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IMPEDANCE MEASUREMENTS OVER A WIDE FREQUENCY RANGE

By L. E. Packard

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Technical meetings are held on the second Thursday evening each month from September through June at either Havemeyer or Pupin Hall, Columbia University, Broadway and 116th Street, New York The public is invited.

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CLUB NEWS

ELECTION OF ADDITIONAL DIRECTORS

At the Club meeting of March 12th the membership approved steps for making changes in the Certificate of Incorporation and in the Constitution in order to establish the number of officers and directors as eighteen and the quorum at directors' meetings as six. Following this meeting, the Certificate of Incorporation was duly amended by appropriate steps, so that five additional directors were elected at a meeting of the Board of Directors on April 14th. The new directors are as follows:

Charles W. Horn
J. Kelby Johnson
Frank King
Haraden Pratt
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ADVANCEMENT TO FELLOW GRADE

The Board of Directors voted on January 23rd to offer advancement from the Member to the Fellow grade of membership to a number of qualified Members. To date acceptances of the higher grade have been received from the following:

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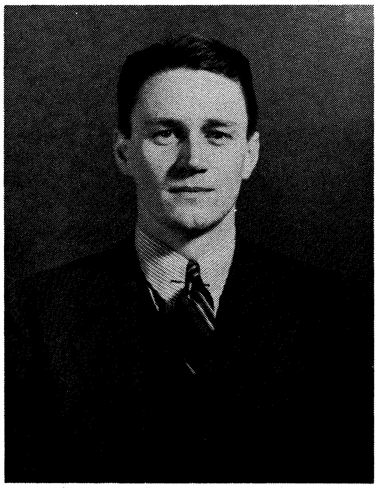
By L. E. Packard*

The frequency, along with the parameters resistance, capacitance and inductance, must be given if the electrical properties of a material are to be completely described. Most materials change their electrical properties even over such a narrow range of frequencies as the audio-frequency band. Hence, with the range of interest in electrical properties of materials extending many decades above and below the audio-frequency range, changes that cannot be considered negligible are involved.

Figure 1, taken after Murphy and Morgan[1], illustrates typical changes that may be obtained with the simplest of materials. It will be noted from these curves that considerable variation in parameters may be obtained over the frequency range extending from below a millicycle to above 100 megacycles. The regions of change are marked "Interfacial Polarization" in the low frequency range and "Dipole Polarization" at the higher frequencies. If this curve were to extend to even higher frequencies in the infra-red part of the electromagnetic spectrum, a similar region of change would occur due to atomic polarization; at still higher frequencies in the visible spectrum another such region due to electronic polarization would be found. With the more complex materials the position of polarization in the frequency spectrum may be changed and other polarizations may be introduced.



L. E. Packard, the author of this paper, was born in Somerville, Massachusetts on January 21, 1914. He received the B. S. degree in electrical engineering from the Massachusetts Institute of Technology in 1935. From 1935 to 1936 he did laboratory and development work for the Mason-Nielon Regulator Company. From 1936 to the present time he has been a member of the engineering staff of the General Radio Company, being now their engineering representative in New York City.

The appreciable variation in characteristics of a material brought about by polarization means that radio parts, such as coils, condensers, insulators, etc., using these materials must be tested at operating frequencies. Tests at frequencies other than that of normal operation might be greatly misleading and would not have any direct bearing on the performance of such parts when placed in service. With the extension of radio and television to higher frequencies the necessity of measurements at tens and hundreds of megacycles is now generally realized.

The effect of polarization on the behavior of electrical insulating materials is of principal concern when their application to specific uses is involved. To those interested in conducting research as to the cause of a material's behavior, the characteristics of the polarization are of assistance because they yield much helpful information concerning the electrical and molecular structure of the materials.

Measurements at "Infra-Low" Frequencies

The interests of the communication engineer and the chemist and physicist are centered primarily around measurements at audio and higher frequencies. In the electric power field recent theoretical investigation into methods of determining the condition of electrical power insulation, such as used in power transformers, bushings, and generators, has involved measurements nearly as many decades below 1 kilocycle as the communication work has above.

Interfacial polarization usually occurs well below 1 cycle for most insulating materials. A measure of the relaxation frequency due to interfacial polarization, rather than the usual quantities of direct-current resistance and 60-cycle power factor, has promise of

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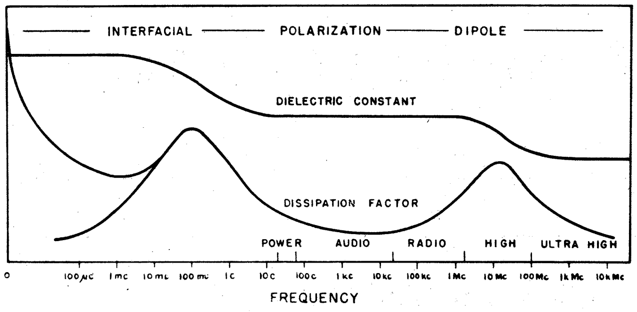

Fig. 1 Variation of Material Properties with Frequency.

leading to an improvement in the technique of indicating insulation conditions or predicting failure. At frequencies below about 10 cycles per second, bridge and resonance methods cannot be successfully employed for obvious reasons. The technique of obtaining dielectric constant and loss factor from the millicycle region to 10 cycles involves a mathematical analysis of the curves of charge or discharge current. Such curves can be obtained through the use of a megohm bridge by taking readings and plotting the resistance of the sample under test versus time. Such measurements can be taken with a high-resistance bridge such as shown in Fig. 2[2]. Equivalent circuits consisting of series and parallel combinations of resistance and capacitance may be set up, which will produce a resistance-versus-time curve of similar shape. From such a circuit of known parameters the variation of capacitance-and-loss-factor versus frequency for the sample under test can be determined. In the paper[3] "The Basis for the Nondestructive Testing of Insulation," Robert F. Field has discussed the technique of measurement and analysis of such curves together with the value of such information in predicting insulation condition.

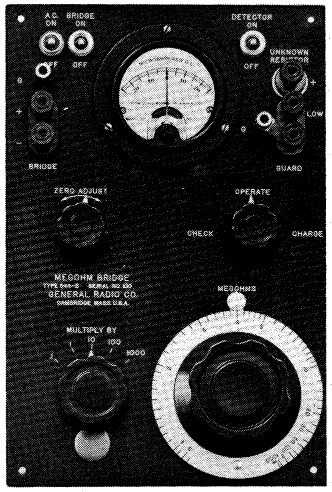

Fig. 2 High Resistance Bridge

MEASUREMENTS AT AUDIO AND HIGHER FREQUENCIES

Above about 10 cycles per second impedances are measured and compared by null methods as used in the various bridge circuits and T-networks or by deflection methods as used with tuned circuits. In general, the null methods are superior in precision of setting to the deflection methods because the latter are limited by the scale length of the deflecting meter. At the lower frequencies precision of setting is of primary importance and null methods are used almost exclusively.

