet such strangers and introduce them to other members.

THE OUTPUT CHARACTERISTICS OF AMPLIFIER TUBES*

By

J. C. Warner and A. V. Loughren

(Research Laboratory, General Electric Company)

It has long been common practice to define the capabilities of an amplifier tube in terms of certain constants or characteristics, such as mutual conductance, amplification constant, input impedance and output resistance. As long as the primary interest is in the *amplification* which the tube will give in a definite circuit a few such quantities furnish all of the information necessary for determining the performance of the tube, but when the tube is to supply an appreciable amount of power to the load circuit they are entirely inadequate.

Improvements in loud speaker design have almost invariably increased the demand on the tube which is supplying the power to the loud speaker. It has been necessary to increase the output of the tube or decrease the distortion caused by the tube itself, or both. It has become important, then, to have an accurate knowledge of the maximum undistorted output which the tube can supply.

In order to bring out the distinction between the *maximum output* of an amplifier tube and the *maximum amplification,* it may be well to review briefly some of the different methods of using amplifier tubes in radio receiving circuits. The terms "voltage amplifier," "current amplifier" and "power amplifier" are often used to distinguish the general types of amplifiers, although all of these, strictly speaking, are *power* amplifiers, since the power controlled in the output circuit is always larger than the power supplied to the input of the tube. However, the terms "voltage amplification," "current amplification," etc., may be used correctly to indicate the performance of a tube in a particular circuit. Other performance characteristics which are sometimes important are the "current output per volt input" and the "power output per volt squared input." Of these quantities the

* Received by the Editor, April 16, 1926. Presented at a meeting of the Institute of Radio Engineers, New York, N. Y., November 3, 1926.

ones most often used are perhaps the two last named and the voltage amplification.

The voltage amplification is

$$A_v = \frac{\mu R_p}{R_p + r_p} \tag{1}$$

where μ = amplification constant
r_p = internal plate resistance
R_p = load resistance

The current output per volt input is

$$A_{cv} = \frac{\mu}{R_p + r_p} \tag{2}$$

The power per volt squared input is

$$A_{pv} = \frac{\mu^2 R_p}{(r_p + R_p)^2} \tag{3}$$

It may be noticed that the mutual conductance, $\frac{\mu}{r_p}$, does not appear directly in any of these relations. This illustrates the fact that the amplification of a tube is not directly proportional to the mutual conductance, although this factor is often used as a "figure of merit" for the tube. The only justification for this is that tubes designed for the same sort of service can be roughly compared by the mutual conductance, but when the amplification constant or plate resistance differs greatly—that is, of the order requiring a different type of load circuit—a comparison of mutual conductance loses its significance.

Factors Determining Amplification

Equation (1) shows that for a given value of μ and r_p the voltage amplification increases when R_p is increased and approaches μ in the limit. Practical circuit limitations usually prevent R_p from going much over 500,000 ohms and the amplification is seldom over 75 percent of μ. With an inductive load it is, of course, possible to approach much closer to the full value of μ.

In order to illustrate the effect of the tube constants on the amplification, three sets of curves have been drawn, which show the relation between the amplification constant of a tube and the actual amplification in terms of voltage, current and power. A cylindrical electrode structure, similar to that used in the UX-199 Radiotron, was taken for these examples and it was assumed that the amplification constant was varied by changing the grid mesh, no other structural change being made. Figure 1 shows the variation in the plate resistance of this type of tube when the amplification constant is varied.

Figure 2 gives the relation between μ and the voltage amplification for several values of load resistance. The decrease in amplification with low load resistance at the higher values of μ, is, of course, due to the fact that r_p rises more rapidly than μ. Otherwise all of the curves would rise indefinitely.

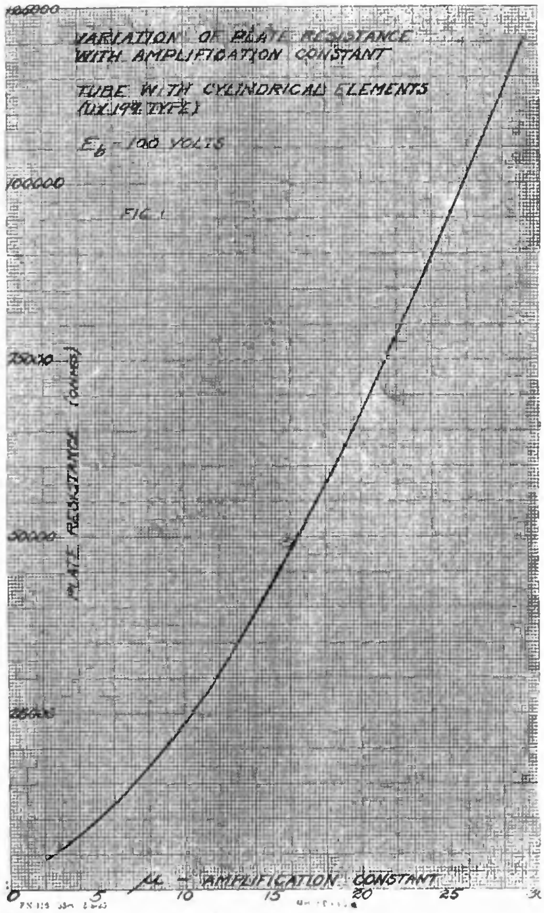

FIGURE 1

Figure 3 shows the variation in current output per volt input for different load resistances.

The relation between μ and power output per volt squared input is shown in Figure 4. The envelope of the curves for fixed load resistances gives the output for a variable load resistance, which is kept equal to the plate resistance of the tube. It is interesting to note that if the tube resistance is fixed, the maximum power per volt squared is obtained when the load resistance is made equal to the tube resistance, but if the load resistance is fixed, the tube resistance should be made considerably higher than the load resistance. It will be seen later that neither of these conditions holds for maximum undistorted power output when sufficient input voltage is available.

Use of Plate Characteristic Curves for Calculating Output

The above relations between input voltage and output voltage, current and power, hold only when the amplitudes

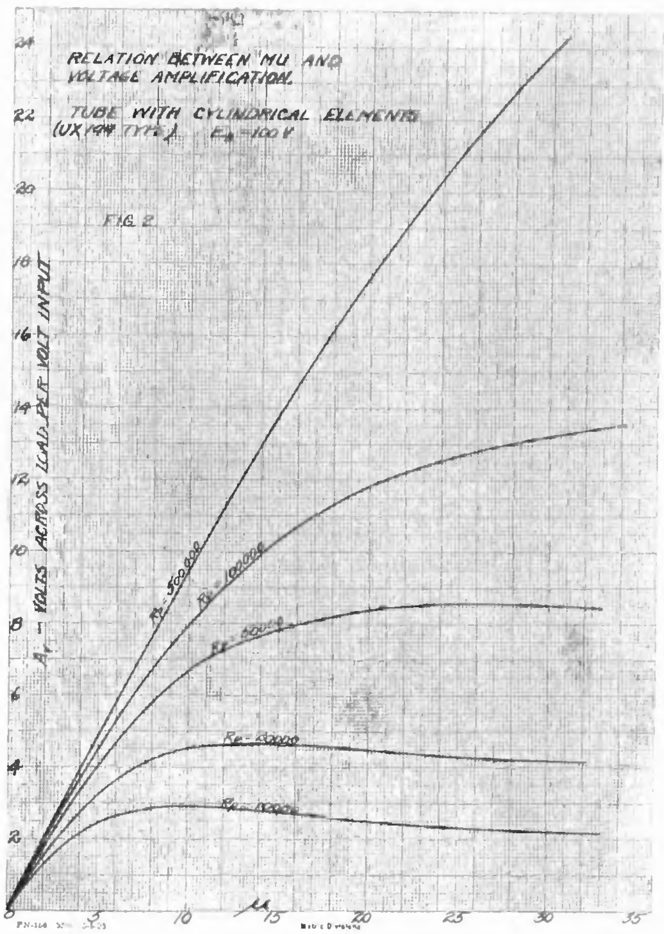

Figure 2

are small. This condition usually exists in all but the last tube of an amplifier, but in this tube the amplitudes must be large, since the power supplied to the loud speaker is often considerable. It then becomes necessary to determine the output characteristics of the tube feeding the loud speaker, and in particular it is desirable to know the *maximum power output* which the tube will supply without distortion.

The usual method of determining the output of a tube when the amplitudes are large involves drawing the complete dynamic characteristic, which is a rather laborious process when a large number of different conditions are to be considered. A much

FIGURE 3

simpler method gives all of the information furnished by the dynamic curve, and in the rare cases when the dynamic curve is required it may be drawn easily from the data obtained by the simpler method.

This method of analysis makes use of the family of plate voltage-plate current curves as shown in Figure 5, and combines these static characteristics with the load characteristic in such a way as to show the current and voltage at any instant.

The method was worked out primarily for a circuit in which the load resistance is in series with the supply voltage, as in Figure 6. However it applies equally well to a circuit in which the plate voltage is supplied through a choke or where the load is coupled through a transformer, provided the mean current does not change greatly when the signal is applied. Since this corresponds to the conditions for low distortion the method may be applied safely to the cases where the load is not in series with the plate supply voltage as long as the distortion does not rise above the limit which should be permitted in practice.

Referring again to Figure 5, the plate current at any instant

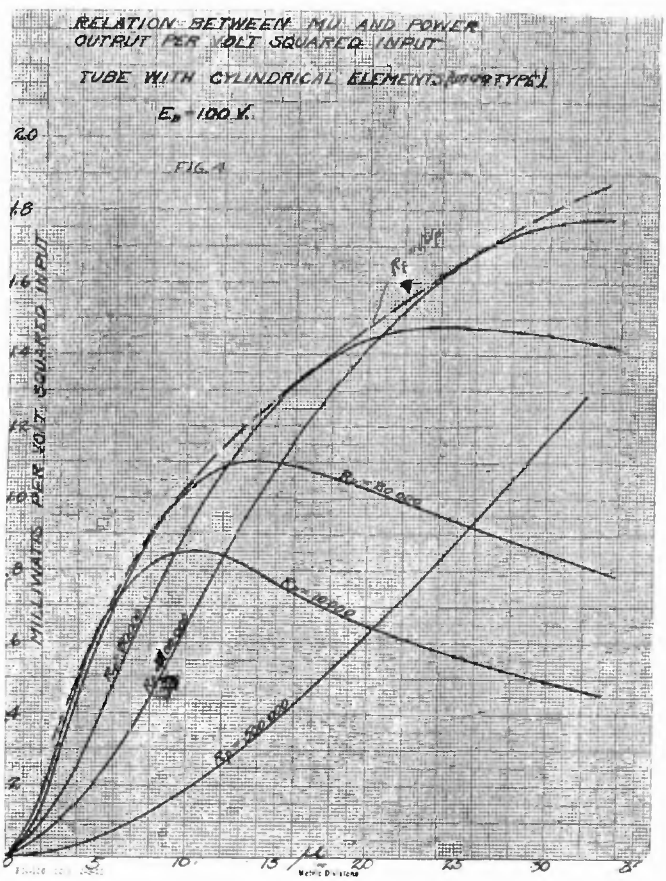

FIGURE 4

is determined by the voltages on plate and grid, and the plate voltage in turn is determined by the battery voltage and the $I\,R$ drop in R_p. These conditions can be expressed by two equations:

$$i_p = f(v_p, \mu\, v_g) \tag{4}$$

$$v_p = E_b - i_p\, R_p \tag{5}$$

Since the first equation is not linear and can not be easily expressed, the simplest solution is graphical. The typical plate voltage-plate current curves of Figure 5 are plotted from equation (4) by assigning arbitrary fixed values of v_g and plotting the $v_p - i_p$ curves from experimental data. Now if equation (5) is plotted the intersection of its graph with one of the plate current curves gives the plate current for that particular value of grid

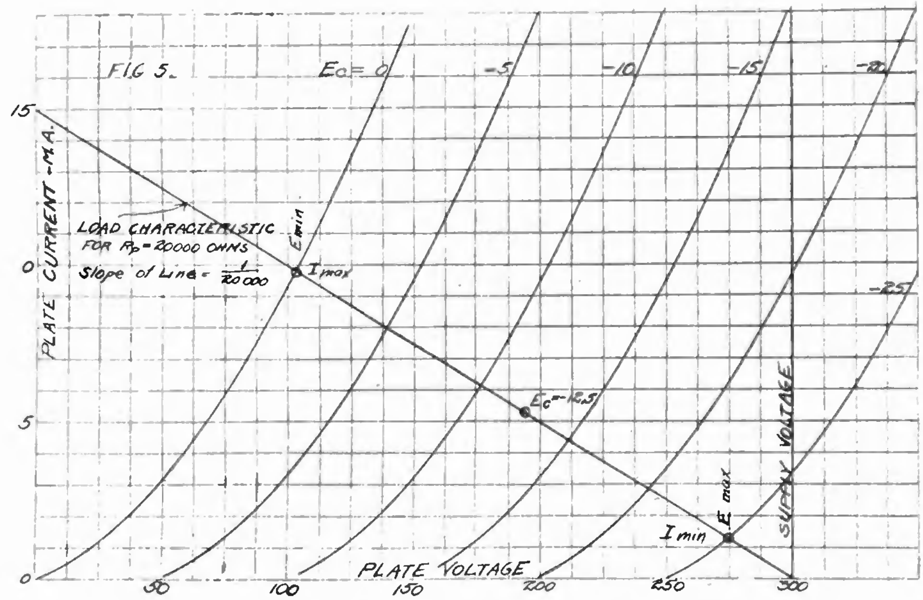

FIGURE 5—Tube and Load Characteristics

voltage. The slope of the load characteristic is, of course, equal to the reciprocal of the load resistance.

Conditions for Maximum Output with Low Distortion

In order to prevent distortion in a tube certain conditions must be satisfied: First, the grid must not be allowed to become

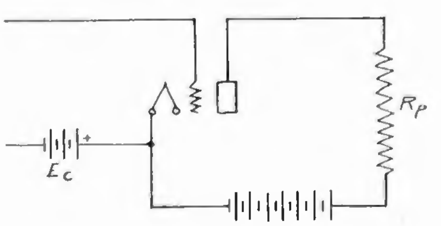

FIGURE 6—Amplifier Circuit

sufficiently positive to draw appreciable grid current, and, second, the plate current must at no portion of the cycle be allowed to fall to so low a value that distortion is caused by curvature of the dynamic characteristic.

Distortion results from the grid becoming positive because the input circuit usually has rather high impedance, and during the time when the grid is positive current flows through this impedance reducing the voltage at the tube by the amount of the voltage drop in the impedance. Grid current flows during one-half of the cycle only and the grid terminal voltage wave is, therefore, flattened or otherwise distorted on this half cycle.

The second condition—that the plate current must not decrease below a certain point—may be shown either theoretically or experimentally to be necessary if the tube is to produce only a small amount of harmonic current. This is rather obvious from the shape of the characteristic curves, but will be brought out more fully later.

With these two conditions, and making certain simplifying assumptions, it has been shown by W. J. Brown* that the maximum undistorted output is obtained when the load resistance is equal to twice the internal resistance of the tube. In proving this relation Brown has made use of the grid voltage-plate current static characteristic, but for the sake of simplicity the writers have preferred to show the proof with the plate voltage-plate current characteristics, although the method is otherwise essentially the same as that used by Brown.

In determining the conditions for maximum output several assumptions must be made. As has just been stated, the grid must not at any time be allowed to become sufficiently positive to take current and the plate current swing must be confined to that part of the dynamic characteristic which does not have excessive curvature. Further, the grid bias must be allowed to take the value corresponding to the optimum condition, and for the purpose of calculating the conditions for maximum output the static characteristics are assumed to be straight over the range used. These first three assumptions are clearly justified both in determining the optimum conditions and the actual output, although the second involves a definition of the allowable distortion. The last assumption, of course, cannot be made when the actual output is to be calculated, but is justifiable in determining the conditions for maximum output.

Figure 7 shows another family of static plate voltage-plate current characteristics for different grid voltages, which will be used in illustrating the method of determining maximum output conditions. These are drawn as straight lines above the hori-

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*Proc. of Phys. Soc. of London. Vol. 36, Part 3, April 15, 1924, p. 218.

zontal line marked "I_{min}," this being the region to which the current swing is confined. I_{min} represents the lowest plate current at any time in the cycle. E_o represents the d-c. plate voltage, measured at the tube.

