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FAULT LOCATION TECHNIQUES FOR TRANSMISSION LINES AND CABLES

by Martial A. Honnell

THE RADIO CLUB OF AMERICA

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FAULT LOCATION TECHNIQUES FOR TRANSMISSION LINES AND CABLES

By
MARTIAL A. HONNELL*

Presented before the Radio Club, November 9. 1951

INTRODUCTION

The problem of locating faults on transmission lines has existed ever since the installation of the first commercial telegraph system over a hundred years ago. Needless to say, many refined techniques have been developed for locating faults and minor irregularities on lines varying in length from a six-inch wave guide to a 2000-mile ocean cable. The basic principles underlying some of the methods employed to find the distance to discontinuities on metallic circuits are identical to those employed in radar devices, in mine detectors, and in supersonic thickness detectors.

The testing departments of the large communication and power companies employ highly trained personnel who are experts in the use of fault-location devices which are suitable for their particular line facilities. Typical fault location sets vary in price from $150 for a resistance bridge to over $10,000 for a d-c cable-fault locating set which weighs over 3000 pounds. It can be said that the large companies are adequately handling the problem of fault location. But small companies such as radio stations cannot normally justify the cost of fault-locating equipment, because of the infrequent occurrence of faults on their radio-frequency lines, on their audio circuits or on their private program circuit facilities. Nevertheless, a line fault is a serious and expensive problem for these organizations when it does occur.

The major portion of this talk is devoted to a fault-location technique which is particularly useful to groups who have occasional line fault problems. It is believed that a portable test set based on the principles outlined will be useful to all organizations having fault location problems on their communication, power, and radio-frequency transmission lines and circuits.

TYPES OF FAULTS

In view of the fact that the measuring technique which is to be demonstrated permits the measurement of the distance to faults that are as close as 2 feet and as far as a hundred or more miles on appropriate wire circuits, the viewpoint adopted is that a lamp cord, or any two-conductor circuit is a transmission line.

Most faults may be placed under the general classification of shorts, opens or crosses. Various combinations of these faults may exist. Furthermore, some faults exhibit a low resistance, while others exhibit a high resistance. It is clear that a fault may be of a permanent or of an intermittent character. In many cases, an intermittent fault, or a high resistance fault may be carbonized and reduced in resistance by passing a large current through the fault. In other cases, shorts caused by slivers of copper in coaxial cables may be burned out by discharging a charged condenser through the cable fault.

METHODS OF FAULT LOCATION

Most fault location methods now in general usage can be classified as follows:

1. Inspection methods.
   A. Direct visual examination for a visible fault.*
   B. Close inspection for evidence of heat, smoke, odor, or noise resulting from insulation break-down.
2. Continuity tests.
   A. Test lamp and battery.
   B. Ohmmeter, voltmeter and ammeter tests.
3. Resistance bridge tests.
   A. Wheatstone bridge tests for resistance.
   B. Loop tests of the Murray and Varley types.
4. Capacitance bridge tests.
   A. Capacitance bridge with low-frequency a-c, or slowly-reversing d-c, excitation.

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*Professor Electrical Engineering, Georgia Institute of Technology.

*Editor's Note: Emphasis was called to the importance of visual examination. A small length of solid copper, gas-dielectric, coax was exhibited having a pronounced dent in the outer surface (made by a rifle bullet). This fault could not be detected at low power levels - only at higher power sufficient to arc over internally. The fault was readily located by visual inspection after several electrical methods had failed.

   - B. Special capacitance bridge configurations employing the capacitance between lines as bridge arms.
5. Tracing current methods.
   - A. Steady, or pulsing, direct current is caused to flow on cable and field or potential drop is explored along cable.
   - B. Audio-frequency a-c current is sent through cable, and magnetic field is explored with pick-up coil, or device, connected to head phones.
6. Pulse tests.
   - A. Radar technique utilizing d-c pulses.
   - B. Radar technique utilizing pulse-modulated carrier.
   - C. Radar technique utilizing fault-generated surges.
7. Impedance variation methods.
   - A. Measurement of complex input impedance of line over a wide frequency range with impedance bridge or other impedance-measuring instrument.
   - B. Measurement of line input voltage, current or phase angle over a wide frequency range in order to locate several successive zeros and poles of impedance.
     1. These measurements may be made with a signal generator used in conjunction with a high-frequency voltmeter, ammeter, phase meter, or oscilloscope.
     2. These measurements may also be made with a frequency-modulated oscillator and oscilloscope to provide a panoramic display of relative impedance.
   - C. Location of successive zeros or poles of line input impedance by use of grid-dip oscillator.
8. Special unexploited methods.
   - A. Frequency-modulated radar techniques.
   - B. Phase measurements on steady-state reflected signal.