Residuals that are present in all circuit parameters do not seriously impair the performance of measuring circuits at audio frequencies. In most circuits residual impedances if not negligible can be compensated for so that their effects are nullified.

Most audio-frequency bridge circuits are made up of both fixed and variable resistance and capacitance standards. At audio frequencies such standards are convenient and their residuals are sufficiently small so that they can be either neglected or easily compensated for. Among the most widely used circuits in audio-frequency bridge design are the Impedance Bridge and the Schering Bridge[4].

IMPEDANCE BRIDGE

The impedance bridge shown in Fig. 3, consists basically of a pair of resistance ratio arms, a standard condenser against which the unknown reactance is compared, and a resistance either in series or in parallel with that condenser in order to balance the loss factor of the unknown reactance. A series combination of standard condenser and variable resistor is usually used for the measurement of samples having small loss, and a parallel combination for samples having high losses. As with most bridges, either the generator or detector, but not both, can be connected to ground, thus necessitating the use of an isolating transformer.

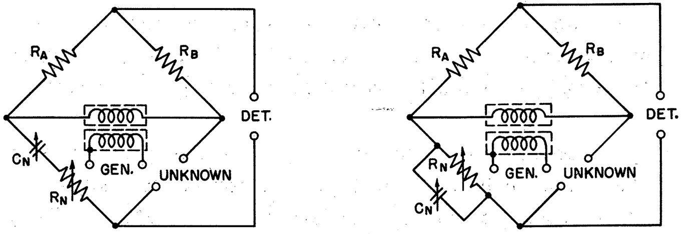

Fig. 3 Two Forms of the "Impedance Bridge" Differing in Method of Obtaining Loss-Factor Balance.

Balance can be accomplished by varying capacitance C_N and resistance R_N. When an unknown impedance, Z_x, consisting of R_x plus jX_x, is to be measured a differential procedure is usually followed consisting of an initial balance (R_1 and C_1) for an auxiliary capacitance and a final balance (R_2 and C_2) for the unknown impedance connected either in series or in parallel with the auxiliary capacitance. Care should be taken to avoid resonance effects.

If the series combination of impedance and auxiliary capacitance is used with this procedure, the resistive and reactive components of the unknown impedance can be determined from the formulas,

$$R_x = R_2 - R_1,$$

and

$$X_x = \frac{1}{\omega} \frac{C_2 - C_1}{C_1 C_2}$$

If the parallel substitution method is used, the unknown-conductance component is represented by

$$G_x = \frac{R_1 - R_2}{R_1 R_2}$$

and the unknown susceptance component by

$$B_x = \omega (C_2 - C_1).$$

The resistive and reactive components may then be determined from the conductance and susceptance values by means of the following formulas:

$$R_x = \frac{G_x}{G_x^2 + B_x^2},$$

and

$$X_x = \frac{-B_x}{G_x^2 + B_x^2}$$

If capacitors only are to be measured, direct reading of both capacitance and loss factor can be accomplished by balancing the reactive component with the ratio arm R_A[5]. If this is done the capacitance standard C_N may be fixed, thus permitting the variable resistor R_N in series or in parallel with it to be calibrated for direct reading of the loss factor. With this type of bridge the unknown capacitance is given by

$$C_x = C_n \frac{R_A}{R_B}$$

The *loss factor*, or *dissipation factor*, is given by

$$D_x = \frac{R_x}{X_x} = R_N \omega C_N$$ for the series connection of C_N and R_N, and by

$$D_x = \frac{1}{R_N \omega C_N}$$

for the parallel connection.

A fact which is sometimes overlooked when capacitance measurements are made with such an instrument is that with the series combination of standard condenser and resistor, capacitance readings obtained are equivalent-series capacitances of the unknown condenser, whereas if the parallel combination is used the bridge readings are equivalent-parallel capacitances. When capacitances with small losses are involved, the difference between the equivalent series and parallel capacitances is so small that it can be neglected, but with condensers having large losses the equivalent-series capacitance may differ greatly from the parallel capacitance; usually it is the parallel capacitance that is of the greatest interest. Conversion from equivalent-series to equivalent-parallel capacitance can be readily made with the following formula:

$$C_p = \frac{C_S}{1 + D^2}$$

The frequency range over which these impedance bridges can be conveniently used is restricted principally by the variable resistors which are inherent in its design. The residuals in variable resistors that have been so far designed are of sufficient magnitude to confine their use to low or audio frequencies.

SCHERING BRIDGE

The Schering Bridge[6] is also widely used for impedance measurements at audio frequencies. This is shown in Fig. 4; it is similar to the impedance bridge, the principal difference being that the loss-factor balance is accomplished by a variable capacitance across one of the resistance ratio-arms rather than by a variable resistance combined with the standard condenser. The reactance balance is obtained by varying the standard condenser. The reactance and loss-factor balances are independent of each other, and are such that they

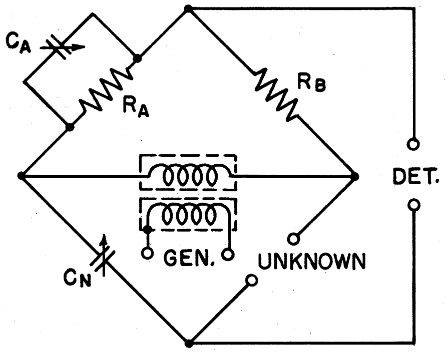

Fig. 4 Connections of the Schering Bridge

can be made direct-reading in terms of capacitance and dissipation factor. This bridge, therefore, consisting only of fixed resistors and variable condensers, is better suited than the Impedance Bridge to operation at the higher frequencies. When the Schering Bridge is used for capacitance measurements the following formulas apply:

$$C_X = C_N \frac{R_A}{R_B},$$

$$D_X = \frac{R_X}{X_X} = Q_A = R_A \omega C_A,$$

where Q_A is the conventional Q for the combination of C_A and R_A.

Inductive as well as capacitive reactance can be measured with this instrument through the use of the differential method of measurement, as previously outlined in the discussion of the Impedance Bridge.

The Schering Bridge in slightly modified form, and suitable for operation up to as high as 4 megacycles, has been available for several years. The operation of the instrument at higher frequencies has until recently been limited by residuals in fixed resistors, variable capacitors, isolating transformers, and wiring. At the higher frequencies these residuals introduce errors of such magnitude that in the selection of measuring method precision of reading no longer predominates. The choice of bridge circuit, T network, or tuned circuit method may, therefore, be determined by residual parameters rather than by precision of deflection reading or null indication.

TUNED CIRCUITS

Tuned circuits have long been used for the comparison of capacitance and resistance at high frequencies. The considerable disrepute into which this method has fallen is perhaps largely attributable to a disregard of the effect of residual impedances, rather than any intrinsic inferiority. With suitable precautions, resonance methods are the equals of bridge methods at the higher frequencies, and it is probable that as the upper limit of measuring frequency is raised tuned circuits will continue to be used.