A straight line, $A\ B$, whose slope is the reciprocal of the load resiatance is drawn across the family of curves. This must be drawn in such a way that the grid voltage at the point where it crosses the E_o line is half the grid voltage of the point where it

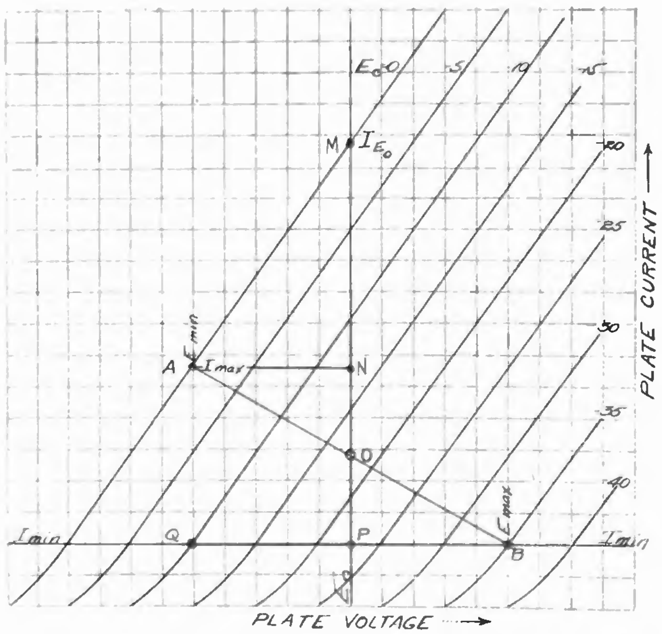


FIGURE 7—Tube Characteristics for Showing Conditions for Maximum Understorled Output

crosses the I_{min} line. The ends of this line then give I_{max} and I_{min} as well as E_{max} and E_{min}, which are the instantaneous plate voltages and currents at the ends of the swing. The grid bias is the grid voltage at which the line $A\ B$ crosses the E_o line; the grid swings to zero on the one side and to twice the bias on the other.

The output power is

$$P=\frac{1}{8}(E_{max}-E_{min})(I_{max}-I_{min}) \tag{6}$$

and the load resistance is

$$R_p=\frac{E_{max}-E_{min}}{I_{max}-I_{min}} \text{ or } \frac{BQ}{AQ} \tag{7}$$

If I_{Eo} is the plate current at a plate voltage equal to E_o and grid bias of zero, the internal resistance of the tube is

$$r_p = \frac{1}{2}\frac{(E_{max} - E_{min})}{I_{E_o} - I_{max}} \text{ or } \frac{1}{2}\frac{B\,Q}{M\,N}$$

and

$$E_{max} - E_{min} = 2r_p(I_{E_o} - I_{max})$$

$$P = \frac{1}{4}r_p(I_{max} - I_{min})(I_{E_o} - I_{max})$$

Since E_o is fixed

$$(I_{max} - I_{min}) + (I_{E_o} - I_{max}) = const. \text{ or } N\,P + M\,N = const.$$

Then P is maximum when $I_{max} - I_{min}$ is equal to $I_{E_o} - I_{max}$ or $N\,P = M\,N$

but since

$$I_{max} - I_{min} = \frac{E_{max} - E_{min}}{R_p} \text{ or } N\,P = A\,Q$$

and

$$I_{E_o} - I_{min} = \frac{E_{max} - E_{min}}{2\,r_p}$$

$$R_p = 2\,r_p \tag{8}$$

or the load resistance is equal to twice the internal resistance.

It will be noticed that this condition is not the same as the condition for maximum amplification in watts per volt squared input. Lowering the load resistance would tend to raise the output but would at once cause distortion, since the plate current swing would fall below the previously assigned value of I_{min}.

The above-mentioned method of determining the maximum output neglects plate power dissipation as a possible limitation, in a large power amplifier. If the value of I_o is found to be so large that the product $E_o I_o$ exceeds the allowable plate loss, the conditions must be modified. When a signal is impressed on the amplifier and an output is produced, the plate loss is less by that amount, but it is not permissible to take advantage of this as an amplifier is ordinarily subject to silent periods during which the entire plate circuit input is expended in heating the plate. A similar limitation occurs in a receiving tube when I_o is too large for the safe operation of the tube or approaches too near to the total electron emission from the filament.

In order to reduce $E_o\,I_o$, E_o may be decreased—and incidentally I_o—or I_o alone may be decreased. Figure 8 shows power output, I_o, and plate dissipation for the UV-211 tube ($\mu = 12$), plotted against plate voltage. Two curves are shown for each quantity, one for best conditions with the given plate voltage, the other for such grid bias as gives a plate circuit input of 75 watts. It is assumed throughout that the peak value of the grid swing is equal to the grid bias; that is, that the grid potential varies from zero to $-2\,E_c$, when maximum power is demanded from the amplifier. The lower set of curves shows the plate circuit input increasing quite rapidly with voltage. As it passes the

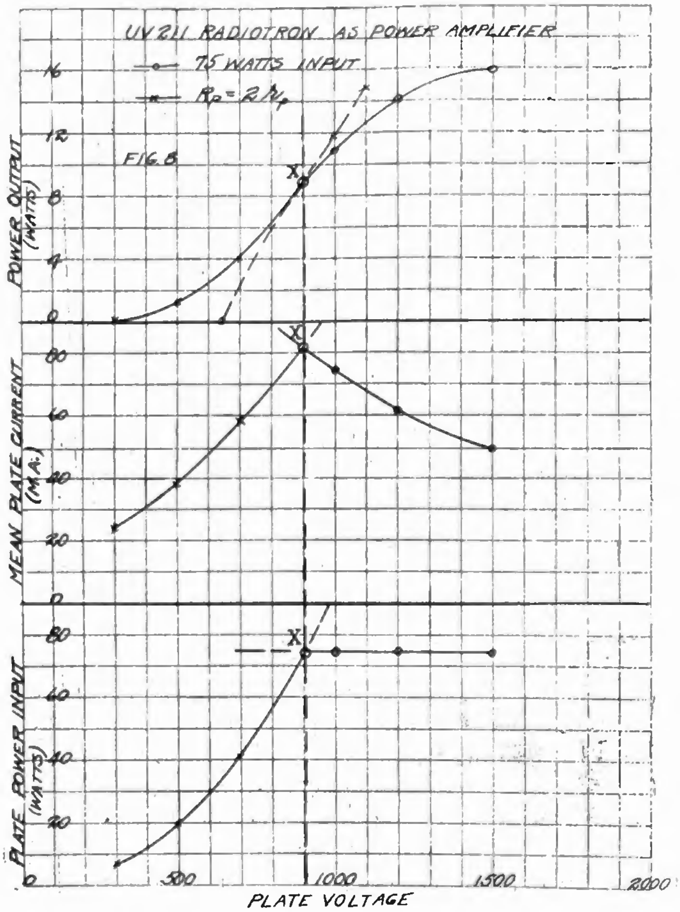


FIGURE 8

75-watt point the operation is shifted to the other curve, on which input is constant. The next set of curves above shows the static value of plate current as a function of plate voltage. At the point at which the dissipation reaches 75 watts, the operating point shifts from a rising curve to the hyperbola $E_o\,I_o = 75$, shown on the right hand side of the vertical broken line. The upper set of curves shows the power obtainable under each condition (*i.e.*, constant plate input of 75 watts and maximum output) as a function of plate voltage. From these it may be seen that it is best simply to decrease I_o by increasing the grid bias rather than to decrease E_o, and consequently I_o, in case the plate circuit input is too high. For example, suppose that it is desired to operate this tube at 1,100 volts. The dissipation under maximum output conditions is over 100 watts—too high, accordingly, as the tube is rated at 75 watts anode dissipation. The output would be 15 watts. Now if E_o is decreased until the dissipation is 75 watts, the output (at point X) is 9 watts, and the plate voltage about 900. But if E_o is maintained at 1,100 and the plate current is reduced to 0.068 by increasing the grid bias, the output is 12.5 watts—a 40 per-cent gain over the power at the point X.

Calculation of Maximum Output

The calculation of the maximum undistorted output will next be illustrated in detail, with consideration of the case where there are no restrictions as to grid bias and plate current as well as those cases where certain restrictions apply. Figure 9 shows a

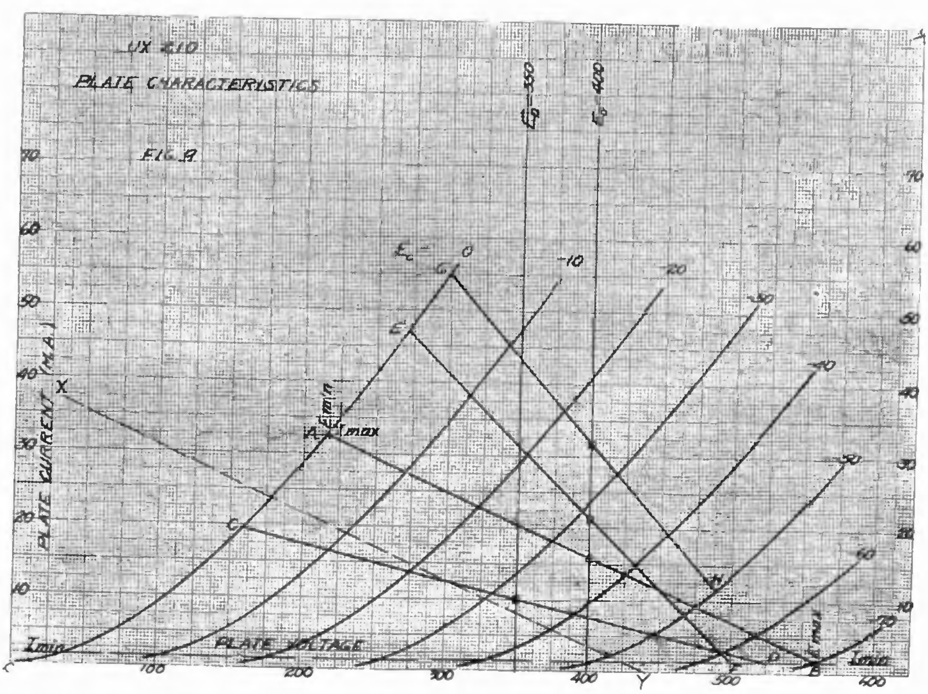


Figure 9

family of plate voltage—plate current curves for the UX-210 Radiotron which will be used for these illustrations. This tube has been designed for use as an oscillator or as an amplifier for plate voltages not exceeding 400 volts. As an oscillator the tube is rated at 7.5 watts output, and the safe plate power dissipation is 12 to 15 watts, depending somewhat on the conditions of use.

The complete procedure is as follows:

(1) The family of plate voltage—plate current curves must be drawn for negative grid voltages up to at least twice the maximum grid bias which is to be used. This point can usually be estimated after a preliminary examination of the first characteristics drawn. It is not necessary to plot all of the curves from experimental data. The curve for zero grid voltage and one or two negative voltages should be drawn from experimental data; then as the amplification constant of the tube is known the other curves may be drawn in.

(2) The minimum plate current—that is, the plate current at the negative end of the grid voltage swing—must next be determined. The exact choice of this is dependent partly on the load resistance which is to be used and partly on the amount of distortion which is allowable. Since "allowable distortion" is difficult to define, the value of I_{min} is best chosen arbitrarily. After the output characteristics have been found the percentage of harmonic current in the output can be calculated (only the second harmonic need be considered) and if it is too high a second calculation may be made with a higher value of I_{min}. I_{min} may be from 1/10 to 1/5 of I_o in most of the ordinary types of tubes when the second harmonic current is not allowed to exceed 5 per cent of the fundamental.

It is usually convenient to draw a horizontal line corresponding to I_{min} across the characteristics; then only that part of the curve family which is above this line is to be used.

(3) There are now four methods of procedure, depending on the predetermined conditions as to plate voltage, mean plate current, grid voltage, etc., and also the relation of the tube constants to these conditions.

It is assumed that the plate voltage is predetermined according to the maximum safe voltage which can be applied to the tube in question or according to the supply voltage available.

Case I. Given:

D-C. Plate Voltage (E_o)
Minimum Plate Current (I_{min})

To find:

Load Resistance (R_p)
Grid Bias (E_c)
D-C. Plate Current (I_o)
Power Output

Under these conditions the maximum output will be obtained as previously explained when the load resistance is equal to twice the plate resistance of the tube. The tube resistance itself varies somewhat, depending on the grid bias ultimately chosen, but a sufficiently close estimate of the final mean plate current can be made in order to find the point where the plate resistance is to be calculated. For example, it is reasonable to suppose that the direct-plate current of the UX-210 at 400 volts plate voltage will be about 15 milliamperes and the plate resistance at this current is found to be 5,500 ohms. (If the actual current is found later to be much different from 15 milliamperes a second approximation will be necessary). A straight line, XY, whose slope is equal to the reciprocal of the load resistance—*i.e.*, 11,000 ohms—is now drawn across the family of curves to serve as a guide. This line is not absolutely necessary, but is a matter of convenience to make it easier to locate the final load line.

Next, another straight line, AB, is drawn parallel to XY, beginning on the $E_b - I_b$ curve for $E_c = 0$ and ending on the I_{min} line. This must cross the E_o line at a value of E_c, which is exactly half the value of E_c at the point where it crosses the I_{min} line. Thus AB crosses the E_o line at $E_c = -35$ and the I_{min} line at $E_c = -70$. I_o is 16 milliamperes.

This straight line AB furnishes all of the desired information for instantaneous voltage and current, power output and per cent second harmonic current.

$$E_{max} = 560 \text{ volts}$$
$$E_{min} = 215 \text{ volts}$$
$$I_{max} = 32.5 \text{ milliamperes}$$
$$I_{min} = 1.5 \text{ milliamperes}$$
$$\text{Power Output} = 1/8\,(560-215)\,(32.5-1.5)\times 10^{-3}$$
$$= 1.34 \text{ watts}$$

The ratio of second harmonic current to the fundamental in the plate circuit with a resistance load in series with the plate is

$$\frac{\tfrac{1}{2}(I_{max}+I_{min}) - I_o}{I_{max} - I_{min}} = \frac{17-16}{31} = \frac{1.0}{31} = 3.2 \text{ per cent.}$$

From the above results it can be seen that the best conditions for undistorted output from the UX-210 at 400 volts on the plate are:

$R_p = 11{,}000$ ohms. $E_c = -35$ volts. $I_o = 16$ milliamperes.

The alternating grid voltage (signal) is $\frac{\sqrt{2}}{2} \times 35$, or 24.8 volts r.m.s.

Case II. Given:

D-C. Plate Voltage (E_o)
Minimum Plate Current (I_{min})
Direct Plate Current (I_o)
(With large power tubes it is usually the plate power input ($E_o I_o$) that is fixed rather than I_o alone.)

To find:

Load Resistance (R_p)
Grid Bias (E_c)
Power Output

This case differs from Case I only when the value of I_o as calculated for Case I comes out above the allowable maximum for the tube. (This maximum current is the direct current under the operating conditions but with no signal, and should not be confused with I_{max} which refers to the peak value of current during the swing.)

For example, it will be assumed that the plate voltage is 350 volts on the UX-210 and that the direct current must be limited to 10 milliamperes. This immediately fixes a point on the E_o line through which the load characteristic must pass. E_c for this point is -33 volts. The lower end of the load characteristic must cross I_{min} at $E_c = -66$ volts. These two points then fix the line $C\ D$ from which the required output data can be obtained as follows:

$$E_{max} = 525 \qquad I_{max} = 19.5$$
$$E_{min} = 160 \qquad I_{min} = 1.5$$

$$\text{Power Output} = 1/8 \times 365 \times 18 \times 10^{-3}$$
$$= 0.822 \text{ watt}$$

$$\text{Load Resistance} = \frac{365}{18} \times 10^3 = 20280 \text{ ohms}$$

The signal voltage is 23.4 volts r.m.s.