It is believed that the combination resistance-capacitance bridge arranged for Murray-Varley tests represents the most universally satisfactory device for the location of faults. Outstanding merits of the bridge are its inherent accuracy, its portability, and its modest battery requirements. Special forms of the resistance bridge have been developed for low-resistance and high-resistance faults. The signal tracing devices are very useful for finding the exact position of a fault on a short section of a cable, or if the approximate location of the fault on a long cable has been determined with a bridge. The relative merits of other techniques are discussed later.

THE PULSE TECHNIQUE

Application of the pulse technique for the location of faults on transmission lines was described in a paper published by the author in the November 1944 issue of Electronics magazine. Tests made on a 146-mile open-wire line from Atlanta to Birmingham indicated that the pulse technique will accurately display on an oscilloscope the distance to several discontinuities simultaneously present on a line. The conclusions reached as a result of these experiments were stated as follows:

"The pulse technique appears promising as a method of measuring the distance to a discontinuity on a transmission line. If the normal pulse history of a particular line is photographically recorded, any new discontinuity can be readily detected by placing the negative of the photograph over the oscilloscope screen.

An advantage of the pulse technique over other methods of measuring the distance to discontinuities is that a complete instantaneous picture of the entire line is revealed at a glance. In addition, the nature of the discontinuity is immediately apparent.

Possible applications of the pulse technique are: (1) To measure the distance to an open or short-circuit on transmission lines. (2) To measure the distance to irregularities on lines. (3) To measure the velocity of propagation of pulse signals on transmission lines of known length. (4) To rapidly check the value of the characteristic impedance of a transmission line, or to determine whether or not a line is terminated in its characteristic impedance. (5) To continuously monitor a line to determine where and when a break occurs during inclement weather, or during periods when sabotage is expected."

An excellent pulse fault-location test set named "The Lookator" was described in the October 1945 issue of the Bell Laboratories Record. This test set, housed in a case approximately 19 x 19 x 15 inches, weighs a little over 100 lbs., and operates from a 110-volt a-c power supply. In the opinion of the author, this represents a transportable rather than a portable test set. The Lookator with its 165-microsecond pulse will indicate very clearly the distance to missing loading coils in loaded transmission lines, to contact made by swinging tree branches, and to high-impedance intercepting taps. A similar pulse test set employing a 0.25-microsecond pulse and appropriate line-balancing, terminating and compensating impedances has been used to measure minor irregularities on coaxial cables in order to insure a minimum of discontinuities on cable installations.

Several organizations have recently conducted experiments in the use of pulse equipment for the location of transient faults on power lines. Stevens and Stringfield of the Bonneville Power Administration have reported the use of the transient surge generated at a fault on a high-voltage transmission line as the pulse signal to indicate the distance to the fault. Leslie and Kidd of the Hydro-Electric Power Commission of Ontario, Canada, have successfully employed d-c pulses and pulse-modulated carriers to measure the distance to faults on power lines. The major disadvantage of the carrier burst method is that the nature of the fault is not clearly revealed in terms of pulse polarity as it is when d-c pulses are employed. The sensitivity of the pulse test is demonstrated by the fact that power-line transpositions were clearly revealed during the course of these experiments. An important advantage of the pulse fault-locating test set from the power viewpoint is its ability to show transient faults and intermittent faults in the presence of existing normal line discontinuities.

THE IMPEDANCE VARIATION TECHNIQUE

The author has recently directed his efforts toward the development of fault-location techniques utilizing test equipment ordinarily available at radio stations, or similar organizations. This technique is based on the following well-known principles:

The input impedance-frequency characteristic of a transmission line under open-circuited and short-circuited conditions has the general appearance illustrated in Fig. 1. It is to be noted that, under either condition, successive impedance minimas (or maximas) occur for frequency increments which make the line electrically one-half wavelength longer. For example, if the input impedance of a short-circuited transmission line is measured as the frequency is increased, the line presents a maximum impedance to a frequency at which the line is electrically a quarter-wavelength long. Next, the line presents a minimum impedance to a frequency at which the line is a half-wavelength long, etc.