The tuned circuit selected[7,8] as being the most desirable for dielectric studies over a wide frequency range is the susceptance-variation method. This circuit is shown in Fig. 5. It embodies only a fixed coil and a variable condenser. Most other tuned-circuit methods require the use of a fixed resistor in addition to an inductor and condenser and there is the difficulty that resistors of sufficiently high value have not so far become available for the higher frequencies. Parallel connection of the unknown is used because of the errors coming from the extra residuals that would be introduced if the unknown were placed in series. Capacitive coupling between tuned circuit and generator is selected because it is easier to adjust over a wide range of frequencies than is resistive or inductive coupling. A vacuum-tube voltmeter is satisfactory as a null indicator because it requires only a very small amount of power for operation and can be made quite sensitive.

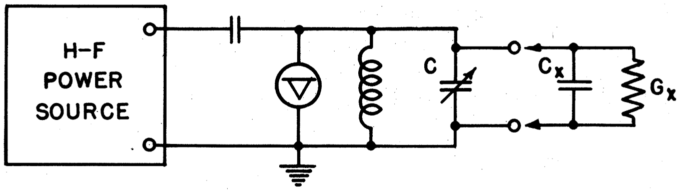

Fig. 5 Connections for Susceptance-Variation Method

The susceptance-variation method of determining dielectric properties involves re-establishing resonance with a variable condenser after the air dielectric between a pair of test electrodes has been replaced by the unknown material. The conductive component of the unknown dielectric is determined by the change in voltage at resonance after the sample has been introduced, and from the breadth of the resonance curve without the specimen.

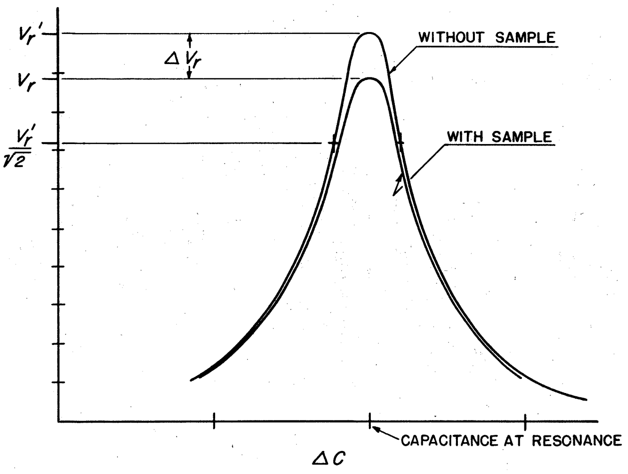

Fig. 6 Measurement of Dielectrics by Susceptance-Variation Method

If V_r = maximum voltage at resonance with specimen, then $V_r + \Delta V_r = V_r^1$ = maximum voltage at resonance without specimen.

G_r = circuit conductance with sample

G_x = conductance of sample alone

$G_r - G_x = G_r^1$ = circuit conductance without sample

C_x = capacitance of sample alone

C_a = equivalent air capacitance of sample

ΔC_r = change in capacitance necessary to re-establish balance after sample has been removed.

$$C_x = C_a + \Delta C_r.$$

The dielectric constant K is

$$K = \frac{C_x}{C_a} \qquad (1)$$

The voltage indicated by the vacuum-tube voltmeter varies inversely as the conductance,

$$\frac{V_r}{V_r^1} = \frac{G_r^1}{G_r} = \frac{G_r^1}{G_r^1 + G_x}$$

The unknown conductance is,

$$G_x = G_r^1 \frac{\Delta V_r}{V_r},$$

Let C_1 = capacitance for $\frac{V_r}{\sqrt{2}}$ on one side of resonance curve, and

C_2 = capacitance for $\frac{V_r}{\sqrt{2}}$ on other side of resonance curve.

In these terms,

$$G_r^1 = \frac{\omega (C_2 - C_1).}{2}$$

Substituting this we obtain

$$G_x = \frac{\omega (C_2 - C_1)}{2} \times \frac{\Delta V_r}{V_r},$$

$$D_x = \frac{G_x}{\omega C_x} = 1/2 \frac{(C_2 - C_1)}{C_x} \times \frac{\Delta V_r}{V_r} \qquad (2)$$

Fig. 7 shows an early model of the susceptance-variation circuit illustrating the basic simplicity of this method. It consists of variable air-condenser, a pair of electrodes for holding the specimen, and a yoke with terminals for connection of the coil, detector, and generator. With this arrangement, however, capacitance variation is obtained only by the variable air-condenser. Since this method depends on ability to measure small changes in capacitance, such a condenser as used in this model is suitable only for samples with high dielectric loss, for which large changes in capacitance result. This type of condenser has the added disadvantage that at the higher frequencies corrections must be made for changes in residuals brought about by changes in capacitance setting.

In an improved model, shown in Fig. 8, a micrometer is provided for controlling the spacing of the movable electrodes, thus making it possible to measure minute changes in capacitance. The larger variable air condenser is used to tune the circuit to resonance at the

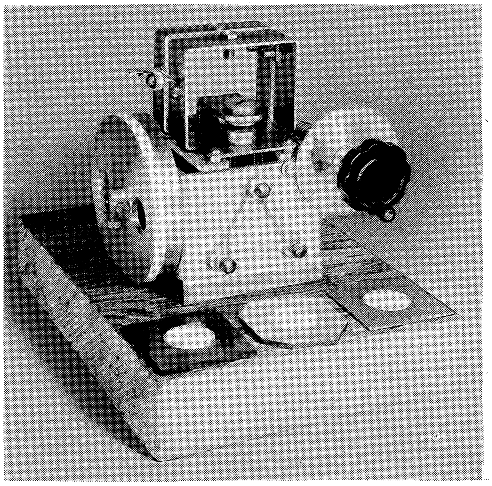

Fig. 7 Early Model of Susceptance-Variation Circuit

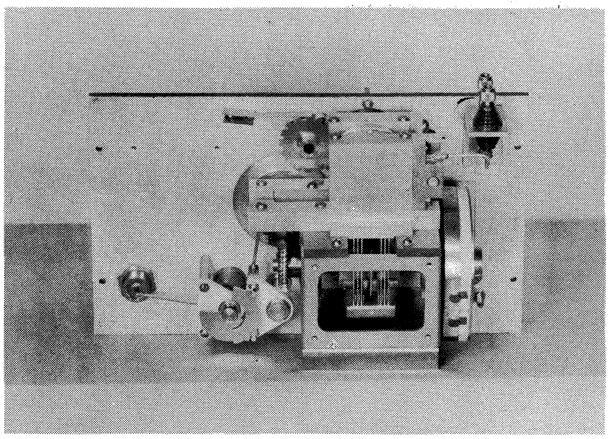

Fig. 8 Improved Susceptance-Variation Equipment

desired frequency, afterwhich adjustments are made only with the micrometer-controlled electrodes. Such an arrangement produces no appreciable change in residuals and the computations are confined to the use of equations 1 and 2. Two-inch electrodes are used and mounted directly on top of the variable air condenser. Figure 9, which is a panel view of this instrument shows the controls, including the micrometer and the connections to coil, generator, and detector. Curves of capacitance and dissipation factor expressed as functions of frequency for familiar insulating materials are shown in Figures 10 and 11.