Case III. Given:

Plate Voltage (E_o)
Load Resistance (R_p)
Minimum Plate Current (I_{min})

To find:

Grid Bias (E_c)
Plate Current (I_o)
Power Output

The procedure here is exactly the same as for Case I, excepting that the load resistance instead of being the optimum value is previously fixed. Assuming plate voltage 400 and a load resistance of 5,000 ohms, a line is drawn with a slope of $\frac{1}{5000}$; this intersects the E_o line at a grid voltage which is one-half the voltage at the point where it crosses the I_{min} line. This is the line EF; the grid bias is 31.5 volts and the direct plate current 21.5 milliamperes.

$$E_{max} = 500 \text{ volts} \qquad I_{max} = 47$$
$$E_{min} = 272 \text{ volts} \qquad I_{min} = 1.5$$
$$\text{Power Output} = 1/8 \times 228 \times 45.5 \times 10^{-3}$$
$$= 1.3 \text{ watts}$$

In this case the second harmonic current is nearly 15 per cent of the fundamental—an amount which is likely to be excessive. To decrease the distortion the calculations leading to the choice of grid bias and load resistance may be repeated with a higher value of I_{min}, say 6 or 8 milliamperes. This would reduce the harmonic to a reasonable value, although at the expense of a small reduction in the power output.

Case IV. Given:

Plate Voltage (E_o)
Grid Voltage (E_c)

To find:

Load Resistance (R_p)
Power Output

In this case it is assumed that the grid bias is fixed and cannot be adjusted to the optimum value. If the plate current corresponding to this grid voltage is equal to or less than that found by the method given for Case I, the methods of Case I or Case II may be used. If the plate current is more than that found for Case I the procedure is slightly different.

Referring again to Figure 9 it will be assumed that the plate voltage is 400 and the grid bias is -25 volts. This fixes the operating point at once and shows the direct plate current to be 32 milliamperes. The problem then becomes to find the load resistance which will give the highest output for a signal voltage of 17.7 volts r.m.s. Since the input voltage is fixed the condition that $R_p = 2r_p$ no longer gives the maximum output and the oad resistance should be decreased until $R_p = r_p$, or until the plate current swings down to I_{min}.

At $E_o=400$, $E_c=-25$, r_p is equal to 4350 ohms. The line GH shows the load characteristic for a resistance equal to this. Since at $E_c=-50$ the line $G\,H$ does not go below the I_{min} line it represents the optimum condition. If H had gone below I_{min} it would have been necessary to raise R_p in order to prevent distortion.

The output characteristics then are:

$$E_{max}=488 \qquad I_{max}=55.$$
$$E_{min}=300 \qquad I_{min}=11.6$$

$$\text{Power Output}=1/8\times 188\times 43.4$$
$$=1.02 \text{ watts}$$

Relation of Design of Tubes to Power Output

A study of the characteristics of tubes having the same general dimensions—*i.e.*, electrode areas and spacings—but different values of amplification constant, shows that in general the lower the amplification constant the higher will be the maximum output obtainable from the tube even though the amplification is lower. This, of course, is the result of lowering the plate resistance, which can be done only by lowering the amplification constant at the same time. It is assumed that the load impedance can be varied to fit the tube impedance and that the same plate voltage is used in each case. This may be easily understood in a qualitative way by referring again to the power equation

$$P=\frac{\mu^2E_g{}^2R_p}{(r_p+R_p)^2}$$

and if

$$R_p=2r_p$$

$$P_{max}=\frac{2\mu^2E_g{}^2}{9r_p} \tag{9}$$

Now, if μ is decreased E_g may be increased at least as rapidly without causing distortion. At the same time r_p decreases, even if the mean plate current is kept constant, thus causing an increase in P_{max}. Actually E_g may usually be increased more rapidly than μ is decreased, making a still greater increase in P_{max}.

Figure 10 illustrates this variation of maximum output with amplification constant in a larger power amplifier tube of the UV-211 Radiotron type. The straight line represents the output with a fixed plate power input of 75 watts. The curved line represents the output with no limit on input. However, under the latter condition the plate power loss would overheat the tube if μ were lowered much below 16.

One of the most common uses for a power amplifier tube is in connection with a radio receiving set for supplying power

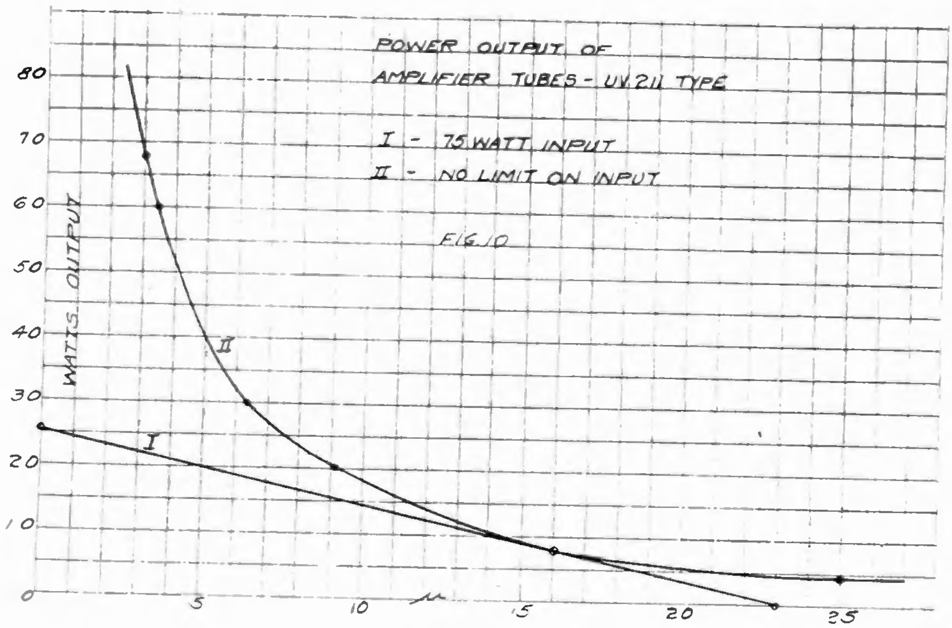


FIGURE 10

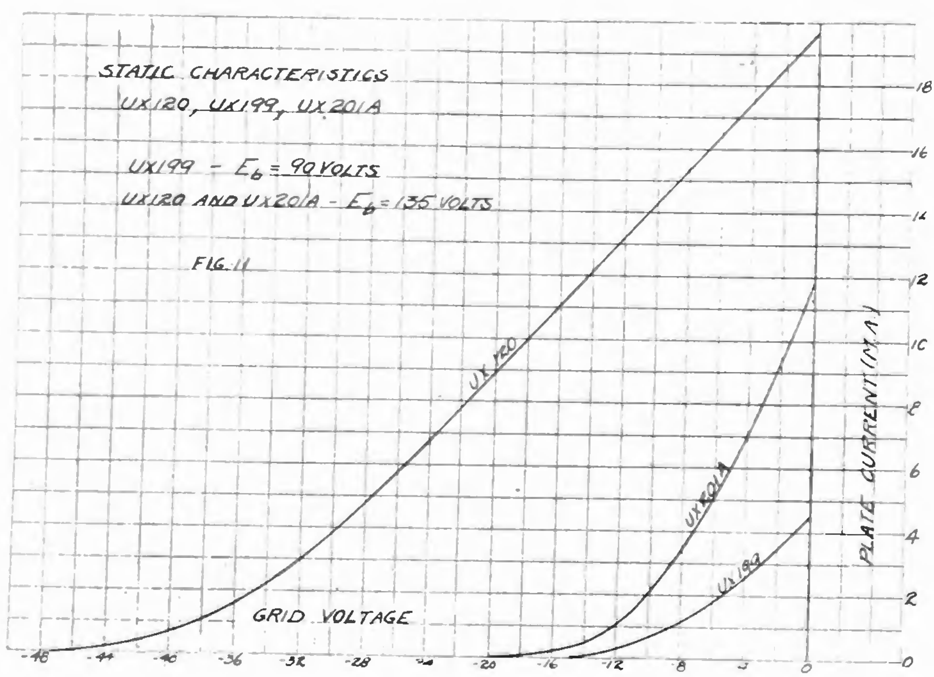


FIGURE 11

to the loud speaker. Recent improvements in loud speakers have increased the importance of high output and low distortion from the last tube in the amplifier. Three Radiotrons have been developed lately to meet the demand for a tube for this class of service. These are the UX-120, the UX-171 and the UX-210. The characteristic curves of the UX-210 have been used to illustrate the methods of determining the output.

It has been pointed out that increasing the plate voltage

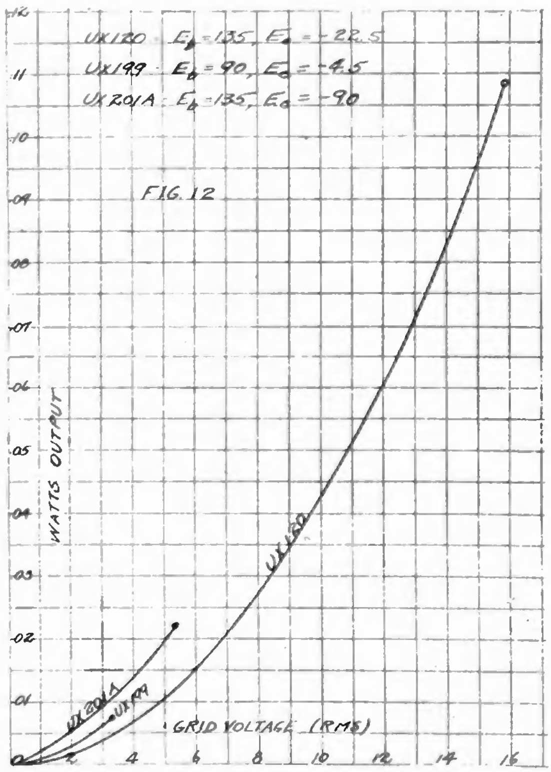


FIGURE 12—Input Voltage—Undistorted Power Output—Load Resistance 10,000 Ohms

increases the maximum output rapidly. The UX-210 is an example of a tube designed for operation at relatively high plate voltage and capable of supplying a large amount of power to a loud speaker without distortion. However there are many cases where the high plate voltage and filament power required by this tube are not available. For instance, it is often desirable to operate a set entirely from dry batteries, in which case both the filament power and the plate voltage are limited. The UX-120 has been developed for this purpose.

The UX-120 has a filament requiring 3 volts and 0.125 ampere. This voltage allows operation in parallel with other dry battery tubes such as the UX-199.

The noticeable features of this tube are the low amplification constant, averaging 3.3, and the high grid bias—22.5 volts. The reason for these values has already been explained. The maximum output is much greater than can be obtained from the UX-199, as a result of the higher plate voltage and the lower amplification constant and plate resistance.

Figure 11 gives a comparison of the static grid voltage-plate

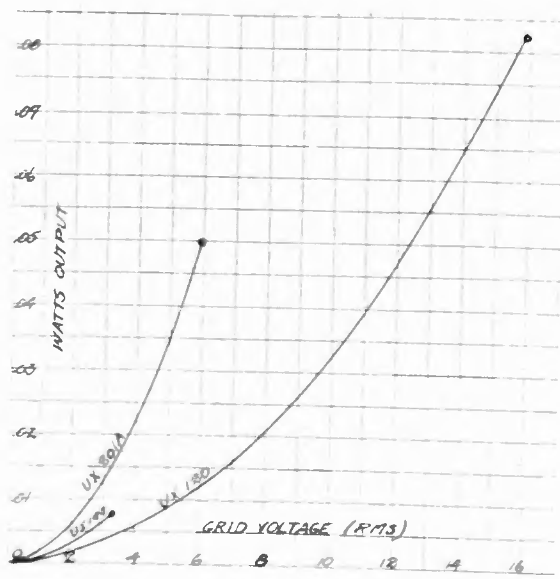


FIGURE 13—Input Voltage—Undistorted Power Output—Load Resistance 20,000 Ohms
UX 120 — $E_b = 135$, $E_c = -22.5$
UX 199 — $E_b = 90$, $E_c = -4.5$
UX 201A — $E_b = 135$, $E_c = -9.0$

current characteristics of the UX-199, UX-201-A and UX-120, each at its normal plate voltage.

Figures 12 and 13 show the relation between the input voltage and output power up to the distortion limit. Figure 12 is drawn for a load resistance of 10,000 ohms and Figure 13 for 20,000 ohms. It will be noticed in each case that the curves for the UX-199 and UX-201-A rise rapidly at first, due to the higher amplification, but are limited at relatively low input voltages either by the grid becoming positive or by excessive curvature of the plate current characteristic.

The third power amplifier tube, the UX-171, is intermediate in size and output between the UX-120 and UX-210.

The UX-171 has a 5-volt, 0.5 ampere filament and can be operated at plate voltages up to 180 volts. At this voltage the grid bias required is approximately −40 volts. The amplification constant is approximately 3 and the plate resistance is of the order of 2,000 to 2,500 ohms under usual operating conditions. Thus the UX-171 fills a place with reference to the UX-201-A much the same as the UX-120 with reference to the UX-199. Figure 14 shows static and dynamic characteristics of the UX-171. Figure

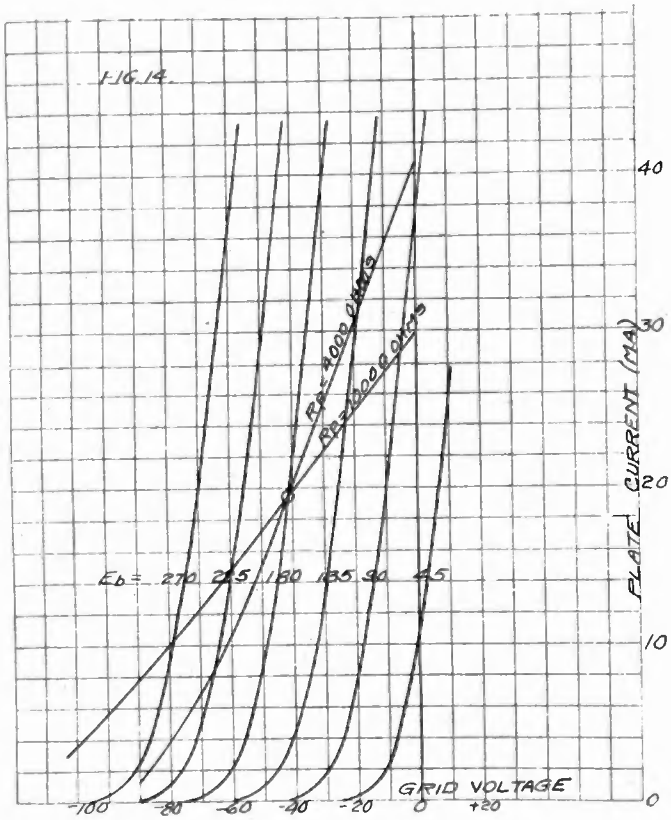


FIGURE 14—Static and Dynamic Characteristics—*U X* 171

15 gives the relation between a-c. input voltage and output power for load resistances of 4,000 and 10,000 ohms.

Table I gives a tabulation of some of the constants of the more commonly used Radiotrons. The first half of the table shows the constants of the tubes themselves. The second half gives the maximum undistorted output (assuming not more than 5 percent second harmonic current in the load), the load resistance at which the maximum output is obtained, the input grid voltage required to produce this output, and the amplification of the tube with this same load resistance.

As has already been pointed out, analytical methods are not accurate for calculating the maximum power output. For this reason the product of the quantity A_p—the power output per

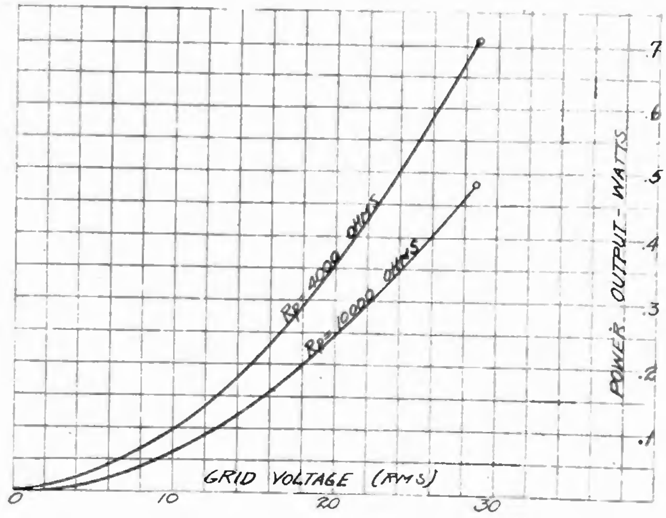


FIGURE 15—Power Output—UX 171
$E_b = 180$ $E_c = -40.5$

volt squared input—and the square of the r.m.s. grid voltage for P_{max} will not always check exactly the figure given for P_{max} itself, as this latter was obtained in every case by graphical methods.