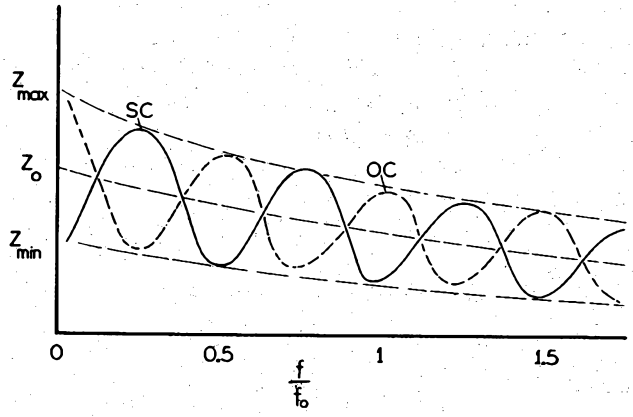


Fig. 1 - Relative impedance values of short-circuited line (SC) and open-circuited line (OC) for a transmission line of fixed length. At the frequency f_o, the line is one wavelength long.

The frequencies corresponding to successive Z_{min} (or Z_{max}) values may be employed to measure the distance to an open-circuit, to a short-circuit or to other types of discontinuities on a transmission line by use of the following equation which is derived in most standard transmission books:

$$D = \frac{V}{2(f_2 - f_1)}$$

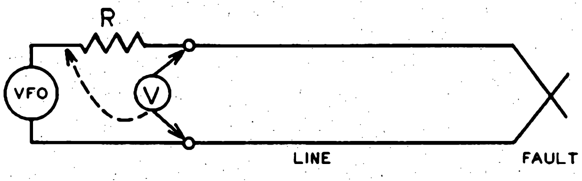
Where D is the distance to the fault, V is the average velocity of propagation on the line, f_1 is the frequency corresponding to any Z_{min} (or Z_{max}) point, and f_2 is the frequency corresponding to the next successive Z_{min} (or Z_{max}) point.

It is well to remember that the lowest frequency corresponding to Z_{min} for a short-circuited line is the frequency which makes the line one-half wavelength long, while for an open-circuited line it is the frequency which makes the line one-fourth wavelength long. This information may also be employed to determine the length of a line by use of the following equations:

For short-circuited line $D = V/2F$
For open-circuited line $D = V/4f$

Where f is the lowest frequency to which the line presents a minimum impedance. (These equations are interchanged for resonance frequencies which produce a Z_{max}.)

It is apparent that the input voltage, or the input current, of the transmission line will go through the same cyclic variations as the input impedance. These excursions may, therefore, be employed to identify the frequencies of the successive zeros or poles of the transmission line input impedance. A suitable arrangement for locating faults by using an audio oscillator, or a signal generator, in conjunction with a diode voltmeter or a vacuum-tube voltmeter is shown in Fig. 2.



VFO - Variable-frequency oscillator.
V - Vacuum-tube voltmeter.
R - Any convenient value from $Z_o/2$ to $2Z_o$.

Fig. 2 - Simple arrangement for locating a line fault.

If the transmission line has moderate losses, the voltmeter reading will drop sharply at frequencies corresponding to zeros of impedance and it will rise to a maximum at frequencies corresponding to poles of impedance. It is obvious that the input current will vary in inverse relationship to the voltage. This current may be measured by connecting the voltmeter across the resistor shown in Fig. 2. Allen and Gross of the Pennsylvania Water and Power Company described a fault-location device employing the current-measuring technique in the Bulletin of the Edison Electric Institute for August 1935.

If the transmission line has high losses, or if it is terminated in a resistive discontinuity having a magnitude which approaches the line characteristic impedance, the voltmeter excursions will be small, because the reflected wave will be much smaller than the applied wave. In this case, the circuit arrangement utilizing a bridge, a hybrid coil, or other form of directional coupler, shown in Fig. 3 will prove to be useful. The response of the meter to the outgoing wave can be reduced to any desired magnitude by adjusting the balancing resistor to a value approaching the characteristic impedance of the line. Since the effect of the outgoing wave can now be reduced to the same order of magnitude as that of the reflected wave, the voltmeter reading will go through large excursions as the frequency is varied. This will permit a more rapid and precise determination of the frequencies corresponding to the zeros and poles of impedance.