Tuned-circuit methods, although very flexible, are limited in use principally to the testing of samples of insulating dielectric. At the present time no instrument has been made commercially available that is capable of the wide range of testing at higher frequencies that can be accomplished with a single instrument at audio frequencies. Measurement equipment, therefore, becomes of a more specialized nature and methods other than tuned circuits must be used. This is the case for measuring condensers, transmission lines, inductances, and antennas.

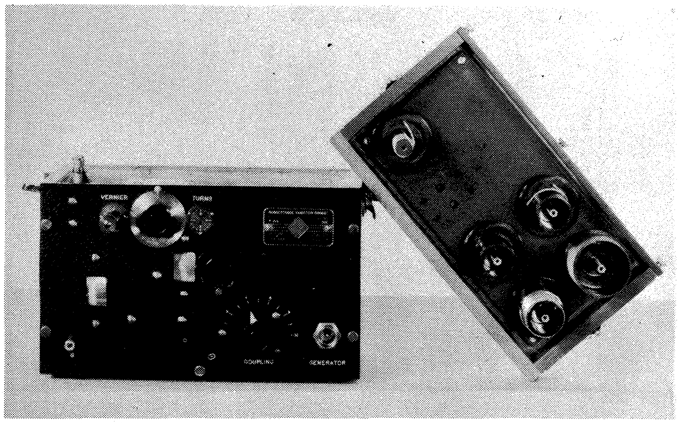

Fig. 9 Panel View of Improved Susceptance-Variation Equipment

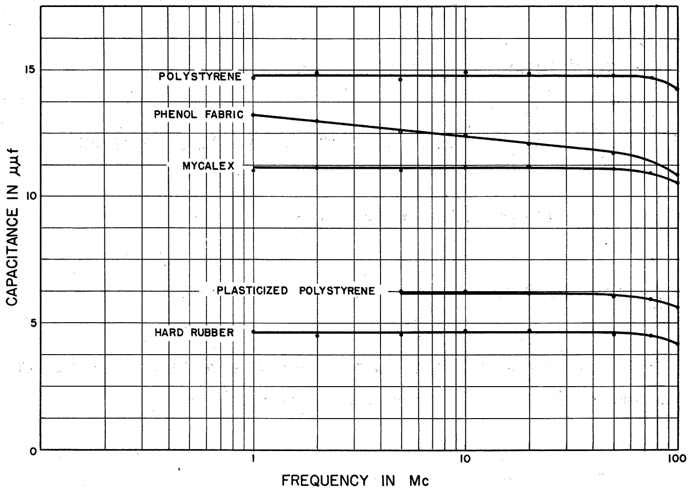

Fig. 10 Relation of Capacitance and Frequency

THE "TWIN T" NETWORK

An instrument has been developed using the "Twin-T Network"[9,10] which is suitable for measurements involving highly reactive elements. The Twin-T type of circuit has the advantage over regular bridge methods in that both the generator and detector can be operated with one side grounded without the use of isolating transformers. In the design of this apparatus[11] careful consideration of possible combinations of T-networks led to the selection of one combination in which the only variable elements were condensers. With this

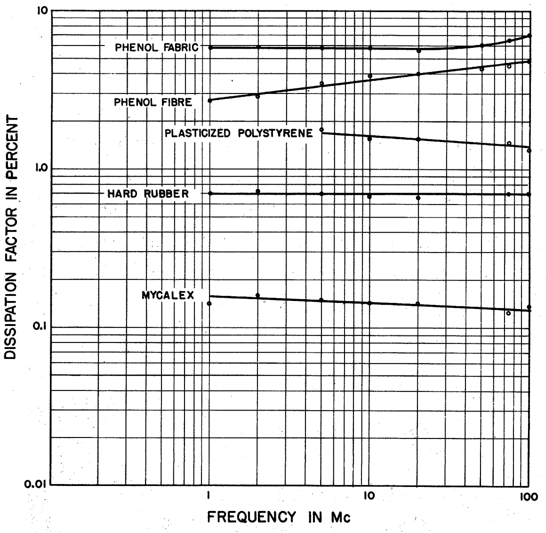

Fig. 11 Relation of Dissipation Factor and Frequency

arrangement the isolating transformers and variable resistors which formerly limited the extension of bridges to high frequencies have been avoided. This instrument inherently measures susceptance and conductance, the susceptance or capacitance being indicated directly in micro-microfarads by condenser C_B, as shown in Fig. 12. The conductive component is balanced by means of C_G and is direct-reading in micromhos. The calibration of the capacitance scale is unaffected by frequency. This is not true, however, for the conductive component as the range of its scale varies directly as the square of the frequency. The range of the conductance condenser C_G can be controlled by the fixed condensers C' and C''. The panel view of the instrument, Fig. 13, shows the controls which are as follows:

1. A variable condenser used to measure susceptive components and having a dial directly calibrated from 100 to 1100 micro-microfarads
2. An auxiliary condenser, consisting of a bank of fixed condensers controlled by push buttons and a small variable section, in parallel with the susceptance condenser, for making the initial susceptance balance
3. A coil switch marked with the frequency range covered by each tuning coil
4. A variable condenser used to measure conductive components and having two scales, one reading from 0 to 100 micromhos and one reading from 0 to 300 micromhos
5. A conductance-range-change switch with four positions to give 0 to 100 micromhos at 1 megacycle, from 0 to 300 micromhos at 3 megacycles, from 0 to 1000 micromhos at 10 megacycles, and from 0 to 3000 micromhos at 30 megacycles.

Residual impedances in the circuit parameters place a definite frequency limit for satisfactory operation. To realize practical operation within the limits imposed by the parameters themselves requires that no additional errors be introduced by wiring. As will be evidenced by inspection of the back view, Fig. 14, wiring to critical portions of the circuit has been reduced to the direct connection of terminals without interconnecting wires. This construction offers an interesting contrast to wiring in low-frequency apparatus. In order to eliminate interconnecting wire it becomes a problem of constructing each part in the circuit to special specifications rather than connecting together standard parts with suitable wiring, as is the practice at low frequencies. The frequency-range switch assembly, Fig. 15, and the standard variable air condenser, Fig. 16, serve to illustrate this.