Tube	Plate Voltage E_b	Grid Bias E_c	D.-C. Plate Current (Milli-amperes) I_b	Amplification Factor μ	Plate Resistance (Ohms) r_p	Mutual Conductance (Micromhos) g_m	(Micromhos) $\frac{\mu^2}{r_p}$	Load Resistance R_p	$\frac{\mu}{R_p+r_p}$ Output Current per Volt (Micro-amperes) A_c	$\frac{\mu R_p r}{R_p+r_p}$ Output Voltage per Volt Input A_v	$\frac{\mu^2 R_p}{(R_p+r_p)_2}$ Output Power per Volt Squared Input (Milli-watts) A_p	A-C Grid Voltage (R.M.S) for P_{max} E_g	Maximum Undistorted Output (Milli-watts) P_{max}
UX-199	90	— 4.5	2.5	6.5	15250	425	2770	15250	212	3.25	.690	3.18	7
	90	— 7.5	1.3	6.45	19250	335	2160	32000	126	4.00	.505	5.30	14
UX-201-A	90	— 4.5	2.0	8.5	12000	708	6000	15000	315	4.70	1.480	3.18	14
	90	— 6.0	1.2	8.4	15400	550	4620	30000	185	5.55	1.025	4.24	17
	135	— 9.0	2.55	8.4	11000	764	6410	22000	255	5.60	1.430	6.36	55
UX-120	135	—22.5	7.0	3.3	6600	500	1650	6560	250	1.65	.412	15.90	105
	135	—26.7	5.5	3.2	7500	427	1365	15000	142	2.13	.302	18.90	110
UX-171	90	—16.5	10.0	3.0	2350	1275	3820	4000	472	1.89	.893	11.58	105
	135	—27.0	16.0	2.9	2100	1380	4000	4000	475	1.90	.902	19.10	320
	180	—40.5	20.0	2.9	2000	1450	4200	4000	483	1.93	.934	28.60	710
UX-210	135	— 9.0	5.0	7.5	8000	940	7050	15000	326	4.89	1.59	6.36	64
	250	—18.0	11.5	7.5	5600	1340	10050	11000	451	4.97	2.25	12.72	340
	400	—35.0	16.0	7.5	5400	1390	10400	11000	457	5.03	2.30	24.80	1340
UV-203-A	1000	—22.5	26.0	25.0	8800	2840	71000	17600	947	16.70	15.80	15.90	3920
UV-211	1000	—48.5	75.0	12.0	3400	3530	42400	6800	1177	8.00	9.41	34.30	11000

NOTES ON THE DESIGN OF RESISTANCE-CAPACITY COUPLED AMPLIFIERS

By

Sylvan Harris

The function of the inter-stage coupling devices used in low frequency amplifiers is to transfer the alternating voltage developed in the output circuit of one amplifier by the action of an alternating voltage on the input of that tube, to the input of a second amplifier, with the utmost fidelity. The matter of amplification will not be considered in this paper excepting insofar as it is related to the voltage ratio of the coupling device at various frequencies.

The need for the "distortionless" amplifier, in the laboratory, in public address systems, and in radio transmitting and receiving apparatus, is evident, and it is desirable to know to what extent the operation of an actual amplifier may differ from that of the perfect amplifier. In other words, it may be possible to design an amplifier which is "distortionless" for practical purposes, and it is the purpose of this paper to consider the matter from this angle.

The low-frequency amplifier in receivers actuates a reproducer; if the pressure established in the air by the diafram of the loud-speaker or telephone receiver is assumed to be a linear function of the output voltage of the amplifier, the latter can be studied with regard to the auditory sensation, by noting that the ear, over a very wide range of sound intensity, is sensitive to changes of intensity of approximately ten per cent, and that this seems to be true regardless of frequency.*

Although for many purposes a variation of ten per cent in the voltage ratio of an amplifier from one frequency to another may be excessive, this figure will be used for purposes of illustration. There is also to be considered the commercial phase of the problem, where a compromise is required between results and

Received by the Editor, June 2, 1926. To be presented at a meeting of the Institute of Radio Engineers, New York, N. Y., December 1, 1926.

* Bell System Tech. Jour., October, 1923. "Physical Measurements of Audition," Harvey Fletcher.

costs. The problem then is to find the required conditions in an amplifier coupling device under which the voltage ratio will not change more than 10 per cent from very high audible frequencies down to an arbitrary cut-off frequency. A cut-off frequency of 50 cycles per second was used in calculating the curves given here.

The wiring diagram of the resistance-capacity coupled amplifier in its simple form is shown in Figure 1, together with the equivalent circuit in Figure 1A. The voltage V_g is the output

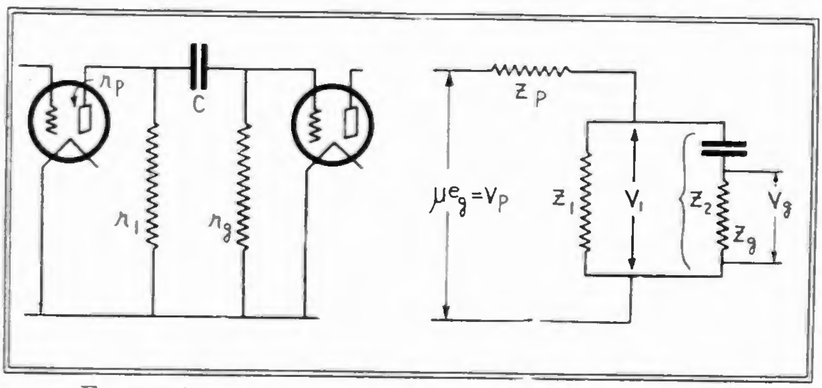


FIGURE 1 FIGURE 1-A

voltage of the coupling device and is impressed on the input of the second tube. V_p is the voltage input to the coupling device and equal to the voltage impressed on the input of the first tube multiplied by the voltage amplification constant of that tube or $\mu\, e_g$. The solution of Figure 1A follows:

$$\frac{V_g}{V_p} = \frac{V_g}{V_1} \times \frac{V_1}{V_p}$$

$$\frac{V_g}{V_1} = \frac{Z_g}{Z_2}$$

$$\frac{V_1}{V_p} = \frac{\dfrac{Z_1 Z_2}{Z_1+Z_2}}{Z_p + \dfrac{Z_1 Z_2}{Z_1+Z_2}} = \frac{Z_1 Z_2}{Z_p Z_1 + Z_p Z_2 + Z_1 Z_2}$$

$$\frac{V_g}{V_p} = \frac{1}{\dfrac{Z_p}{Z_g}\left[1+\dfrac{Z_2}{Z_1}\right]+\dfrac{Z_2}{Z_g}} \tag{1}$$

Substituting the vectorial impedance as represented in Figure 1, the relation between V_g and V_p for the resistance-capacity coupled amplifier is

$$K=\frac{V_g}{V_p}=\frac{1}{\frac{r_p}{r_g}\left[1+\frac{r_g-j/\omega c}{r_1}\right]+\frac{r_g-j/\omega c}{r_g}}$$

The absolute value of K is then:

$$K=\frac{1}{\sqrt{\left[\frac{\frac{r_1 r_g}{r_1+r_g}+r_p}{\frac{r_1 r_g}{r_1+r_g}}\right]^2+\frac{1}{\omega^2 r_g^2 C^2}\left[\frac{r_p}{r_1}+1\right]^2}} \tag{2}$$

The maximum voltage ratio is obtained when C is infinite. Equation (2) then reduces to

$$K_{max}=\frac{\frac{r_1 r_g}{r_1+r_g}}{\frac{r_1 r_g}{r_1+r_g}+r_p} \tag{3}$$

which is independent of frequency. The physical significance of this is apparent; the maximum voltage ratio is the ratio of the joint resistance of r_1 and r_g in parallel, to the sum of this joint resistance and r_p.

Equations (2) and (3) are shown plotted in Figures 2 and 3. It is desired to make the voltage ratio at a given cut-off frequency,

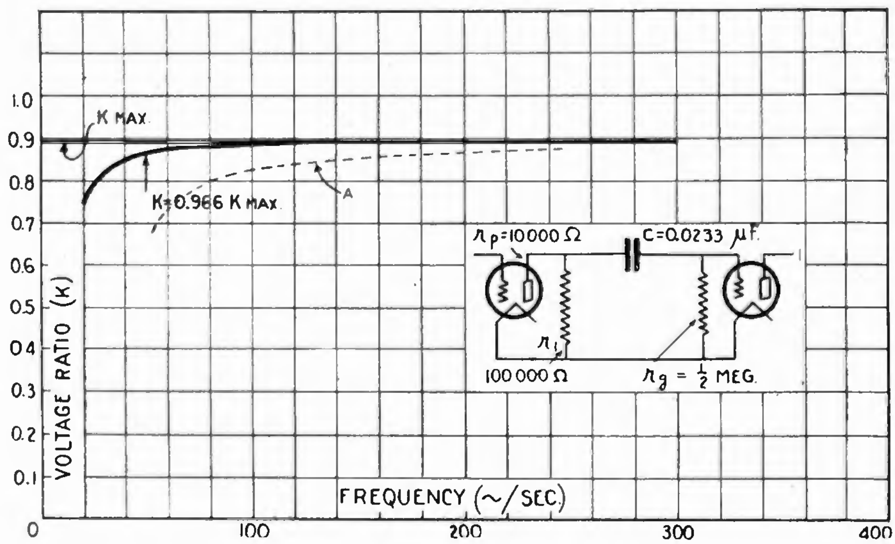


FIGURE 2

f_o, say 50 cycles per second, a certain fraction, k, of the maximum voltage ratio possible with the given combination of resistances.

The latter is the same as the voltage ratio at very high frequencies. Therefore:

$$k = \frac{K}{K_{max}} \tag{4}$$

Performing the operation indicated by (4), and solving for C,

$$C = \frac{(r_1+r_p)}{2\pi f_o[r_g(r_1+r_p)+r_1 r_p]\sqrt{\frac{1}{k^2}-1}} \tag{5}$$

This equation has been plotted in Figure 4, for three different values of k. In the present problem the lower limit of the voltage

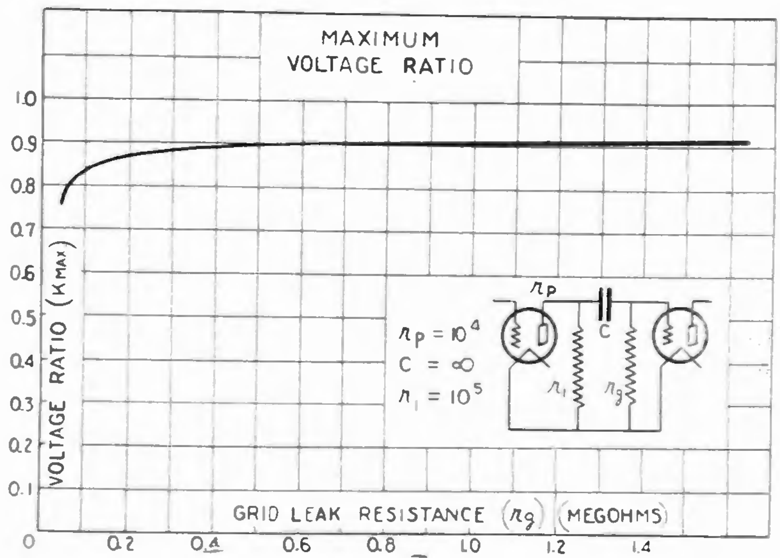


FIGURE 3

ratio is 90 per cent of the maximum attainable voltage ratio at the output of the amplifier. If there are two identical stages in the amplifier the value of k per stage will be $\sqrt{.90}$ (or 0.949); if there are three identical stages the value of k per stage will be $\sqrt[3]{.90}$ (or 0.966).

Figure 3 has been plotted for the purpose of noting what effect the grid-leak resistance has on the voltage ratio. For $r_p =$ 10,000 ohms, and $r_1 = 100{,}000$ ohms, it will be seen that little is gained in voltage ratio by making the grid-leak resistance greater than about 0.5 megohm. Applying this value to Figure 4, the capacity required in a three-stage amplifier in which the output voltage will not drop more than ten per cent from the high frequencies down to 50 cycles per second, is 0.0233 μf. These values were then used to calculate the curve of Figure 2.

The choice of r_g from Figure 3 depends not only upon the desired voltage ratio, but must also be sufficiently low that the grid does not accumulate an excessive grid charge. This matter is apart from the subject of this paper, but is to be considered in the design of the amplifier.

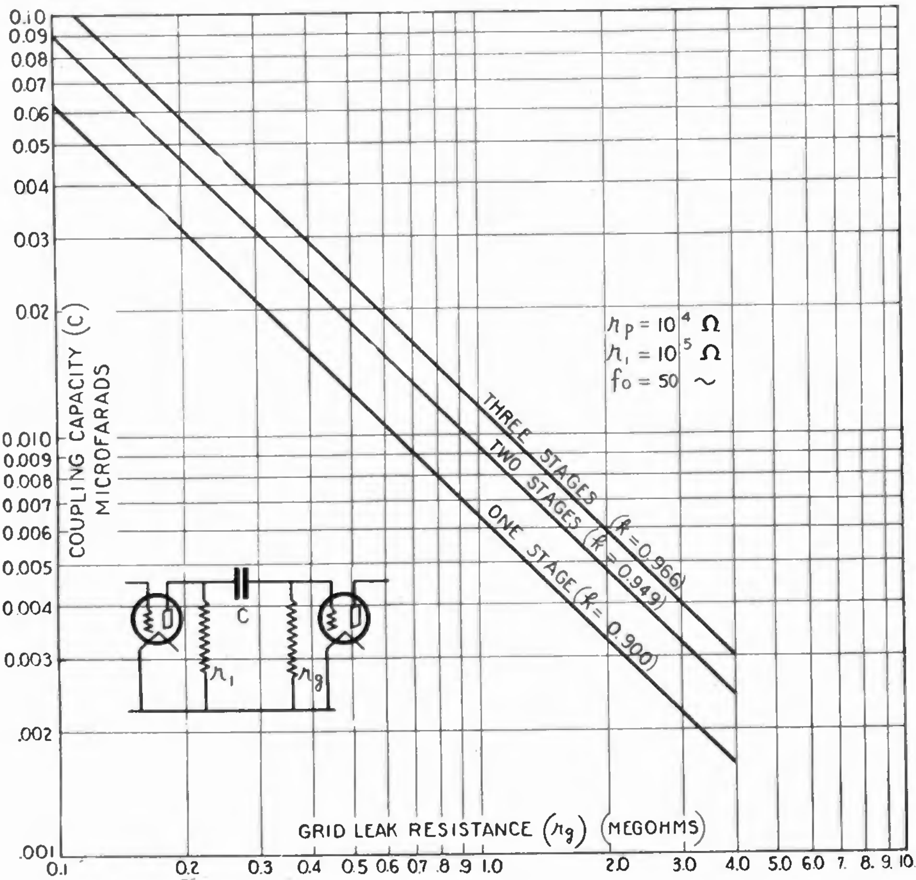


FIGURE 4

To illustrate the effect on the frequency characteristic of using too small a coupling condenser the curve marked "A" in Figure 2 was obtained experimentally, using the same resistances indicated on Figure 2, but a much smaller condenser.

SUMMARY: An analysis of the coupling in the resistance-capacity coupled amplifier is given, in which the variation of the voltage ratio with frequency is considered. A method is given for determining the values of the resistances and capacities for which the variation of voltage ratio over a given frequency range will be a definite and known amount.

SIMULTANEOUS ATMOSPHERIC DISTURBANCES IN RADIO TELEGRAPHY

By

M. Baumler

(Fourth Contribution from the Telegraphentechnischen Reichsamt.)