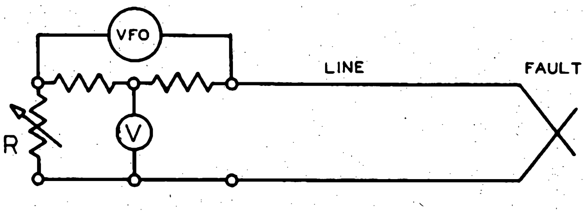


Fig. 3 - Bridge arrangement used to increase excursion of voltmeter reading when measuring lossy lines. R may be a 1000-ohm carbon potentiometer.

A cathode-ray oscilloscope and an oscillator may be used to determine the frequencies at which the phase angle of the line input impedance goes through zero, since for a low-loss line these frequencies correspond to the zeros and poles of impedance. The vertical input of the oscilloscope is connected across the line terminals, and the horizontal input is connected across a small resistor in series with one oscillator lead to the line. With this arrangement an elliptical pattern is traced on the screen of the cathode-ray tube. At frequencies corresponding to poles of impedance, the ellipse closes to a thin line (or ellipse) having a large slope; and at frequencies corresponding to zeros of impedance, the ellipse closes to a thin line (or ellipse) having a smaller slope. It is apparent that similar measurements may be made with a phase meter substituted for the oscilloscope. This phase measurement technique is not recommended for a high-loss line since, in this case, the frequencies at which the line input impedance goes through maximas and minimas are not directly related to the frequencies producing unity power factor.

GRID-DIP OSCILLATOR APPLICATION

The Megacycle Meter is the simplest and most convenient instrument to use to make fault distance measurements through application of the impedance-variation principle. If the coil of the Megacycle Meter is coupled inductively to a small loop formed at the end of a transmission line, the grid meter will dip sharply as the Megacycle Meter is tuned through its frequency range. These grid meter dips will occur at frequencies corresponding to zeros of the line impedance.

Although any two successive frequencies corresponding to a zero of impedance suffice for the calculation of the distance to a fault, greater accuracy is achieved if the frequency differences between several successive readings are averaged. This will also reduce the likelihood that a zero might be accidentally overlooked.

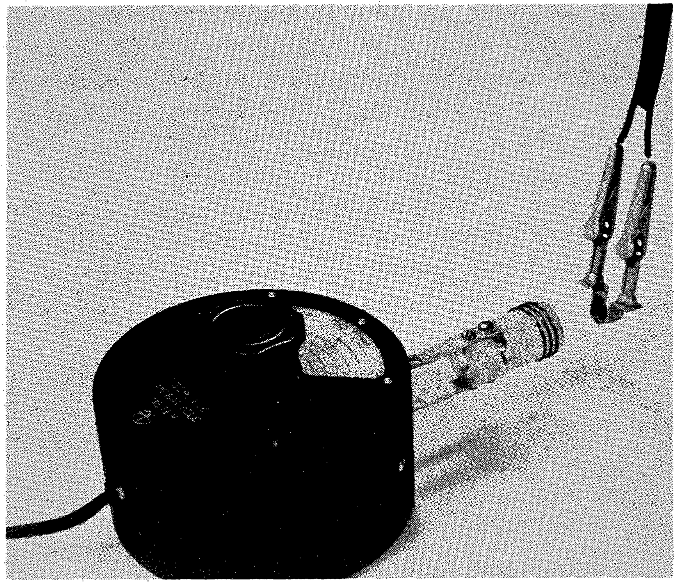


Fig. 4 - Megacycle Meter coil used with clips to form a coupling loop.

It may be necessary to try several different coils initially before any resonances are discovered. A convenient procedure is to start with a high-frequency coil and work downward in frequency until well-defined dips in the grid meter reading are obtained. After resonances are located, the coupling to the loop should be reduced as much as possible in order that there will be a minimum reaction on the frequency calibration of the Megacycle Meter.

