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The BRC UHF Q Meter A New and Versatile Tool for Industry

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Q Meters have been serving the electronic industry for more than 25 years. Their original application was in the design of resonant circuits, in the early days of radio-frequency communication and broadcasting. Since that time, Q Meter applications have multiplied many times.[1-5] The basic theory of Q Meter operation, however, had not changed in all these years, until the development of the new Type 280-A UHF Q Meter.[6] With this change in Q meter theory, the applications will be again multiplied. It is these applications which are the subject of this article. Conventional measurements, as well as unconventional measurements, which include measurements of external resonators and components, and "in circuit" Q measurements, will be described.

PURPOSE

The prime purpose of the UHF Q Meter is to provide industry with a versatile impedance measuring device that will extend Q Meter measurements into the UHF region. The UHF Q Meter is a completely self-contained instrument capable of measuring, rapidly, conveniently, and directly; Q, capacitance, and inductance. Until the advent of the UHF Q Meter, a signal generator, a frequency measuring device, a dc amplifier, and coupling devices were required to make these tedious measurements. Inductance and capacitance, which are now measured directly on the calibrated capacitor, could not even be measured with the above-mentioned equipment.

OPERATING PRINCIPLE

To aid the reader in understanding the theory of the Type 280-A UHF Q Meter it might be well, at this point, to compare its operation with the lower frequency Q Meters, Types 260-A and 190-A. This comparison is especially necessary if use of the instrument, beyond the obvious, is to be understood.

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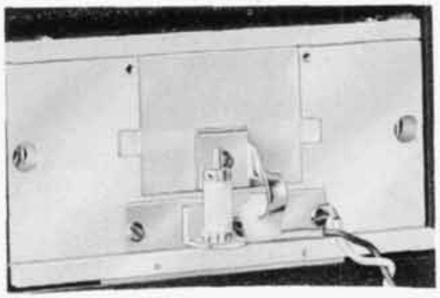
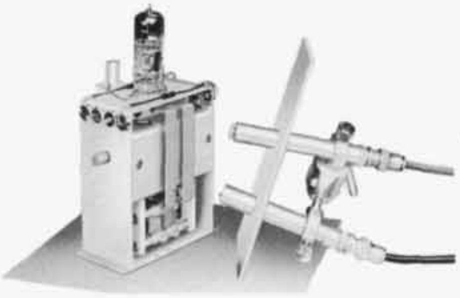
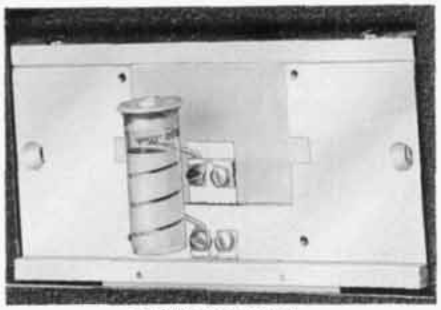


Diode Measurement



"In-circuit" Q Measurement



Coil Measurement

Figure 1. Typical Applications of the UHF Q Meter

Preivous Q Meters utilized the definition that:

$$Q = \frac{X_{LS}}{R_S} = \frac{R_P}{X_{LP}},^*$$

*S and P subscripts indicate series and parallel configurations respectively.

as well as the fact that the voltage (V_C), measured across C (the Q capacitor), has the following relationship at resonance:

$$V_C = QV_S, \text{ or } Q = \frac{V_C^*}{V_S}$$

*Within the Q Meter Q limits (10 to 625).

V_C is the voltage injected in series with the resonant circuit (Figure 2A). If V_S is held constant, then Q is directly proportional to V_C. This basic principle, employed in all BRC Q Meters to date, is known as the "resonant rise" system of making Q measurements.

ESTIMATE THE Q WIN A Q METER

Yes, that is all that is necessary to win the factory reconditioned Type 160-A Q Meter which will be on display in the BRC exhibit at the IRE show to be held in the New York Coliseum from March 20th through March 23rd. The Q Meter will be awarded to the person whose estimate is closest to the actual measured Q of the resonator circuit to be displayed with the Q Meter. *Complete information will be furnished by engineering personnel on duty* in BRC Booths 3101 and 3102.

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The UHF Q Meter uses the peak of the resonant rise to indicate resonance, but employs the bandwidth relationship to determine Q, where:

$$Q = \frac{f_r}{\Delta f} \qquad (1)$$

This relationship is shown in Figure 3. Δf is the frequency between the two 0.707 voltage or half-power points, and f_r is the frequency at the resonant peak. As is indicated in Figures 2B and 4, there are other more subtle differences between the UHF Q Meter and the lower frequency Q Meters. These will be discussed later in this article.

FIELDS OF APPLICATION

Because of its frequency range, the UHF Q Meter will serve many fields of the electronic industry. Some examples of these fields ar given below.