In three previous contributions on the appearance of simultaneous disturbances it was determined that the effect of a large part of the atmospheric disturbances extends not only over a small area around the receiving station, but that these same disturbances are noticeable at observation points at some distance from each other, and also that the range of the effect of the atmospheric disturbances is at times very large. The method of observation consisted of recording the atmospheric disturbances along with reference signals with recording apparatus in two places. The daily time signals from Lyon from 10 o'clock to 10.05 A. M. served as signals for determining simultaneous disturbances. The simultaneous or related disturbances can be determined from the occurrence of the disturbance relative to the simple mark of the time signals. The investigation led to the conclusion that between Gräfelfing, near Munich, and Strelitz—a distance of 580 km.—at which places the receiving apparatus was not influenced by local power disturbances, 98 per cent of all recorded disturbances occurred together. Between Berlin and Strelitz, as well as between Hamburg and Strelitz, the percentage of simultaneous disturbances was smaller, as in the large cities local power disturbances occur as well as the pure atmospheric disturbances. The extension of the experiments from Berlin to the east coast of North America—a distance of 6,400 km.—gives similar indications of simultaneous disturbances.

If one assumes the occurrence of disturbances at great distances as due to the propagation of electromagnetic waves, and that is a prevailing opinion of the nature of the atmospheric disturbances, it is left to try to determine whether disturbances at great distances do occur simultaneously and whether the percentage reaches any considerable amount.

Received by the Editor July 24, 1926. Presented at a meeting of the Institute of Radio Engineers, New York, N. Y., December 1, 1926.

The continuation of the experiments was made possible through the cooperation of the Radio Corporation of America, which had already taken part in the earlier experiments. The receiving stations at Kokohead at Oahu (Hawaiian Islands) and Marshall, California, belonging to the Radio Corporation and a special experiment station of the Telegraphentechnischen Reichsamt at Berlin served as recorder stations. The signals were sent on a wavelength of 17,500 meters from the transmitting station at Rocky Point (WQL) according to the following plan:

Test de WQL Date
a . . . . b . . . . c . . . . d . . . . etc. to z
Test de WQL Date
aa . . . ab . . . ac . . . ad, etc. to az
Test de WQL Date
ba . . . bb . . . bc . . . bd . . . etc. to bz

The space between the two letters or groups of letters amounted to 5 centimeters on the transmitting tape, the transmitting speed being 30 words per minute. The transmitting plan proved to be very satisfactory.

The distance between the transmitting and receiving stations are:

Rocky Point—Berlin 6,400 km.
Rocky Point—Marshall 4,300 km.
Rocky Point—Kokohead 8,200 km.
Marshall—Kokohead 3,900 km.
Berlin-Rocky Point-Marshall 10,700 km.
Berlin-Rocky Point-Marshall-Kokohead 14,600 km.

The great circle distance from Berlin to Kokohead, azimuth 8 degrees west of north, amounted to 11,700 km. The ink recorder of the Radio Corporation was used in Kokohead and Marshall. and a recorder similar in construction to the siphon recorders in cable telegraphy furnished by Fa. C. Lorenz, A.G., was used in Berlin. The investigation was carried out from March 1 to March 28, 1925. The transmitting time was from 3.30-3.35 A. M. eastern standard time or 9.30-9.35 P. M. in Berlin, 12.30-12.35 A. M. in Marshall and 10.30-10.35 P. M. in Kokohead. During the investigation it was, therefore, daylight in Berlin—Sunrise in March being approximately 5.50-6.50 A. M.—and night in Rocky Point, Marshall and Kokohead. The tape of the receiving apparatus was adjusted to a velocity of 1.5 meters per minute. This was not always possible. Photographs of the original tapes show how closely equal spacing of the characters on the various tapes was attained.

The quality of radio reception is dependent upon the ratio of signal strength to the atmospheric disturbances. If the ratio approaches unity, the possibility of recording decreases and reception is impossible if the signals fall below the disturbances or are otherwise suppressed, *i.e.*, if the average strength of the disturbance is higher than the signal strength. In the telephone receiver, disturbances of medium strength are noticeable through a continual grinding noise; in the recorder the pen moves back and forth across the tape tracing a non-readable curve. Such a case is shown in Figure 1, with a section of the tape taken March

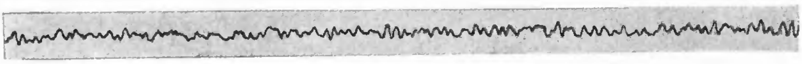


FIGURE 1—Kokohead, March 4, 1925

4, 1925, in which the signals of the transmitting scheme are in general unintelligible. Recording of signals from WQL at Kokohead is often impossible due to atmospheric disturbances, as the intensity is very different on various days. Also it must not be overlooked that the transmitting station at Rocky Point (WQL) is intended for traffic with Europe with distances of from 6,000 to 7,000 km., while the distance from Rocky Point to Kokohead is 8,200 km. with the greater part of the distance over land and hence unfavorable to the propagation of the electromagnetic waves.

We now turn to the results of the investigation. Figure 2 shows the section of the tape aj (- — - — — —) to ak (- — — - —) on March 27, 1925. The letters are somewhat

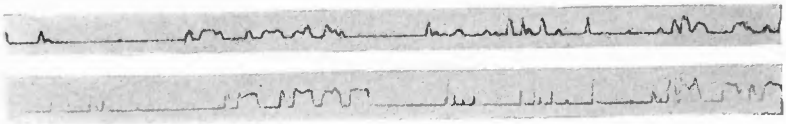
K
M


FIGURE 2—Kokohead and Marshall, March 27, 1925

mutilated in Kokohead but still recognizable. There is no doubt that the disturbance impulses obtained in Marshall are also present in Kokohead. In addition, a few other apparently purely local disturbances are observed in Kokohead.

Figure 3 show a section of the tape bg (— - - - — —.) to bh (— --- ----) on March 14, 1925. The disturbances recorded in Marshall are also recorded in Kokohead. The simultaneity is easily seen by comparing the two tapes. The tape at Kokohead is an example of showing the effect of disturbances on

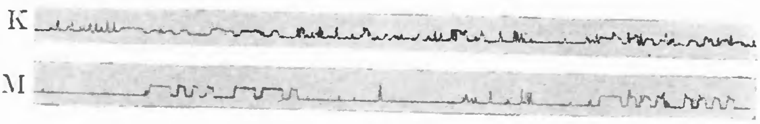


FIGURE 3—Kokohead and Marshall, March 14, 1925

the signals. The disturbances are even stronger than the signals. The reason for the smaller number of disturbances recorded at Marshall as compared to Kokohead is that the ratio of the signal to the strength of the disturbances was higher than in Kokohead and less amplification in the receiving apparatus necessary. The field strength at Marshall was higher, due to the shorter distance from Rocky Point.

Figures 4 and 5 show the tape sections x (—— — ——) to y (— - — ——) and ad (- — — - -) to ae (- — -) on March 10, 1925, at three receiving locations. The records of the signals and the disturbances are well shown. On the tape

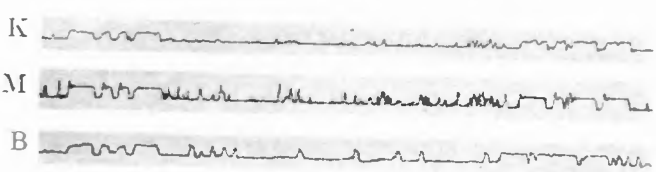


FIGURE 4—Kokohead, Marshall and Berlin, March 10, 1925

from Kokohead and Marshall individual groups of disturbances can be differentiated which consist of several single disturbances. It must be admitted that the disturbance groups and individual

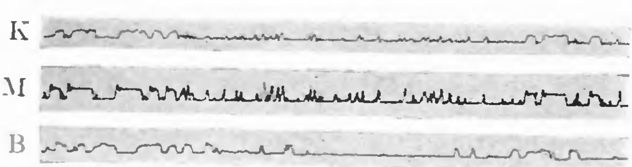


FIGURE 5—Kokohead, Marshall and Berlin, March 10, 1925

disturbances agree completely at the American receiving stations. The disturbances are less in Marshall as the signal amplitude is greater than in Kokohead, so that here the weaker disturbances appear only as smaller deflections above the zero line. From a count of the common disturbances and the determination of the percentage, and even without going through these computations, it is seen that nearly all of the disturbances recorded occur together and are of the same origin. At first sight, no disturbances common to Berlin and both the American receiving stations are received even when one considers the time interval between the reception of a signal and a disturbance impulse which it is assumed is received first in Marshall. For a tape velocity of 150 centimeters in a minute this difference is about 2/3 mm. on the tape. The character of the disturbances in Berlin is apparently quite different from that in Kokohead and Marshall. On the Berlin tape only a few occasional disturbances are seen. If one observes the tape somewhat closer one sees that between the dot and the second dash of the letter y for Kokohead and Marshall (underlined in Figure 4), a disturbance is shown which is also seen to occur in Berlin, for at this place, the y is not clearly recorded but mutilated; also it appears that the strong disturbances directly before the y are common to Berlin and Marshall.

Figures 6 and 7 are sections of the tape from three receiving stations on March 18, 1925.

The tapes are placed alongside each other and one can see the last letters of the test announcement: "Test de WQL March eighteenth." The Morse characters are drawn in on the tape

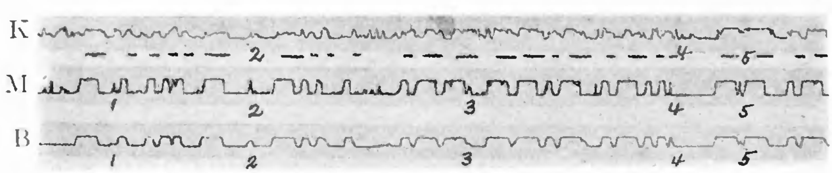


FIGURE 6—Kokohead, Marshall and Berlin, March 18, 1925

taken at Kokohead. The distribution of the disturbances is: few in Berlin, somewhat greater number in Marshall and a large number of disturbances in Kokohead. The signals in Kokohead are considerably mutilated by disturbances so that the text would be unintelligible if it were not known. On closer examination, a large part of the disturbances recorded in Marshall is found in the record at Kokohead, in spite of the great variation in the record. A comparison of the three tapes gives an agreement of a few of the disturbances recorded in Berlin with those in Marshall and even with those in Kokohead. The disturbances occurring simultaneously are marked by means of numbers.

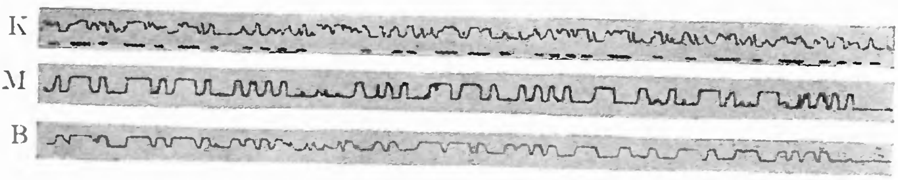


FIGURE 7—Kokohead. Marshall and Berlin. March 18, 1925

Between Berlin and Marshall the disturbances marked 1–8 correspond. On account of the small number of disturbances generally recorded this agreement should not be considered accidental. Between Berlin and Kokohead, an agreement is found in the disturbances marked 2, 4 and 5.

According to the present view, as previously mentioned, atmospheric disturbances consist of electromagnetic waves that have their origin in nature's electrical adjustments; one may speak, therefore, of these as natural waves in contrast with the waves artificially generated at a transmitting station. If we consider atmospheric disturbances as electromagnetic waves, then the laws of electromagnetic propagation must hold, that is, the propagation of disturbances must be better at night than during the day and the disturbances considerably reduced during the transition from darkness to daylight or vice versa, that is, in passing through a twilight zone. The relative location of the four receiving places with respect to day and night has been previously mentioned.

The explanation for the large number of simultaneous disturbances at Marshall and Kokohead lies in the good propagation conditions obtaining at night.

The extent to which disturbances occur simultaneously at different places depends further upon their strength, the distances of the observation points from the source and the sensitiveness of the receiving systems. If the disturbance is very strong, its effect may be felt at widely separated places. It is, however, not to be expected that the number of simultaneously occurring disturbances should reach any large amount and still less so if natural obstacles affect propagation. This accounts for the small number of disturbances common to Berlin and the American observation points. Correlation of the occurrence of disturbances of same origin at still greater distances may be established when proper receiving apparatus is provided.

Sudden disturbances in the electrical field of the atmosphere, the magnetic field of the earth, displacements inside the earth and electrical adjustments in the cosmos may be the source of disturbances. To the variation in the earth's electrical field belong lightning discharges, most important being the strong lightning discharges in the tropics.

By our researches we have ascertained the distant effect of lightning discharges. All unobjectionable disturbances arising from visible discharges should be especially marked on the tape. During the investigation strong thunder storms were encountered in Kokohead whose effect on the receiving system was so strong that the observations had to be suspended to prevent harm to observers and damage to the apparatus.

The results of the investigation are summarized as follows:

A large number of disturbances occur simultaneously in Hawaiian Islands and California, 3,900 km. apart; occasional disturbances occur simultaneously at distances 10,000-12,000 km. apart. The general propagation phenomena of electromagnetic waves are applied to the propagation of disturbances and explain thereby the frequency of the simultaneous occurrence of disturbances.

It is the intention to continue the investigation and to select the conditions so that the observation points lie entirely in light or darkness.

I do not wish to close without heartily thanking the engineers of the Radio Corporation at the receiving stations at Kokohead and Marshall as well as at the transmitting stations at Rocky Point, and especially, Director A. N. Goldsmith, who through their willingness and cooperation made the investigation possible.

SIMPLIFIED S.L.F. AND S.L.W. DESIGN*

By

O. C. Roos

(Consulting Engineer)

A concise paper on the design of S.L.F. condenser plates appeared August, 1925, in the PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, by Mr. H. C. Forbes. The method of attack is shown in Figure 1, where a polar curve 1–2–3–4–5 following a counter-clockwise or positive rotation, has a portion 3–4–5–3 of its polar area, used as a condenser plate. Its curved edge follows the polar equation

$$\rho^2 \theta^3 = K \quad (1)$$

The method of computing plate areas from the initial line o-z is the usual one, but is awkward, as it introduces the possibility of infinite plate areas and zero frequencies—both absurdities.

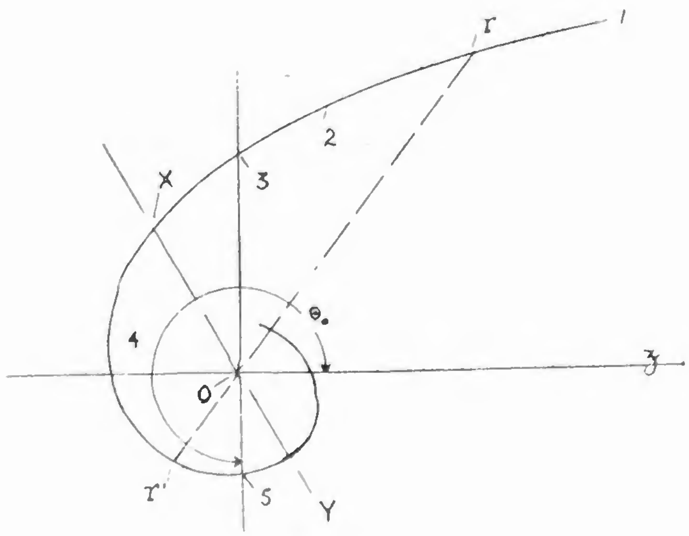


FIGURE 1

Again, the very beautiful simplicity of the law for predetermination of the frequency range as a ratio of f_m to f_n—maximum

*Received by the Editor, September 5, 1926.

and minimum frequencies respectively,—is overlooked and time is used in computation of a quantity that a simple ratio would give, if specified in advance.