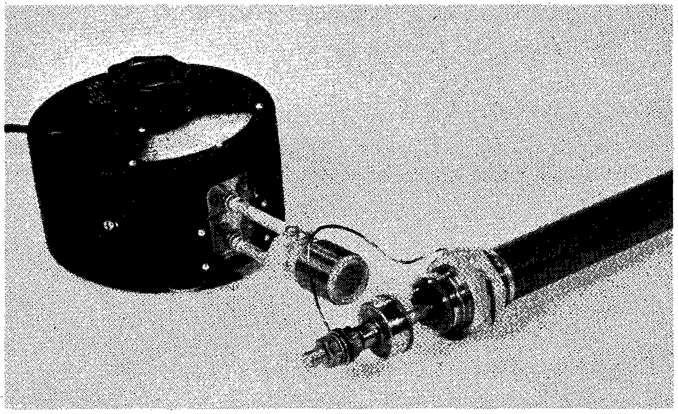


Fig. 5 - Megacycle Meter coupled to solid coaxial line.

The loop formed at the end of the line should be small, and it is important to use close coupling on high-loss lines. In many cases the loop may consist of the extended ends of the line twisted together. It is possible to couple the Megacycle Meter capacitively to the open end of low-loss lines. However, the inductive coupling is preferable.

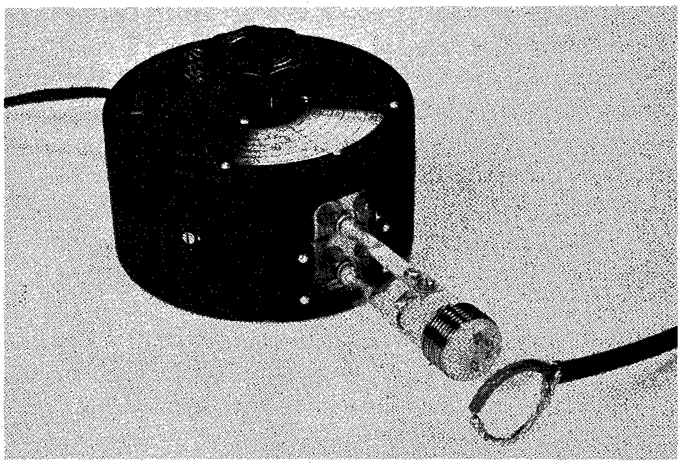


Fig. 6 - Megacycle Meter coupled to flexible coaxial line showing how loop is formed.

Transmission line losses increase directly as the length of the line and these losses also increase with frequency. If the line losses are high, there will be only a slight variation in impedance as a function of frequency, and it may be impossible to locate the zeros of impedance. Fortunately, long lines permit the use of low frequencies for the determination of a fault.

If other lines, or sections of wire, are coupled or are connected to a line on which measurements are being made, many random resonances will be measured, and the desired frequencies will be obscured. In many cases spurious couplings may be made innocuous by application of basic transmission line principles. For example, the offending line section may be terminated in its characteristic impedance in order to make it non-resonant.

The standard megacycle Meter with a frequency range of 2.2 to 400 megacycles will permit the

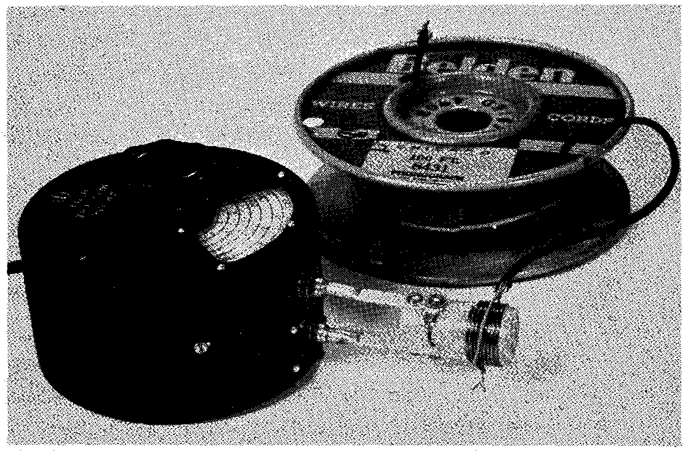


Fig. 7 - Measuring length of phonograph pickup cable on spool.

measurement of faults which are at distances of approximately 2 feet to a half mile. With coils covering the frequency range down to 100 kilocycles, frequency increments of 10 kilocycle can be read with a good degree of accuracy so that the upper range of measurement is extended to 10 miles.