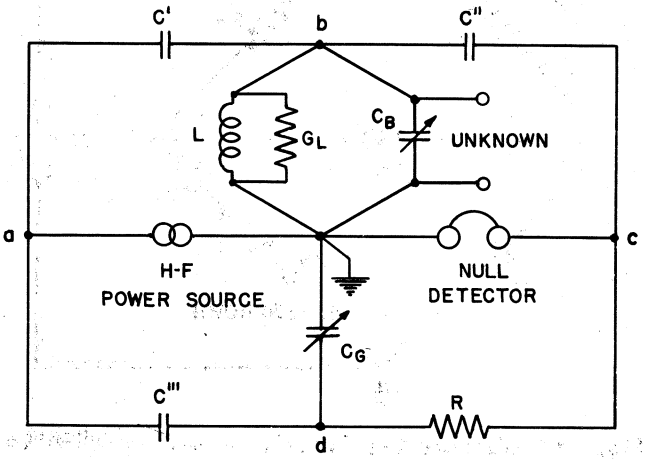

Fig. 12 Twin T Circuit

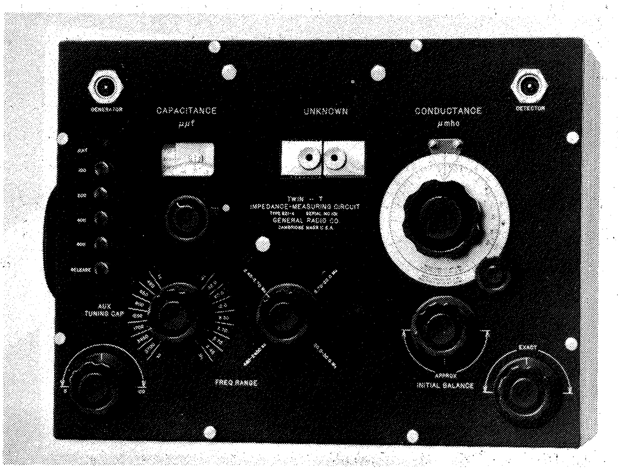

Fig. 13 Twin T Apparatus

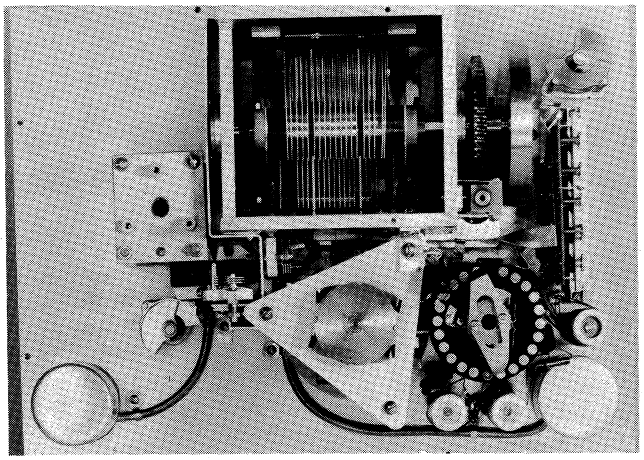

Fig. 14 Wiring of Twin T Apparatus

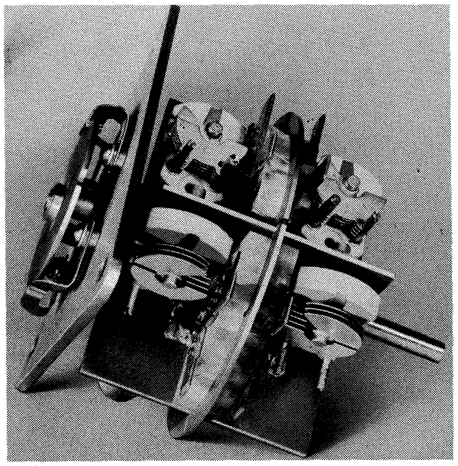

Fig. 15 Frequency Range Switch Assembly

The standard variable air condenser employs all of the latest improvements in high-frequency condenser design.[12, 13] An insulated rotor with rotor take-off discs and multi-fingered brushes at both ends is used to decrease series resistance, and a two-point current entry is made to the stator to reduce both residual inductance and resistance. The wide conductance and capacitance ranges of this instrument make it particularly suitable for a wide variety of impedance measurements of highly reactive samples up to about 30 megacycles, this frequency limit being due to the residual inductance in the standard condenser (approximately 0.006 microhenries). The effect of this residual inductance is to cause the capacitance readings to be too high.

THE SCHERING BRIDGE

Another class of measurement is the study of impedances comprised of almost pure resistance with slight positive or negative reactance. Transmission lines, cables, and antennas are perhaps typical.

The series-substitution Schering Bridge[14] is suitable for this work. It meets the requirements of being composed of only fixed resistors and fixed or variable condensers. An isolating transformer must, however, be used and it has been only recently that isolating transformers capable of being effective at high radio frequencies have been designed.

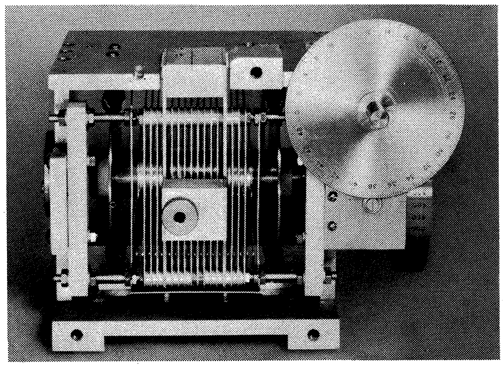

Fig. 16 Standard Variable Air Condenser of Twin T

The fundamental circuit of this bridge is shown in Fig. 17. Here C_p is a variable condenser which indicates the reactive component of the unknown impedance, and C_A indicates the equivalent series resistance. Resistor R_p is used to compensate for any initial resistive component introduced by stray and initial capacitance of C_A across the ratio arm R_A. Fig. 18 is the same circuit with details added to show shielding and additional elements involved in the construction of a

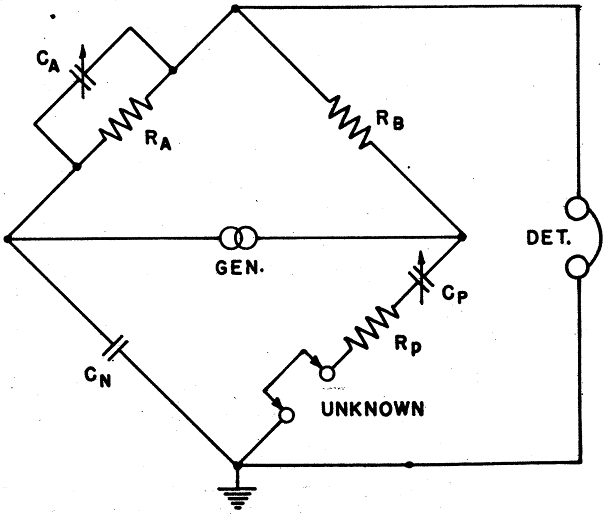

Fig. 17 Fundamental Circuit of Series-Substitution Schering Bridge

working instrument. Condenser C_p is calibrated directly in reactance. Its range is changed from positive to negative reactance by changing the ratio arm R_A. The function of C'_p is to establish an initial balance of C_p thus making the calibration of C_p direct-reading in unknown reactance. Variable capacitors C'_p and C_p are isolated from each other by shielding in order to prevent interaction resulting from rotor movement. A second shield entirely encases condensers C_p and C'_p and their wiring, as any stray capacitance from these parts to ground would appear across the unknown terminals. This intermediate shield is tied to the junction of R_B and C'_p and it, in turn, has its stray capacitance controlled by a third and outer shield connected to point "a" of the bridge. This places the capacitance between intermediate and outer shields across the generator, so that no errors result. The capacitance of the outer shield to ground is represented in Fig. 18 as C_N, and functions as the standard condenser across arm a-d. The trimmer condensers C'_N and C''_N are used to compensate for any change in stray capacitances from arm a-b brought about by the reactance-sign switch.