For example, in Figure 1a we have a circular stator and a S.L.F. rotor plate. The latter has its straight edge 3–0–5 at right angles to the initial line *o–z* and its shortest radius at 0–5 makes an angle of 270 degrees with *o–z*. In Forbes' notation

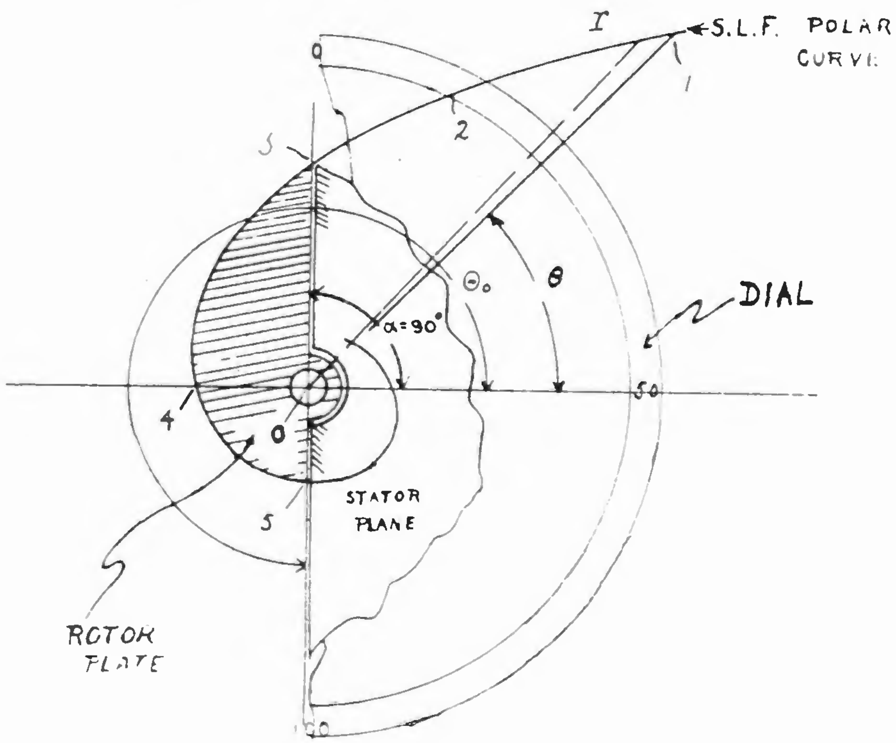


FIGURE 1a

this angle is θ and gives C_o or a zero capacitance, corresponding to stray capacitances which make up the polar area to infinity beyond his $\theta=0$, which is really 270 deg. or $3\pi/2$. This fictitious area for outside capacitances C_o is A_o.

$$A_o=\frac{K}{\theta_o^2}=\frac{K}{\left(\frac{3\pi}{2}\right)^2} \tag{1.1}$$

and could have been used in place of C_o times a constant. The relationship between maximum and minimum plate areas and the longest radius in the plate polar curve would then have been apparent.

Forbes writes $$C_\theta=\frac{D^2}{(D/C_o-K\theta)^2} \tag{2}$$

and it is obvious that when we rotate the plates positively,—counter-clockwise—the effective capacitance C_o may become infinite. This equation means that the 270-degree angle through z–1–2–3–4–5 in Figure 1a, corresponding to minimum frequency D/C_o or f_n, is unlimited in polar area. Therefore, if it could be meshed to give capacitance with another such plate, the frequency would be zero. No mention is made of any limit of positive plate rotation, although this must be 180 degrees and in any case less than C_o or 270 degrees. The capacitance may therefore be increased without limit by positive rotation, to 270 degrees with this as the greatest theoretical rotation of dial.

The awkwardness of this point of view—*i.e.*, working from the initial line of the polar plate-area curve,—should be noted. Even though this initial area is infinite, it does not include the important capacitance C_o which is due to the stray and extra capacitances related to the condenser at its "zero" position. This zero capacitance C_o and its predetermination is the whole secret of a rigorously accurate S.L.F. or S.L.W. condenser and should preferably be in the form of a simple ratio of the final polar radius angle to the initial polar radius angle of the plate-curve area to be selected.

When the plates are completely meshed in Figure 1a the wave length is three times its value at the zero position. In Figure 2 let us imagine a symmetrical stator plate completely meshed

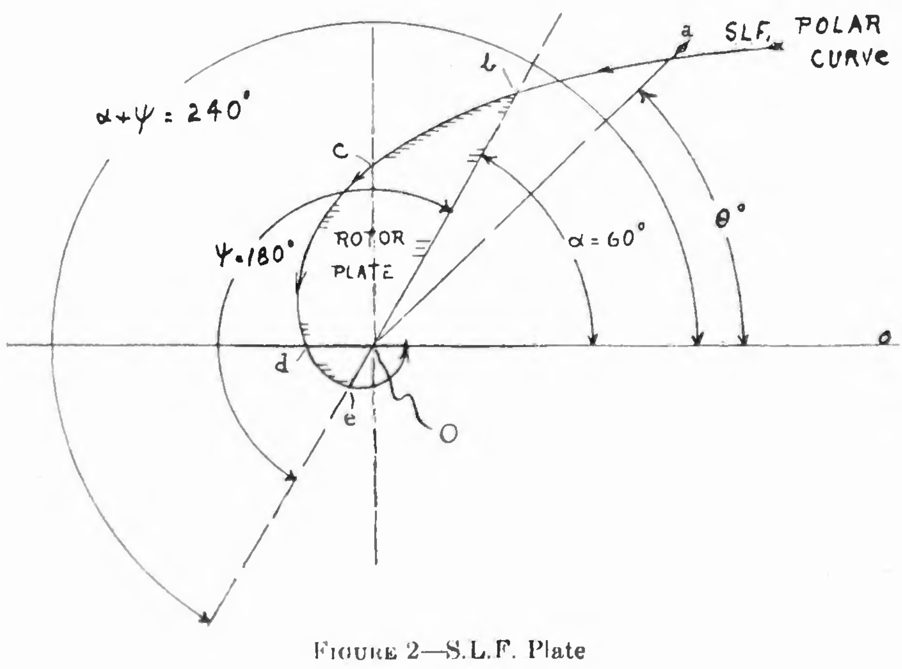


FIGURE 2—S.L.F. Plate

with the rotor $b-c-d-e-b$. Its edge coincides with the rotor plate edge $e-o-b$. Then the wave length is shortest and is four times that given by the fictitious area, C_o, beyond $o-e$ and which is one-fifteenth of the total plate area meshed.

In all plate-area ratios the effective "area" added by the wiring and stray flux is present as a practically constant extra quantity, for all positions of the rotor. If the maximum capacitance C_o in Figure 1a is 513 $\mu.\mu.f.$ then the external or minimum capacitance C_o must always be kept at one-ninth of this or 57 $\mu.\mu.f.$

Most radio manufacturers have ignored this requirement. One cannot design S.L.F. or S.L.W. condensers accurately without adjustable verniers for a constant C_n. The writer has been able to do this systematically. The self-capacitance of the same type of coil varies 10 per cent in production, so an adjustable extra capacitance is absolutely imperative for accurate S.L.F. or S.L.W. characteristics.

Re-examining our rotor plate, we will find that of 513 $\mu.\mu.f.$ total capacitance, 8/9 or 456 $\mu.\mu.f.$ corresponds to the plate area, and the balance is the everpresent "zero" capacitance.

The question now is: since we can't use the infinite "plate area" in Figure 4, to the "right" of $o-b$, where can we find this "zero" capacitance area, corresponding to 57 $\mu.\mu.f.$

The answer is simple but has not yet been given in any paper. The polar area from $o-e$ continued onward counter-clockwise forever—($\theta=\infty$)—is not infinite but finite. It is equal to C_n and

$$C_n = \frac{M}{(a+\psi)^2} = 57 \ \mu.\mu.f.$$

Hence by integrating from o–b corresponding to $\theta = a$ to $\theta = a + \psi$ we have $C_n = \frac{M}{a^2} = 513 \ \mu.\mu.f.$ or

$$C_m = \frac{M}{a^2} = 513 \ \mu.\mu.f., \text{ or } C_m/C_n = 9.$$

Mr. Forbes explicitly defines C_o as that capacitance which is present in the circuit when θ, the variable angle from the initial plate position, is made equal to zero. The presence of an infinite value for one of his limiting capacitances, *i.e.* polar areas, indicates that he has integrated said area from the initial line $O-o$ in Fig. 1a, counter-clockwise, instead of clockwise from the pole or what is the same thing, counter-clockwise from the initial angle a of the polar area, in Figure 2, to infinity. In this way the polar area comes out for the condenser plates, as

$$A = \frac{K}{a^2} - \frac{K}{(a+\psi)^2} \tag{3}$$

Now the frequency is given by

$$f = \frac{1}{\sqrt{A_\theta}} = \frac{1}{\sqrt{C_\theta}} = m\,\theta \tag{4}$$

and equation (1.1) is satisfied. The usual allowances of $+r_o^2$ and $-r_o^2$ for stator cut-out and circular separators respectively, produce the normal equation

$$\rho = \sqrt{\frac{4K}{\theta^3} + r_o^2 - r_1^2} \tag{5}$$

The prediction of the ratio $\frac{\lambda_m}{\lambda_n}$ or g is rendered easy and accurate by the formula

$$a = \frac{\psi}{g-1} \tag{5.1}$$

where ψ is the angle of the rotor plates—usually 180 degrees—and a is the initial angle in Figure 1.

If $g=2.5$—corresponding to $\lambda_m=550$, $\lambda_n=220$ meters—then $a=\frac{180}{1.5}=120$ degrees. Hence the rotor plate would be out from the polar area along the line x–0–y, which is 120 degrees from 0–0.

It is important to emphasize the fact that the area of the polar curve in the condenser plates is $\frac{g^2-1}{g^2}$ of the finite polar area from a to infinity, *i.e.*, if g is 3, then this plate area is 8/9 of the total finite polar area, the smaller or "zero" capacitance "area" being the "area" furnished by wires, tubes and stray flux. It should be noted that the polar curve defined by $\rho^2\theta^3=K$ of Figures 1, 1a and 2 has no point of inflection.

By building up a S.L.W. plate-curve from the pole outward, just as we have done in the above S.L.F. plate-curve, we can make up a combined S.L.W. and S.L.F. plate. The S.L.F. plate has its lower frequencies crowded together on the initial dial divisions. The S.L.W. plate has its shorter waves similarly crowded together on the initial dial divisions.

By starting with 75 degrees on a S.L.W. plate for 1600 to 800 kc. and finishing up with 375 meters to 585 meters on a

S.L.F. plate, we avoid crowding along both S.L.W. and S.L.F. scales.

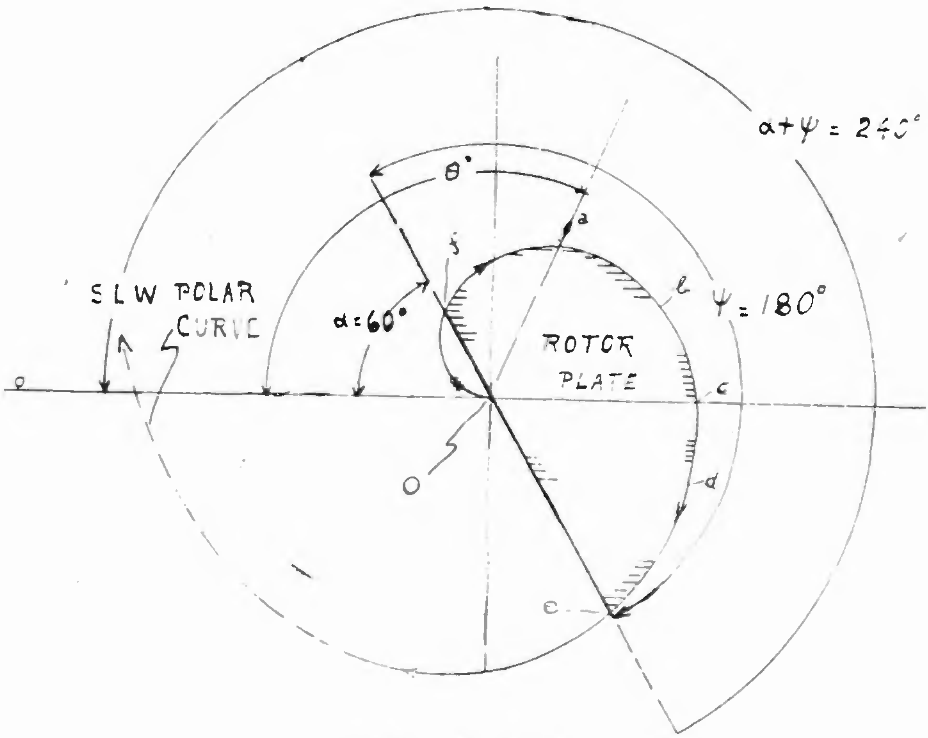


FIGURE 3—S.L.W. Plate

The S.L.W. plate is very easy to select from the S.L.W. polar curve shown in Figure 3. Unlike the S.L.F. curve, this S.L.W. polar curve starts exactly at the pole itself, when θ is

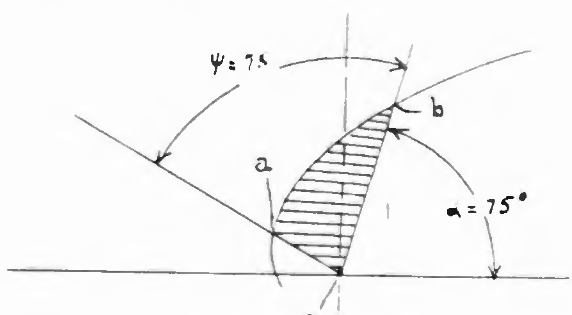


FIGURE 4—S.L.F. Plate Segment

zero. In a word, the radius is zero, in accordance with the equation

$$\rho^2 = 4\,K\,\theta$$

and the area, denoted by A, is given by

$$A = K\,\theta^2$$

The law of relative areas for S.L.W. ranges is the same in form as that for the S.L.F. type of plates, *i.e.* $a = \frac{\psi}{g-1}$ where ψ

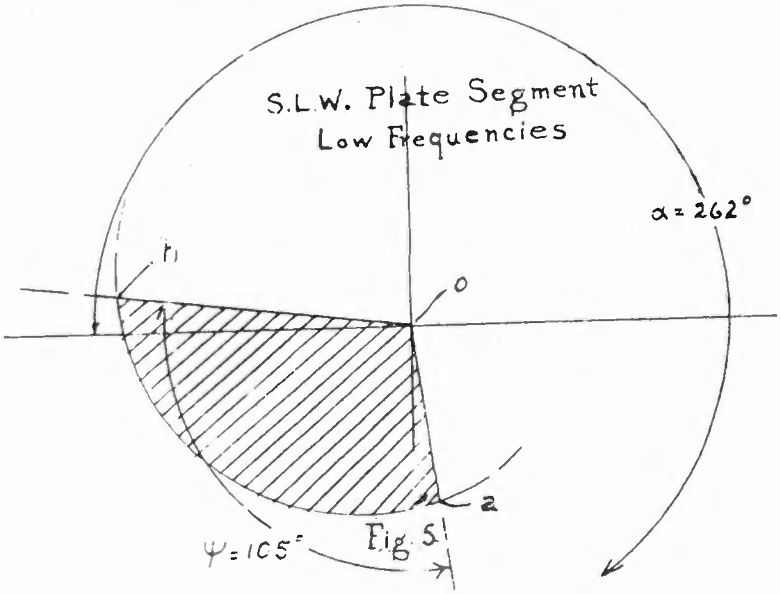


FIGURE 5

is the actual total plate rotation, g is the ratio of maximum to minimum wave length and a is the angle of the shortest polar radius vector used in Figure 3, corresponding to the shortest radio edge (in the S.L.F. plate it is the *longer* radial edge) of the condenser plate.

Working out these angles for the combined plate from

$$\rho^2 \theta^3 = K \text{ for S.L.F.}$$

and $$\rho^2 = 4 K' \theta \text{ for S.L.W.}$$

we find that the S.L.W. shortest edge is at 75 degrees from the initial line—see Figure 4,—and ends at 150 degrees from same. The last edge here and the first edge of the S.L.F. area must be

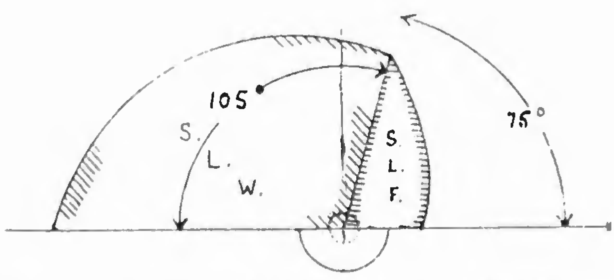


FIGURE 6—Combined S.L.F. and S.L.W. Plate Segments

the same in length, though the S.L.W. and S.L.F. curves need not be tangent to each other at this point, as some engineers seem to think.

The S.L.F. edge is started at 262 degrees and takes up 105 more degrees, ending at 367 degrees, as in Figure 5. Note that its longest radius at 367 degrees is the same as the shortest radius of the S.L.W. polar plate area.

The combined plate is sketched in Figure 6 and as we have two separate constants K and K' we have two degrees of mathematical freedom to make these edges as short or as long as necessary to coincide. No account is taken of cut-outs, for simplicity of illustration.