It is apparent that the velocity of propagation on a particular line can be determined by use of the grid-dip technique on a line section of known length. The grid-dip technique may be employed to locate faults on wire circuits such as radio-frequency transmission lines, microphone cables, lamp cords, power lines, and telephone lines. This technique has been employed to determine the length of a shielded cable wound on a spool. It is much simpler and more rapid to measure a cable 1000 feet long in this manner than to unreel the cable for direct measurement with a rule.

CONCLUSION

All of the fault-location techniques which have been described are useful and important. No single technique is the best overall technique to employ in all fault finding situations. The pulse technique reigns supreme in its ability to show the distance to transient faults and to several simultaneous faults.

One of the most attractive features of the impedance-variation technique is that it can be applied by using a variety of measuring equipment usually found in a radio station or in an electronics laboratory. The grid-dip meter is often the most convenient instrument to use to locate line faults. As a portable battery-operated fault-location instrument, the grid-dip meter utilizes only one tube. Because of its small size and its simplicity, the Megacycle Meter is particularly convenient to use to locate line faults on antenna installations, and on board ships and airplanes.

ACKNOWLEDGMENT

The author wishes to thank Measurements Corporation for its interest in the fault location studies recently completed by him.

REFERENCES

Allen, J.E., and Gross, G.J., "A Method of Locating Faults on Overhead Transmission Lines by Means of High Frequency", Bulletin, Edison Electric Institute, page 309, Aug., 1935.

Honnell, M.A., "Location of Line Faults", Electronics 17: 110-113, Nov., 1944.

Honnell, M.A., "Transmission Line Fault Location with the Megacycle Meter", Measurements Notes, No. 4, June, 1951.

Karapetoff, V., and Dennison, B.C., "Experimental Electrical Engineering", Vol. II, 114-137, John Wiley & Sons, Inc., New York, 1941.

Kittner, J.W., Jr., "Test Sets for Dielectric Faults in Coaxial Cable", Bell Lab. Record, 26: 416-420, Oct., 1948.

Leslie, J.R., and Kidd, K.H., "The Linascope - an Echo-Ranging Type Fault Locator for High Voltage Lines", A.I.E.E. Transactions, Vol. 67, 1948.

Schott, J.T., "The Lookator", Bell Lab. Record, 23: 379-383, Oct., 1945.

Stevens, R.F., and Springfield, T.W., "A Transmission Line Fault Locator Using Fault-Generated Surges", A.I.E.E. Transactions, Vol. 67, 1948.

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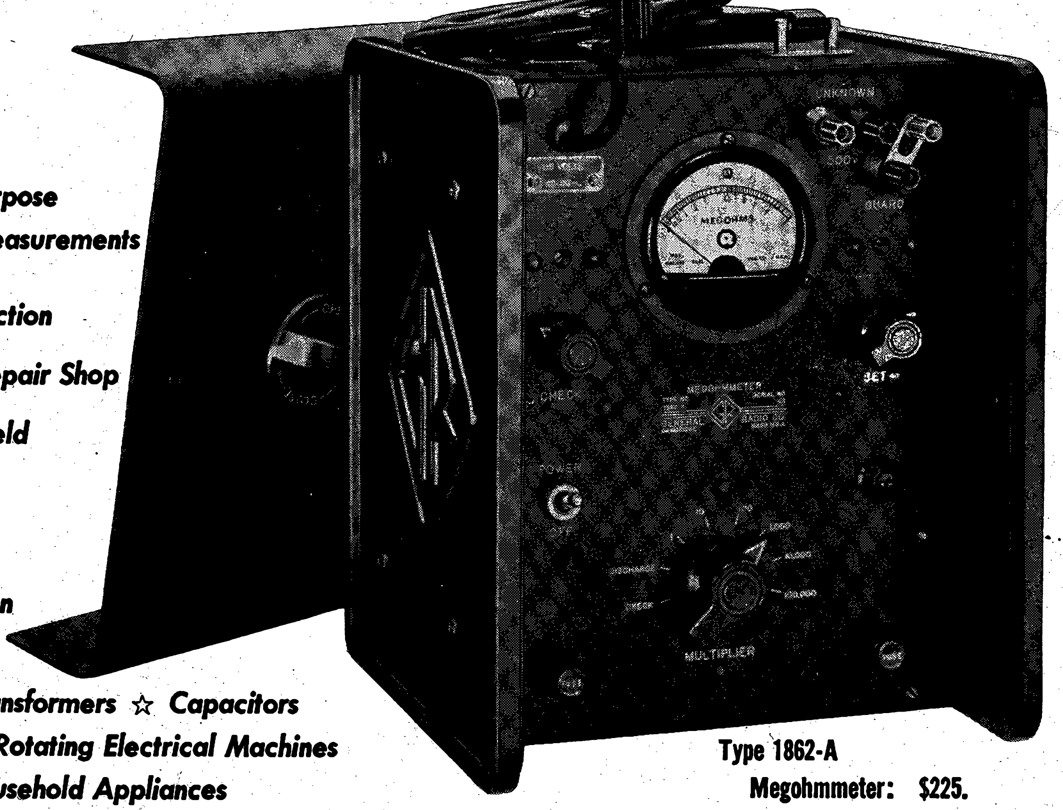