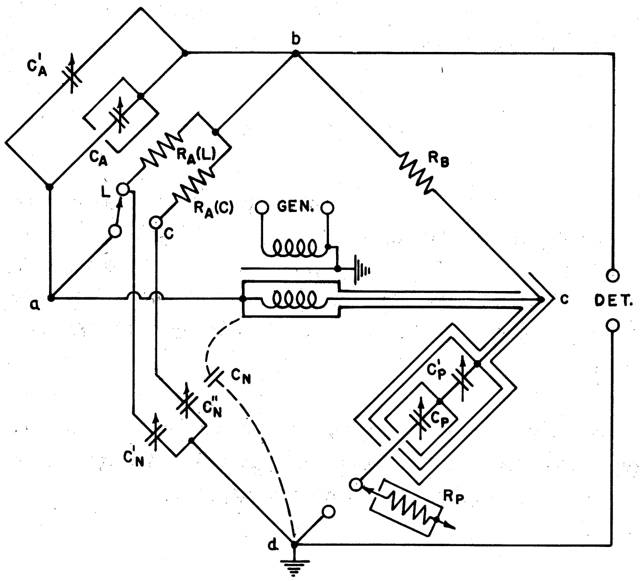

Fig. 18 Detailed Circuit of Schering Bridge

The dial attached to C_p is calibrated directly in plus or minus reactance in ohms at 1 megacycle and has a range of 0 to 4000 ohms at this frequency. Its range varies inversely with frequency above and below 1 megacycle. The resistive component is obtained by a direct-reading dial attached to C_A. The range of calibration is 0 to 1000 ohms spread over a semi-logarithmic scale, as shown in Fig. 19. The calibration of this scale is independent of frequency. In the design of the ratio arm R_B,[15] shown in Fig. 20, a balance has been sought between capacitance and inductance with the result that up to 60 megacycles it appears as a pure resistance of 270 ohms in parallel with a capacitance of less than 0.4 micro-microfarad. The reactance error resulting from this small capacitive component is so small that in most cases it can be neglected.

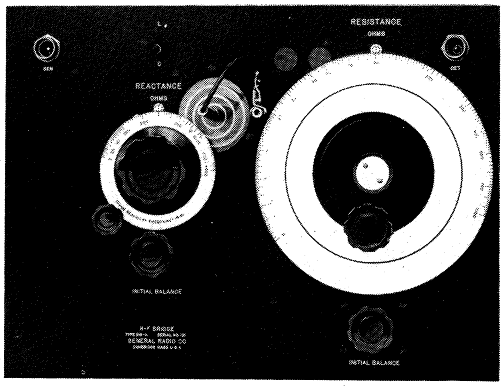

Fig. 19 Series Substitution Schering Bridge

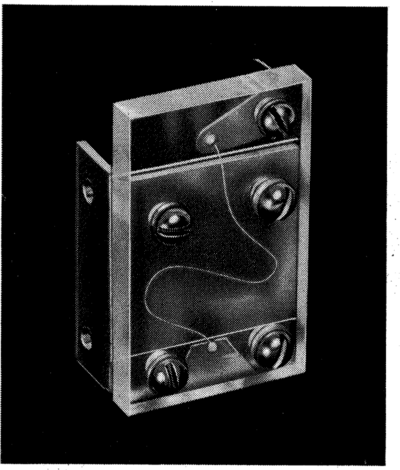

Fig. 20 Typical High Frequency Resistors

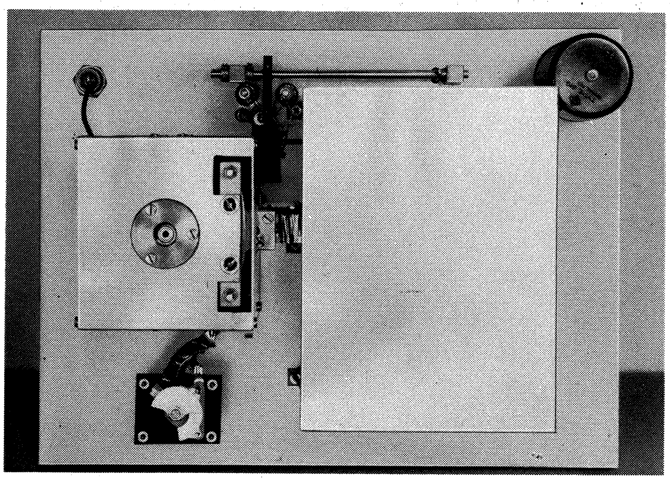

Fig. 21 Back of Panel View of Schering Bridge

This bridge, as with the Twin-T Impedance-Measuring Set, is evidence of care in both design and construction. Wiring to principal components has been almost completely eliminated and all the components have been specially constructed for the instrument. The back-of-panel view, Fig. 21, illustrates this.

The shielded transformer is shown in Fig. 22. Its construction is of great importance in obtaining proper operation of the bridge. In the construction of low-frequency bridge-isolation transformers the location of the primary and secondary shield-overlap points is of no importance. However, in the high-frequency range for which this bridge is designed the slots of the two split brass tubes forming tthe primary and secondary shields must be carefully aligned. If this is not done, serious errors result from the electromotive forces which are induced within the shields.

If known corrections are applied to readings, this modified Schering bridge is useful over a frequency range of from 0.5 to 60 megacycles. A practical lower frequency limit is brought about by the increase of the equivalent series resistance of the reactance condenser with decreasing frequency to such a point that an initial resistive balance is no longer possible. This lower limit occurs at about 0.5 megacycle. Errors at higher frequencies are shown in Fig. 23. These errors are caused by the residual inductance of the resistance condenser C_A.