RADIO SIGNAL STRENGTH AND TEMPERATURE*

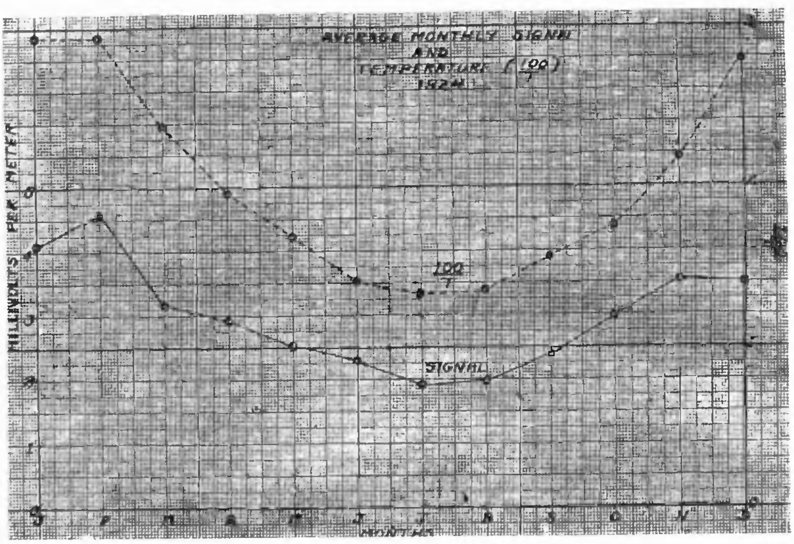
By

L. W. Austin and I. J. Wymore

(Laboratory for Special Radio Transmission Research)

(Conducted jointly by the Bureau of Standards and the American Section of the International Union of Scientific Radio Telegraphy)

During the cold waves of January, 1924, a marked increase in the strength of the signals from the transatlantic radio stations at Tuckerton and New Brunswick, N. J. was observed at Washington.[1] This was considered remarkable as the commonly accepted ideas regarding the earth's atmosphere indicate that there should be no connection between the weather near the ground and conditions at a height of 100 km., or more, where the main variations in signal intensity are supposed to be produced.



Transmission from stations at moderate distances, 200 to 600 km., seems better fitted for the study of possible meteorological influences than that from distant stations; for, while the relative

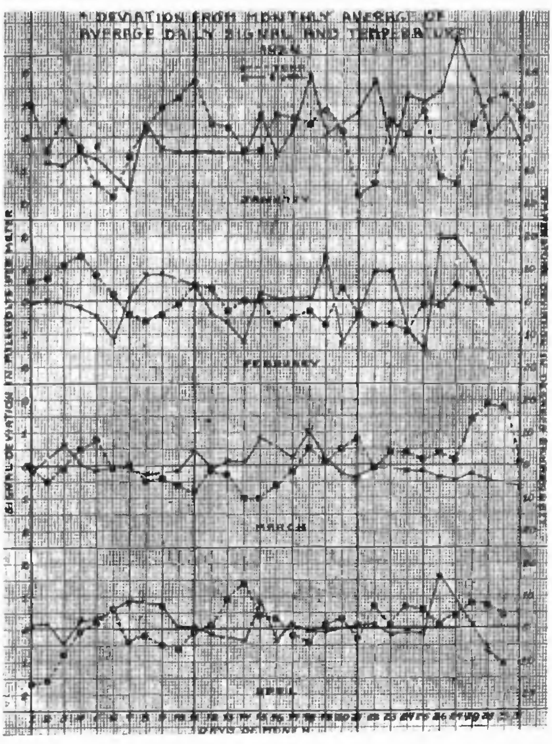
Received by the Editor, August 14, 1926.

*Published by permission of the Director of the National Bureau of Standards of the United States Department of Commerce.

[1] Proceedings of The Institute of Radio Engineers, vol. 12, p. 681; 1924.

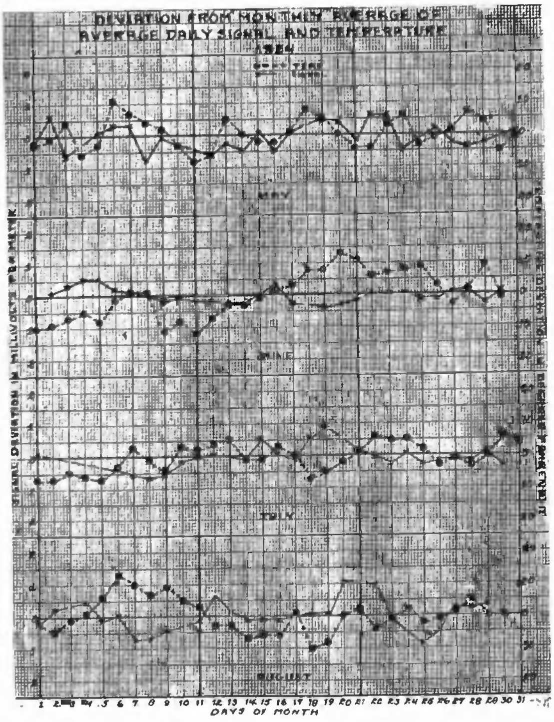
variations in signal field intensity are approximately the same, in the latter case weather conditions can not be expected to be uniform over the whole signal path. For distances much less than 200 km., the variations in signal strength for ths usual trans-atlantic wave lengths may become too small for profitable study.

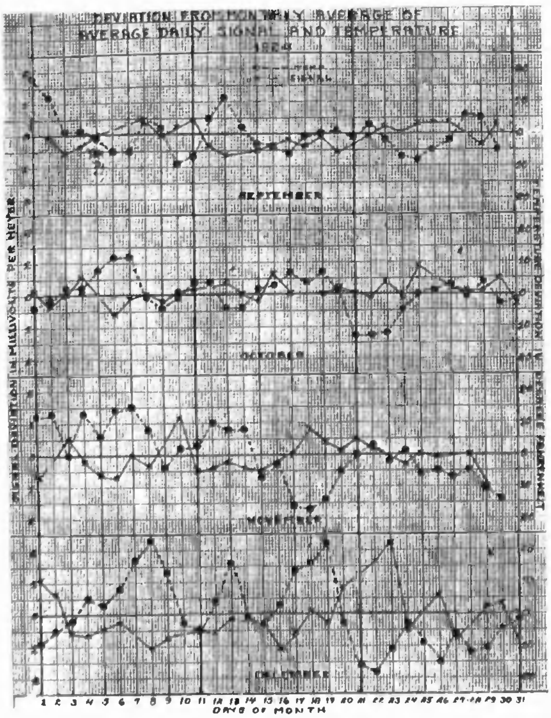
Continued daily observations on the two stations, extending over more than two years appear to prove that there is some kind of inverse relationship between signal strength and local temperature, though this temperature effect is often masked by other influences.



The degree of temperature—signal relationship may be judged from the accompanying curves for the year 1924. In the curve of monthly averages for the year, the average daylight signal intensity of the two stations corrected for antenna current changes is shown in millivolts per meter with the corresponding curve of 100/temp. (F.). The curves of daily averages for each month represent the plus and minus deviations of the signal intensity and of the temperature from the monthly means.

In the case of the curve of monthly averages, the connection between signal and temperature is self evident, the average signals of February being more than twice as strong as those of


DEVIATION FROM MONTHLY AVERAGE OF
AVERAGE DAILY SIGNAL AND TEMPERATURE
1924
MAY
JUNE
JULY
AUGUST
DAYS OF MONTH


DEVIATION FROM MONTHLY AVERAGE OF
AVERAGE DAILY SIGNAL AND TEMPERATURE
1924
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DAYS OF MONTH

July and considerably stronger than would be required by the inverse distance law (3.52 millivolts per meter). The day-by-day relationship is less satisfactory, varying from fairly clear in the winter months to obscure in midsummer.

That the variations in signal strength are actually produced in the upper atmosphere and not in the portion of the wave traveling along the ground seems to be proved by the fact that in the region involved there is no definite change in signal intensity, due to long continued rains or droughts or to the presence or absence of snow, for wave lengths over 1,000 m.[2] In addition, it is hardly conceivable that the rapid intensity changes observed during cold waves could be due to the penetration of frost in the ground, which is of necessity a gradual process.

	Frequency	Wave Length	Antenna Current	Effective Height	Distance
New Brunswick...	22.1 kc.	13,600 m.	600 amp.*	66 m.	281 km.
Tuckerton........	18.9 kc.	15,900 m.	500 amp.	68 m.	251 km.

*All observations are reduced to 600 amperes antenna current for New Brunswick and 500 amperes for Tuckerton.

[2]See PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, vol. 3, p. 310; 1915.

PREFERRED NUMBERS

By

L. A. Hazeltine

Among the many projects in standardization that are being considered by the American Engineering Standards Committee is one with a very wide field of application and of interest to all classes of engineers. This is the use of so-called Preferred Numbers. Such numbers are applicable particularly in the rating of apparatus where the values are initially arbitrary, where the range in values is wide, and where a geometrical series is not precluded by special technical considerations. The rating of motors is an example. A one-horsepower motor is in common commercial use, not because there is naturally more demand for 1 h.p. than for 0.9 or 1.1 h.p., but because the number 1 is a round number. The next larger size might be 1.5 h.p. or 2 h.p., depending on the size of step required by commercial considerations, rather than such odd numbers as 1.45 or 2.1 respectively.

Now the system of preferred numbers that has been most favored is one having the following properties: The numbers are very closely in a geometrical series; they include the number and factor 10, so that the series can be indefinitely extended by factors which are powers of 10; they include a large portion of the "roundest" possible numbers—that is, single-digit whole numbers; they include the number and factor 2; and from the principal series, other series can be derived to give finer or coarser steps. The principal series is given in column 1 of Table I. For a coarser series, every other number may be omitted as in column 2, and for a finer series, geometric mean numbers may be interpolated as in column 3.

These series, with minor modifications, have been accepted in some European countries, conspicuously France and Germany. They are regarded as affording an underlying basis for the rational selection of sizes; and while not always adhered to on account of practical considerations, are given study as a possible solution, followed through in principle or in detail, in so far as conditions seem to permit. At the time of the recent meeting in New York of the International Electrotechnical

Commission, an informal conference was held in which several foreign engineers recounted their experiences with Preferred Numbers, and the consensus of opinion was quite favorable toward their extended use.

TABLE I

1	2	3
1	1	1
		1.12
1.25		1.25
		1.4
1.6	1.6	1.6
		1.8
2		2
		2.25
2.5	2.5	2.5
		2.8
3.2		3.2
		3.6
4	4	4
		4.5
5		5
		5.6
6.4	6.4	6.4
		7.2
8		8
		9
10	10	10
		11.2
12.5		12.5
		14
16	16	16

Possible applications of preferred numbers in the radio field would be in the capacity ratings of fixed condensers and in the resistance ratings of fixed resistors. It would seem that the values given in Table II, which covers only a limited range, would well fill commercial requirements and would be sufficiently

TABLE II

Fixed Condensers, Capacity in Microfarads.	Grid Leaks. Resistance in Megohms.
0.00025	0.25
0.0004	0.4
0.00064	0.64
0.001	1
0.0016	1.6
0.0025	2.5
0.004	4
0.0064	6.4
0.01	10

near the values of present practice to impose no hardship. Many other uses in radio, are, of course, apparent.

The Institute of Radio Engineers is taking part in the study of Preferred Numbers and their application, being represented on the A. E. S. C. Sectional Committee by the writer. Comments by radio engineers would be most welcome. The American Engineering Standards Committee has available a number of publications on the subject, which may be obtained by those interested, on request addressed to its headquarters at 29 West 39th Street, New York City.

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY*

Issued September 7, 1926—October 26, 1926

By

JOHN B. BRADY

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

1,598,630—A. M. WENGEL, Madison, Wisconsin. Filed June 6, 1922, issued September 7, 1926.

ELECTROTHERAPEUTIC APPARATUS for operation from the usual 110-volt, 60-cycle current with an oscillatory circuit connected to a spark-gap system which is excited from a step-up transformer.

1,598,663—J. S. STONE, San Diego, California. Filed November 31, 1920, issued September 7, 1926. Assigned to American Telephone and Telegraph Company.

MULTIPLEX RADIO TELEGRAPHY AND TELEPHONY, in which a plurality of pairs of balanced transmitting antennas and a plurality of pairs of balanced receiving antennas are provided, each transmitting pair being conjugate with each receiving pair.

1,598,848—C. C. CHAPMAN, Palo Alto, California. Filed March 24, 1923, issued September 7, 1926. Assigned to Federal Telegraph Company.

RADIO FREQUENCY ARC CONVERTER AND METHOD OF OPERATING SAME. An arc converter is illustrated having a gaseous atmosphere supplied to the arc chamber. The gaseous atmosphere contains hydro-carbon material and an auxiliary heater is provided for decomposing the hydro-carbon and altering the molecular structure of the material.

1,599,453—H. A. AFFEL, Brooklyn, New York. Filed June 24, 1922, issued September 14, 1926. Assigned to American Telephone and Telegraph Company.

ANTENNA STRUCTURE, for operation with a plurality of different wave lengths where a plurality of filters each having different frequency cut off points are connected between the terminating point of the antenna and an outer end thereof, the distance between each of the filters and the terminating point of the antenna being the optimum length of the antenna for the frequency at which the particular filter cuts off.

1,599,471—R. F. KENYON, San Francisco, California. Filed March 7, 1925, issued September 14, 1926.

RADIO RECEIVER, in which a crystal detector is mounted upon a vertical panel and a rock lever provided for permitting the searching of the surface of the crystal.

1,599,586—E. S. PURINGTON, Cambridge, Massachusetts. Filed April 27, 1922, issued September 14, 1926. Assigned to John Hays Hammond, Jr.

RADIANT SIGNALING SYSTEM, whereby a semi-secret method of broadcasting is provided. Oscillations are produced of substantially constant amplitude and then the frequency wobbled and the signals transmitted by alternately impressing signaling current in the wobbled or unwobbled condition in the transmission circuit.

*Received by the Editor November 22, 1926.

1,559,596—T. SPOONER, Edgewood Park, Pennsylvania. Filed February 14, 1921, issued September 14, 1926. Assigned to Westinghouse Electric and Manufacturing Company.

PARALLEL OPERATION OF ARC OSCILLATORS, for obtaining a high alternating current from a direct current source of low voltage. Choke coils are included in the direct current leads to the arcs to prevent short-circuiting of the oscillating current and there is a ballast resistor individual to each of the arcs.

1,599,657—B. W. DAVIS, Cleveland Heights, Ohio. Filed March 18, 1922, issued September 14, 1926.

RADIO RECEIVING UNIT, consisting of a support for an electron tube, a control rheostat and a jack for providing connections to a telephone headset.

1,599,853—A. TOELLE, Anderson, Indiana. Filed October 13, 1922, issued September 14, 1926. Assigned to General Motors Corporation.

CONDENSER of coiled strip formation where the strips are wound in the shape of a cylinder and the cylinder supported from opposite ends, which provide terminals for the condenser.

1,599,859—C. E. WILSON and H. E. NORVIEL, Anderson, Indiana. Filed July 24, 1922, issued September 14, 1926. Assigned to General Motors Corporation.

CONDENSER of rolled paper and conductive strip construction formed in a compact cylinder body.

1,599,960—G. F. GILCRIST, San Francisco, California. Filed April 27, 1925, issued September 14, 1926.

PORTABLE FOLDABLE RADIO ANTENNA, consisting of wire frames which may be opened to cover a relatively large area or folded into compact size.

1,600,060—H. J. NOLTE, Schenectady, New York. Filed September 18, 1923, issued September 14, 1926. Assigned to General Electric Company.

ELECTRON DISCHARGE DEVICE of high power, wherein the grid is formed in a coil supported upon a frame carried from a ring which is bent around a plurality of supporting arms for providing a rigid mounting for the electrode.

1,600,115—L. D. KIMMEL, Bluffton, Ohio. Filed May, 26, 1923, issued September 14, 1926.

MILLED POST CONSTRUCTION FOR VARIABLE CONDENSER where a hexagonal post is milled to receive the edge of a condenser plate

1,600,204—E. F. W. ALEXANDERSON, Schenectady, New York. Filed November 28, 1924, issued September 14, 1926. Assigned to General Electric Company.