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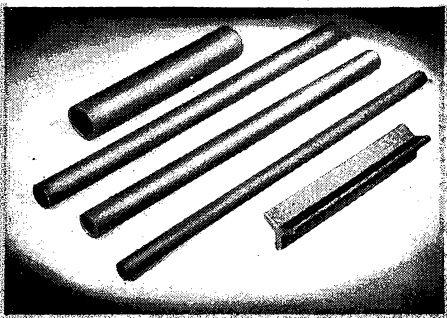

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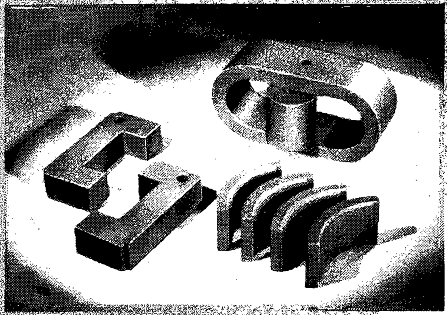

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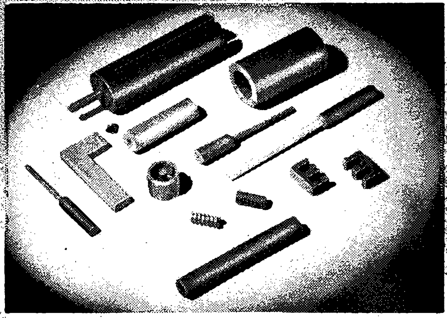

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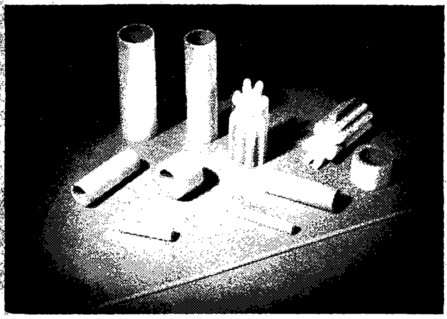

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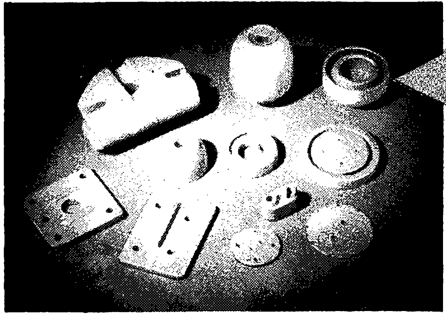

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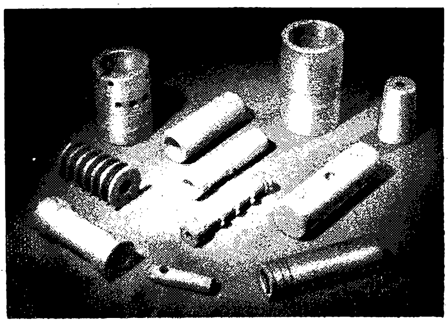

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FEDERAL TELEPHONE & RADIO FTR

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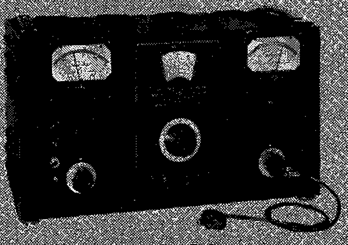
IN EVERY FIELD
There is a Leader!