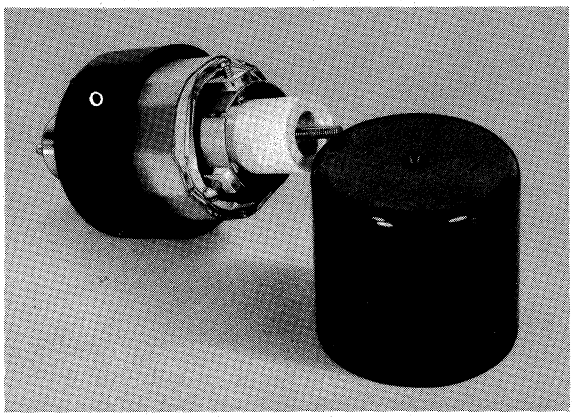

Fig. 22 Shielded Transformer for High-Frequency Use

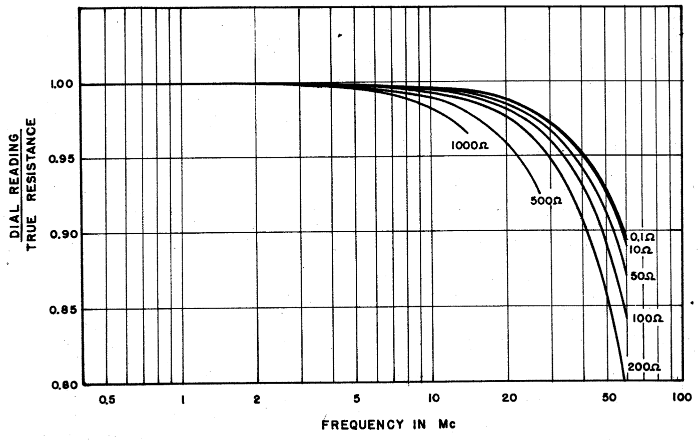

Fig. 23 Bridge Errors at Frequencies Greater than megacycle.

CONCLUSION

With the measuring equipment described herein, impedances can be measured from a millicycle to about 100 megacycles. The instruments mentioned are individually of a specialized nature, but combined provide equipment suitable for almost all classes of measurements.

The trend toward higher frequency continues, and doubtless the future will see additional methods and apparatus for this region of the spectrum.

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CLUB NEWS

(Continued from page 2)

NEW MEMBERS

On April 14th the Board of Directors approved the applications of the following for admission to the Member grade:

Wm. J. Brown, Rochester, N.Y.
Charles L. Cohen, Newark, N.J.
D. D. Jones, New Rochelle, N.Y.
Walter Knoop, Passaic, N.J.
Jerry Minter, Boonton, N.J.
Joseph F. Robertson, 252 E. 61st St., N.Y.C.
David Spies, East Orange, N.J.
John Van Buren, Boonton, N.J.

AMY, ACEVES AND KING IN LARGER QUARTERS

The firm of Amy, Aceves and King, in whose quarters the Club has its office, have moved into larger space in the same building at 11 W. 42nd St., N.Y.C. The change involved a move from the 10th floor to the 14th. The new entrance is at Room 1486.

All the men whose names appear in the firm designation are past or present officers or directors of the Club.

HARRY HOUCK AT MEASUREMENTS CORPORATION

Harry W. Houck, Director, Past President and Medalist of the Club, is now Vice-President and General Manager of Measurements Corporation, makers of radio measuring instruments at Boonton, New Jersey.

At Measurements Corporation are also located John Van Buren, President, and Jerry Minter, Vice-President and Chief Engineer, both of whom have just been elected members of the Club.

JOHN CRAWFORD WITH HAZELTINE

John D. Crawford, one of the assistant editors of the Proceedings of the Club, joined the staff of the Hazeltine Service Corporation at the Little Neck, N.Y., laboratories on March 15th. For the past five years he had been Assistant Secretary of the Institute of Radio Engineers.

NEW SEVENTH EDITION OF DOWSETT AND WALKER "HANDBOOK OF TECHNICAL INSTRUCTION FOR WIRELESS TELEGRAPHISTS"

More than six hundred pages of practical principles and data are contained in the new Seventh Edition of the "Handbook of Technical Instruction for Wireless Telegraphists" by H.M. Dowsett and L. E. Q. Walker, of which the Club recently received a copy for review. The publishers are Iliffe and Sons, Ltd., Dorset House, Stamford Street, London S.E. 1, England. The price postpaid is 25 shillings, 9 pence. The book can be ordered direct with an international money order, or bought through any book store for five or six dollars.

The book gives the general principles of direct and alternating currents which underlie the radio art, followed by description of equipment of various types. The presentation of principles is easily followed and makes the book useful to workers in all branches of radio. The equipment which is described includes marine transmitters and receivers, wavemeters, auto-alarm apparatus, and lifeboat equipment. Additional chapters give good treatments of depth sounding, radio direction finding, and the sound-reproducing systems provided on vessels for the entertainment and instruction of passengers. The equipment described throughout the book is of British make, and is well presented with the aid of drawings and photographs.

The book is recommended for those desiring a clear presentation of principles or the broadening of knowledge afforded by acquaintance with British equipment.

JOHN ARNOLD IN COAST ARTILLERY

John W. Arnold, Fellow of the Club, who has been engaged in engineering with the Western Union Telegraph Company for many years, is now a Major in the Coast Artillery and located at Fort Hancock, New Jersey.

PAUL DEMARS IN NAVY

Paul A. DeMars, a pioneer in frequency-modulation broadcasting as Chief Engineer of the Yankee Network, is now a Lieutenant, Senior Grade, in the Radio and Electrical Section, Bureau of Aeronautics, Navy Department, Washington, D.C.

(Continued on page 15)

CLUB NEWS

ADAIR LEONARD WITH AMERICAN PHILIPS

A. Adair Leonard is now engaged in engineering with the Philips organization in New York, representatives of the large Dutch firm. The group here is proceeding actively with work for the United States defense services, and expects this to expand rapidly in the near future.

WILLIAM FINCH WITH BUREAU OF SHIPS

William G.H. Finch, former Director of the Club and well-known facsimile inventor, was called into active service in the Naval Reserves about December 1st, and is now located in the Bureau of Ships, Washington, D.C. He is a Lieutenant-Commander.

DEATH OF JOSEPH A. HOPFENBERG

Joseph A. Hopfenberg, president of Pennant Trading Corporation, died on January 16th, at the age of 51. His firm has been active in the export to South America of radio apparatus, refrigerators and other electrical appliances, photographic equipment and motion-picture film. In addition to his duties as president, Hopfenberg acted as radio buyer for the firm.

He took a serious interest in amateur photography.

In the early days around 1910, Hopfenberg was active as an amateur radio operator. He became a member of the Club in 1932.