MEANS FOR TRANSMITTING ANGULAR MOTION, where impulses are radiated and the time-period thereof varied in accordance with the position of a transmitting device in such manner that a receiving device is enabled to reproduce the movements of a motion transmitting device.

1,600,421—J. MILLS, Wyoming, New Jersey. Filed December 28, 1920, issued September 21, 1926. Assigned to Western Electric Company.

OSCILLATION CIRCUIT having a high degree of constancy. The circut is enclosed in an envelope where the pressure is maintained low compared to that of the atmosphere for avoiding changes in frequency, due to changes in temperature.

1,601,065—T. R. GRIFFITH, Dover, New Jersey. Filed October 5, 1920, issued September 28, 1926. Assigned to Western Electric Company.

ELECTRON DISCHARGE DEVICE, in which the cathode is centrally positioned with respect to the cathode and grid and water-cooled by an eternal supply of water to the tube.

1,601,066—J. E. HARRIS, Newark, New Jersey. Filed Dcember 8, 1922, issued September 28, 1926. Assigned to Western Electric Company.

ELECTRIC DISCHARGE DEVICE, in which a cathode is provided, composed of barium and strontium oxides and an oxidized nickel chromium alloy grid.

1,601,070—J. W. HORTON, East Orange, New Jersey. Filed April 18, 1922, issued September 28, 1926. Assigned to Western Electric Company.

WAVE METER, comprising resonant circuits for attenuating the current supplied thereto by different amounts and an indicator. Currents are supplied to the indicator in opposite direction and by controlling the resonant circuits the effective currents supplied to the indicator may be measured, which is proportional to the indication of wave length.

1,601,071—J. W. HORTON, Bloomfield, New Jersey. Filed April 18, 1922, issued September 28, 1926. Assigned to Western Electric Company.

OSCILLATION GENERATOR, in which tubes are coupled in feedback relation and the entire oscillating output energy delivered through a path adapted to limit at a predetermined value the amplitude of the oscillator current. Oscillations of a selected frequency are produced by the current transversing this path and the potential of selected frequency may then be impressed upon the control element of one of the tubes of the system.

1,601,075—A. W. KISPAUGH, East Orange, New Jersey. Filed April 10, 1924, issued September 28, 1926. Assigned to Western Electric Company.

SYSTEM OF SPACE DISCHARGE DEVICES, in which energy is supplied to the electrodes of the tubes in proper sequence and its applications controlled to prevent surges in the circuit of the system.

1,601,109—E. L. CHAFFEE, Belmont, Massachusetts. Filed March 31, 1922, issued September 28, 1926. Assigned to John Hays Hammond, Jr.

MULTI-FREQUENCY RESONANT NET WORK, in which oscillations at different frequencies are impressed upon a net work which comprises reversely arranged couplings for preventing current impulses of one of the frequencies from reacting upon the source of the impulses of the other of the frequencies with means operatively connected with the net work for impressing the energy upon the ether for transmission of signals.

1,601,281—K. J. G. AHLSTRAND, Stockholm, Sweden. Filed May 4, 1926, issued September 28, 1926.

VARIABLE CONDENSER FOR TUNING ELECTRIC OSCILLATING CIRCUITS, in which a hollow spindle is provided with an auxiliary shaft thereon for securing a fine variation in the capacity of the condenser independent of larger variation under action of the main plates.

1,601,300—L. DIAMOND, Oakland, California. Filed July 27, 1925, issued September 28, 1926.

HELICAL PLATE CONDENSER, wherein the special relation of the plates may be varied by axial movement of a condenser shaft.

1,601,313—M. LATOUR, Paris, France. Filed August 19, 1921, issued September 28, 1926. Assigned to Latour Corporation.

VACUUM TUBE RELAY, where a direct current generator is arranged to charge a battery, which in turn delivers energy to the circuits of an electron tube.

1,601,322—A. PRESS, Wilkinsburg, Pennsylvania. Filed July 30, 1920, issued September 28, 1926. Assigned to Westinghouse Electric and Manufacturing Company.

DUPLEX RADIOTELEPHONY, in which the transmitting and receiving apparatus is alternately effective during spaced time intervals and so arranged that intermediate such intervals the transmitting apparatus does not interfere with the local receiving apparatus.

1,601,343—O. BUCHHOLZ, Neiderschonhausen, near Berlin, Germany. Filed August 26, 1921, issued September 28, 1926. Assigned to Westinghouse Electric and Manufacturing Company.

WAVE SIGNALING SYSTEM, in which a ground connection may be established between the grid circuit of one of the tubes of a cascade amplifier while such ground connection is prevented with the grid circuits of others of the tubes constituting the amplifier.

1,601,914—J. H. HAMMOND, JR., Gloucester, Massachusetts. Filed December 27, 1916, renewed May 17, 1923, issued October 5, 1926.

SYSTEM OF CONTROL BY LIGHT WAVES, in which a beam of sodium light is transmitted and received by a light sensitive element for actuating a responsive device. The receiving apparatus absorbs a specific spectrum of the light. The mass of material which receives the specific spectrum is rendered periodically effective and ineffective with respect to the indicating device.

1,602,056—PAUL M. TEBBS, Harrisburg, Pennsylvania. Filed December 1, 1924, issued October 5, 1926.

TUBE BASE, in which a tube is provided with side contacting members for establishing connection with radially directed contact members carried by the socket.

1,602,085—C. W. RICE and E. W. KELLOGG, Schenectady, New York. Filed April 10, 1920, issued October 5, 1926. Assigned to General Electric Company.

RADIO RECEIVING SYSTEM, comprising a substantially horizontal directive receiving antenna grounded at both ends with a physical length of at least the order of magnitude of the half wave length of the signaling wave to be received. The reflection of waves along the antenna is prevented and the receiving energy impressed upon the signaling receiving circuit.

1,602,086—C. W. RICE and E. W. KELLOGG, Schenectady, New York. Filed July 15, 1921, issued October 5, 1926. Assigned to General Electric Company.

RADIO RECEIVING SYSTEM, having highly directional characteristics. A low horizontal antenna is provided in which sets of series inductances and capacities are so proportioned that current waves of one particular frequency will be propagated along the length of antenna at a velocity substantially equal to the velocity of light.

1,602,198—M. LATOUR, Paris, France. Filed July 15, 1920, issued October 5, 1926. Assigned to Latour Corporation.

AERIAL FOR RADIO TELEGRAPHY AND TELEPHONY, having a plurality of ground connections with an electrically coupled system connected to the antenna for effecting a predetermined current flow in the ground connections for a given impressed transmitting current.

1,602,201—C. E. PEARSON, Cleveland, Ohio. Filed March 1, 1923, issued October 5, 1926. Assigned to The Teagle Company.

ELECTRICAL CONDENSER, where a plurality of conductive and dielectric sheets are secured under pressure by a resilient metallic clamping sheet which extends over the entire condenser.

1,598,824—P. E. KLOPSTEG, Chicago, Ill. Filed December 6, 1924, issued September 7, 1926. Assigned to Central Scientific Company.

AERIAL FOR RADIO RECEPTION, consisting of a foldable device having a hub with removable arms disposed in said hub. The arms of the frame are odd in number and carry a plurality of loops in staggered relation at each side of the frame.

1,599,104—A. H. TAYLOR, Washington, D. C. Filed May 29, 1923, issued September 7, 1926. Assigned to Wired Radio, Inc.

THERMIONIC VACUUM TUBE CIRCUITS, for transmission where the tube circuits are provided with means for compensating for variations in the supply of energy from the source to the circuits of the tubes during the making of signals.

1,599,180—O. T. McILVAINE, East Cleveland, Ohio. Filed July 2, 1925, issued September 7, 1926. Assigned to The Radio Television Company.

THERMIONIC TUBE, having an electron emitting member heated by a removable electric resistance unit which may be operated from the lighting circuit.

1,602,439—M. LATOUR, Paris, France. Filed (original) July 15, 1920; division filed October 30, 1923; issued October 12, 1926.

ELECTROMAGNETIC WAVE GENERATING SYSTEM, in which an oscillation generator has its output controlled by a tube which is placed in series with the grid filament circuit of the oscillator.

1,602,566—K. BURK, Basel, Switzerland. Filed January 6, 1925, issued October 12, 1926.

FRAME AERIAL FOR RADIO TELEGRAPHY AND TELEPHONY, which may be folded into a compact space. Wire is wound upon a series of spools which are carried by a frame, the wire being formed into polygonal shapes with minimum distributed capacity.

1,602,917—L. O. MARSTELLER, Wilkinsburg, Pennsylvania. Filed August 22, 1922, issued October 12, 1926. Assigned to Westinghouse Electric and Manufacturing Company.

RADIO RECEIVING APPARATUS, of compact size in which the receiving apparatus is contained within a small casing and switching equipment provided on the exterior of the casing for establishing connection with the apparatus interior thereof.

1,602,943—KARL ROTTGARDT, Dahlem, Germany. Filed August 26, 1921, issued October 12, 1926. Assigned to Westinghouse Electric and Manufacturing Company.

ELECTRICAL DISCHARGE VESSEL FOR THE PRODUCTION OF AMPLIFICATION OF OSCILLATIONS, in which a plate electrode and two grid electrodes one on each side of the plate electrode are provided. There is a direct metallic connection between the grid electrodes so that the grid electrodes are maintained at the same potential.

1,602,975—PAUL M. HENGSTENBERG, Wilkinsburg, Pennsylvania. Filed September 16, 1922, issued October 12, 1926. Assigned to Westinghouse Electric and Manufacturing Company.

RADIO RECEIVING APPARATUS, comprising a compact assembly of apparatus in which inductance coils within a casing are connected to an exterior switching apparatus. The supports for the casing also provide connections for the inductances interior of the casing.

1,603,041—R. GAUDIO, Brooklyn, New York. Filed February 18, 1926, issued October 12, 1926.

VARIABLE CONDENSER, comprising a pair of flat annular discs embedded in insulation material, one plate being movable with respect to an adjacent plate for varying the mutual capacity.

1,603,156—FRANK SEELAU, Detroit, Michigan. Filed October 23, 1924, issued October 12, 1926.

VARIABLE CONDENSER, consisting of flexibly mounted plates movable within a casing with a rotatable device for varying the spacial relation between the plates and the casing.

1,603,184—J. J. AURYNGER, Brooklyn, New York. Filed August 16, 1922, issued October 12, 1926.

CONDENSER, in which the plates are provided with a plurality of perferations having equal electric density throughout with a distributed unit area of plate capacity.

1,603,209—J. H. PAYNE, JR., Ballston Spa, New York. Filed September 30, 1922, issued October 12, 1926. Assigned to General Electric Company.

ELECTRICAL DISCHARGE DEVICE for high power operation consisting of a metallic casing with an electrode supported in the casing and a seal including a vitreous sleeve with a flexible member connecting the electrode and the seal.

1,603,284—J. B. JOHNSON, Elmhurst, New York. Filed November 24, 1924, issued October 19, 1926. Assigned to Western Electric Company.

ELECTRIC DISCHARGE DEVICE, having a fluorescent screen comprising a mixture of zinc salt and calcium tungstate.

1,603,369—T. WHEELER, Chicago, Illinois. Filed May 8, 1924, issued October 19, 1926.

LOOP AERIAL AND THE LIKE, which may be folded into a small compact structure for portable use. The cross arms are each arranged to support the wires in spaced relation at the extremities thereof.

1,603,468—BERLIN-FRIEDENAU, Germany. Filed October 19, 1922, issued October 19, 1926. Assigned to Siemens and Halske.

METHOD OF IMPROVING THE INSULATION OF VACUUM TUBES, by providing an outwardly opening concavity whose walls consist of the same material as that which constitutes the tube. The outer opening of the cavity is closed by means of a non-hydroscopic insulator.

1,603,494—E. S. PRIDHAM and P. L. JENSEN, of Oakland, California. Filed November 8, 1924, issued October 19, 1926. Assigned to The Magnavox Company.

RADIO RECEIVING APPARATUS, in which a plurality of variometers are journaled on separate shafts and connected together by gearing for simultaneous control from a central point.

1,603,582—L. M. CLEMENT, Mountain Lake, New Jersey. Filed May 3, 1921, issued October 19, 1926. Assigned to Western Electric Company.

CARRIER WAVE TRANSMISSION SYSTEM, in which radio toll links are provided for connecting ordinary telephone and telegraph systems for two-way communication. The abrupt switching required in establishing radio toll connections introduces the problem of undesirable surges in the transmitter oscillator, and the invention is directed to circuits for avoiding these difficulties.

1,603,640—WALTER C. REED, Dalton, Massachusetts. Filed May 20, 1925, issued October 19, 1926. Assigned to Radio Products and Specialty Company.

RADIO FIXED CONDENSER, where a central eyelet rivet is provided for holding a plurality of concentric plates under pressure.

1,603,939—W. DUBILIER, New York, N. Y. Filed January 21, 1921, issued October 19, 1926. Assigned to Dubilier Condenser and Radio Corporation.

CONDENSER CONSTRUCTION for fixed electrical condensers wherein high insulation is afforded by the arrangement of a plurality of condenser sections into stacks which are separated from each other by dielectric sheets.

1,604,129—A. MEISSNER, Berlin, Germany. Filed August 8, 1922, issued October 26, 1926. Assigned to Gesellschaft fur Drahtlose Telegraphie.

TRANSMITTING ARRANGEMENT FOR RADIO TELEGRAPHY AND TELEPHONY, in which a plurality of separate paths are provided at different areas of the antenna. These areas are positioned at successively increasing distances from the apparatus and the paths have equal impedances.

1,604,140—H. A. AFFEL, Maplewood, New Jersey. Filed September 19, 1924, issued October 26, 1926. Assigned to American Telephone and Telegraph Company.

MULTIFREQUENCY OSCILLATOR, having a closed path in which the oscillations flow with circuits for determining a primary frequency and tuned circuits for providing a plurality of changes in frequency as the energy flows over the path. The frequencies which result from such frequency changes are not related to the primary frequency as harmonics thereof where an antenna is provided with separate paths connecting the apparatus with different areas of the antenna. These areas are at successively increasing distances from the apparatus and the paths have equal impedances.

1,604,171—C. B. KINLEY, Detroit, Michigan. Filed June 23, 1925, issued October 26, 1926.

CONDENSER OPERATING DEVICE, in which a slidable rack is arranged to operate a plurality of pinions for reciprocating sets of condenser plates with respect to other sets of condenser plates for controlling the tuning of a plurality of circuits.

1,604,403—JOHN H. FLYNN, JR., Cincinnati, Ohio. Filed December 15, 1924, issued October 26, 1926.

RADIO APPARATUS, in which a crystal detector is provided having a reciprocatory contacting arm which may be adjusted in position to select a sensitive point on the crystal.

1,604,508—ZISCH, G. J., West Orange, New Jersey. Filed March 25, 1925, issued October 26, 1926.

VERNIER CONDENSER of the variable plate construction where the sets of plates consist of sectors having progerssively differing areas.

1,604,533—RYAN, C. P., East Molesey, England. Filed February 26, 1924, issued October 26, 1926. Assigned to Vickers Limited.

RADIO CONTROL APPARATUS, which is tuned to the tone frequency of the signals and selectively actuated by incoming signals for closing a local control circuit.

D-71,138—FREDERICK DIETRICH, New York City, N. Y. Filed June 28, 1926, issued September 28, 1926. Assigned to Brandes Laboratories, Incorporated.

TABLE CONE DESIGN as manufactured by Brandes Products Corporation comprising an acoustic chamber and cone with a parabolic sound reflecting chamber enclosing the cone.

1,604,017—C. A. BRIGHAM and D. H. MOSS of Newark, New Jersey. Filed October 2, 1925, issued October 19, 1926. Assigned to Brandes Laboratories, Incorporated.

CONE TYPE LOUD SPEAKER, where the cone diaphragm is mounted within an acoustic chamber such as the cabinet of a radio receiver, and the sound reproduction modified by the operation of the cabinet.

1,600,980—WILLIAM H. GERNS, of East Orange, New Jersey. Filed December 11, 1925, issued September 28, 1926. Assigned to Brandes Laboratories, Incorporated.

SOUND REPRODUCER, consisting of an electro-magnetic operating mechanism having a screw threaded casing which may be adjusted to selected positions with respect to a sound-reproducing diaphragm for fixing the magnetic gap for efficient operation for particular programs.