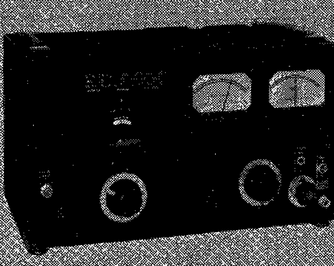
—and following every leader are those who would rather copy than create!

Substitutes are not acceptable where precision instruments are required, that is why engineers the world-over specify the MEASUREMENTS line. They know that—

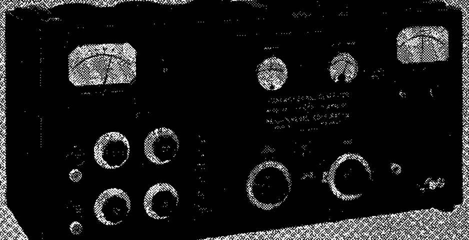
STANDARDS ARE ONLY AS RELIABLE AS THE REPUTATION OF THEIR MAKER



Model 65-B
STANDARD SIGNAL GENERATOR



Model 80
STANDARD SIGNAL GENERATOR



Model 84
STANDARD SIGNAL GENERATOR

MEASUREMENTS "FAMOUS FIRSTS" in *Laboratory Standards*

1939 MODEL 54 STANDARD SIGNAL GENERATOR—Frequency range of 100 Kc. to 20 Mc. The first commercial signal generator with built-in tuning motor.

MODEL 65-B STANDARD SIGNAL GENERATOR—This instrument replaced the Model 54 and incorporated many new features including an extended frequency range of 75 Kc. to 30 Mc.

1940 MODEL 58 UHF RADIO NOISE & FIELD STRENGTH METER—With a frequency coverage from 15 Mc. to 150 Mc. This instrument filled a long wanted need for a field strength meter usable above 20 Mc.

MODEL 79-B PULSE GENERATOR—The first commercially-built pulse generator.

1941 MODEL 75 STANDARD SIGNAL GENERATOR—The first generator to meet the need for an instrument covering the I.F. and carrier ranges of high frequency receivers. Frequency range, 50 Mc. to 400 Mc.

1942 SPECIALIZED TEST EQUIPMENT FOR THE ARMED SERVICES.

1943 MODEL 84 STANDARD SIGNAL GENERATOR—A precision instrument in the frequency range from 300 Mc. to 1000 Mc. The first UHF signal generator to include a self-contained pulse modulator.

1944 MODEL 80 STANDARD SIGNAL GENERATOR—With an output metering system that was an innovation in the field of measuring equipment. This signal generator, with a frequency range of 2 Mc. to 400 Mc. replaced the Model 75 and has become a standard test instrument for many manufacturers of electronic equipment.

1945 MODEL 78-FM STANDARD SIGNAL GENERATOR—The first instrument to meet the demand for a moderately priced frequency modulated signal generator to cover the range of 86 Mc. to 108 Mc.

1946 MODEL 67 PEAK VOLTMETER—The first electronic peak voltmeter to be produced commercially. This new voltmeter overcame the limitations of copper oxide meters and electronic voltmeters of the r.m.s. type.

1947 MODEL 90 TELEVISION SIGNAL GENERATOR—The first commercial wide-band, wide-range standard signal generator ever developed to meet the most exacting standards required for high definition television use.

1948 MODEL 59 MEGACYCLE METER—The familiar grid-dip meter, but its new design, wide frequency coverage of 2.2 Mc. to 400 Mc. and many other important features make it the first commercial instrument of its type to be suitable for laboratory use.

1949 MODEL 82 STANDARD SIGNAL GENERATOR—Providing the extremely wide frequency coverage of 20 cycles to 50 megacycles. An improved mutual inductance type attenuator used in conjunction with the 80 Kc. to 50 Mc. oscillator is one of the many new features.

MODEL 112 U.H.F. OSCILLATOR—Designed for the many applications in ultra-high frequency engineering that require a signal source having a high degree of frequency accuracy and stability. Range: 300 Mc. to 1000 Mc.

1950 Model 111 CRYSTAL CALIBRATOR—Measurements' most recent "first"—a calibrator that not only provides a test signal of crystal-controlled frequency but also has a self-contained receiver of 2 microwatts sensitivity.

1951 MODELS 30 and 31. INTERMODULATION METERS—With completely self-contained test signal generators, analyzers, voltmeters and power supplies. Other new Measurements' "FIRSTS" soon to be announced.

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