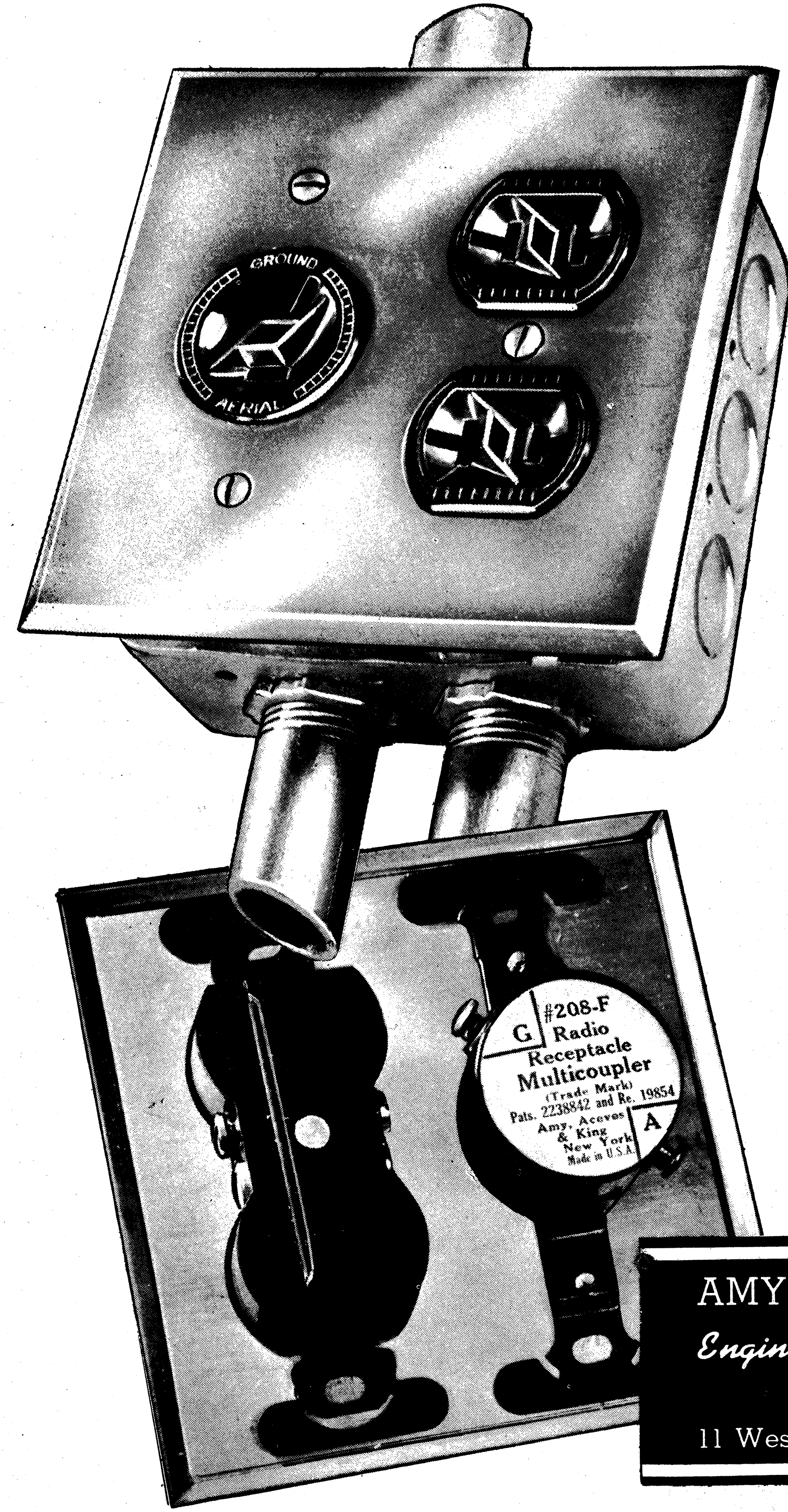
RECENT CLUB MEETINGS

On January 15th, H.E. Hallberg of RCA Communications presented a paper "The Sun, the Earth and Short-Wave Propagation", which included exceedingly interesting data on the sun's rotation, its spots, its large prominences, the layers of the earth's atmosphere, and temperatures in the various layers, correlation of sunspots and magnetic activity on the earth, and related topics. He pointed out that radio transmission involving passage of names over the magnetic poles is generally poor. There is much to be gained by using such transmitting and receiving locations that the regions around the north and south magnetic poles are avoided; for instance the choice of an East Coast or a West Coast location as the United States end of a radio circuit should be made on this basis rather than by considering distance alone.

At the February meeting John Van Buren gave a description of the ultra-high-frequency signal generator produced by Measurements Corporation. This goes up to about 400 megacycles. An ingenious system of circular transmission lines is rotated for change of frequency while stationary contacts break up the unused portion into sufficiently short portions to avoid absorption at frequencies within the range. Another unusual feature is a special system of connectors for switching the desired amount of attenuation into the circuit.

On March 12th, Mr. Lorber of the faculty of RCA Institutes, presented an analysis of high-fidelity modulators, such as suitable for broadcasting. He pointed out the benefit of applying the modulating audio voltage simultaneously to the plate and grid of the final high-frequency stage, and also to the grid of the driver stage.

The Noiseless Antenna System
including F-M RECEPTION!



● **Yes, it takes more than just a "radio outlet" for satisfactory radio reception. Particularly so with those all-wave sets in general use, and now with FM sets becoming increasingly popular. That's why the question is posed: What's behind the radio outlet? Upon the answer may depend the getting and holding of good tenants, in this radio age.**

WHY MAKESHIFT SYSTEMS ARE TOO COSTLY IN THE LONG RUN

"Radio Outlet" is a very loose term. It may mean no more to average builder, operator or owner than an outlet marked "Radio." Behind it may be a wire or crude loop concealed behind plaster wall. Or even an ordinary aerial worked without essential couplers. Such radio outlets may cost half or a third that of genuine radio outlets—and be worth exactly nothing. For the tenant, plugging in his set, will get weak signals and powerful background noises. That alone, in this radio age, results in dissatisfied tenants, and that's costly at any price.

WHY NOISE REDUCTION IS SO ESSENTIAL

Good reception starts with a powerful, clean signal. That means a good aerial, properly installed. The signal must be conveyed to each radio outlet. That means a transmission line immune to "man made" static. With maximum signal and minimum background noises, reception is at its very best.

WHY THE NEW MULTICOUPLER ANTENNA SYSTEM

With the ever growing search for better radio reception and the recent demand for frequency modulation (FM) reception, the New Multicoupler Antenna System has been carefully designed. It is thoroughly engineered, fully covered by adjudicated patents, universally recognized and sold under license by such outstanding companies as the General Electric Company and The Arrow-Hart & Hegeman Electric Company for national distribution.

This Multicoupler System is found today in thousands of apartment houses. Over 200,000 such outlets are in daily use; Parkchester, the world's largest apartment community, has over 12,000 such outlets. And now with the FM reception feature included, the New Multicoupler Antenna System is the logical answer since it provides lasting satisfaction with noise-free broadcast, short-wave and FM reception.

WHY YOU NEED OUR SPECIFICATIONS —OR PROPERTY SURVEY

Don't take a chance on "radio outlets." Specify the New Multicoupler Antenna System (licensed under the A.A.K. patents). We'll gladly send complete specifications for your protection. Or better still, we'll gladly survey plans or buildings for radio outlet requirements. Just address . . .

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