FIELD	SPECIFIC APPLICATIONS
Missile and Rocketry	**Telemetry and remote control systems.**
Communications	**Commercial, mobile airborne, relay networks, amateur radio, UHF television, and military mobile.**
Navigational Aids	**Glide slope**
Radar and ECM	
Components and Materials Manufacturers	**Inductors, cores, capacitors, UHF diodes, insulators, and resistors.**
Other Fields	**Accelerator, medical research, and basic research of new materials.**

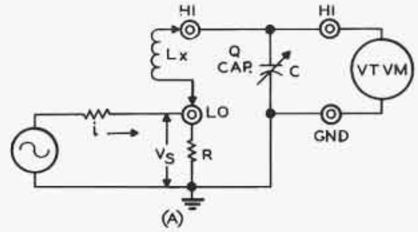
BASIC OR CONVENTIONAL MEASUREMENTS

Set-up Procedure

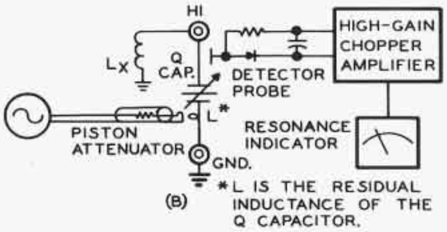
A condensed set-up procedure will be given at this point to aid in the understanding of the instrument. The same procedure is used for both conventional and unconventional measurements. Arbitrarily, it will be assumed that the Q and inductance of a small inductor is going to be measured.

1. The component to be measured is clamped to the Q capacitor terminals by means of the clamps provided (Figures 1 and 5), or by other suitable means.

2. The oscillator is adjusted to provide the desired operating frequency by means of the appropriate controls.



Simplified Circuit — Conventional Q Meter (Type 260-A)



Simplified Circuit — UHF Q Meter Type 280-A

Figure 2. Comparison of Q Measuring Circuit in Conventional Q Meters and the UHF Q Meter

3. The Q capacitor is adjusted until output is indicated on the resonance indicating meter.

4. The Q capacitor or Q (frequency) control is adjusted in conjunction with the Level Set control until the resonant peak is indicated at full scale on the meter.

5. The appropriate Q dial is locked and its knob is turned clockwise to the proper half-power point which is indicated by the Q mark on the meter.

6. The Q dial is unlocked and the knob is rotated in a counter-clockwise direction, through the resonant peak, to the opposite half-power point; also indicated by the Q mark on the meter.

7. Q is read directly on the appropriate Q dial, capacitance is read directly on the Q capacitor dial, and inductance is read directly on the integral calculator dial.

Inductance Measurements

Inductance measurements are a primary function of all Q Meters. The UHF Q Meter capacitance dial is provided with a spiral calculator to compute inductance from the capacitance reading and the operating frequency. The direct-reading inductance range is 2.5 to 146 millimicrohenries (Figure 6). Circuit Q is read directly from the CIRCUIT Q dial.

Capacitance Measurements

Capacitance measurements are second nature to a Q Meter, but are indirect measurements in that a reference inductor or "work. coil" must be used. The clamps provided with the instrument permit individual connection of the work coil and the unknown capacitor for parallel measurements. Standard Q Meter procedure is then employed to make the parallel capacitance measurements and all general Q Meter equations [2,7] apply. Q_1 and C_1 of the work coil are measured; then, with the unknown capacitor (C_X) connected, Q_2 and C_2 are also measured. The capacitance of the specimen is determined by the equation:

$$C_X = C_1 - C_2$$

and

$$Q_X = \frac{Q_1 Q_2}{Q_1 - Q_2} \times \frac{C_X}{C_1}$$

Dissipation factor measurements can be estimated by referring to Figure 7. For example, a 20-pf capacitor with an R_p of 0.3 meg. ohms can be detected at 210 Mc, using a work coil with a Q_1 of 300. The dissipation factor would then be computed at follows:

$$D = \frac{1}{Q} = \frac{X_C}{R_P} = \frac{40}{0.3 \times 10^6}$$
$$= 130 \times 10^{-6}$$
$$= 0.00013$$

Consider the possibilities if higher Q inductors or resonators are used. One precaution must be observed if a false value for C_2 is to be avoided. The Q dials (frequency dials) should always be returned to their original positions, indicated by the resonant peak of the work coil before C_X was connected.

Direct parallel capacitance measurements, over a range of 0.1 to 20 pf are possible on the UHF Q Meter. It is also possible that capacitance measurements can be extended by a "step-shunt" technique. This technique requires that an external capacitor or capacitors (C_A and C_B), within the capacitance range of the instrument, be calibrated at the frequency of measurement. The external capacitors are then connected in parallel with another work coil and the Type 280-A internal capacitor is adjusted to peak. The external capacitors are removed as required when the unknown capacitor (C_X) is connected. Then:

$$C_X = C_A + C_B + (C_1 - C_2) \quad (2)$$

Series techniques may also be used. Some suggestions on this subject are taken up in the resistance measurement section which follows.

Resistance Measurements

Resistance measurements are also indirect measurements, and the procedure used is identical to that used for capacitance measurements. In this case, however, we are interested in the major parameter of resistance. Figure 8 shows approximate limits of measurable resistance for indicated Q_1 values of 300 and 500, Q_2 values of 20 and 10, and a $\triangle Q$ of 10. Approximate limits for both parallel and series measurements are given. The upper limits of parallel measurements may be extended by utilizing higher Q reference inductors and smaller $\triangle Q$ values. The lower limits of parallel measurements may be extended, slightly, by using additional external capacitance.

At ultra-high frequencies, series measurements present a more difficult problem. First, shunt capacitance and series inductance of the series jig must be small relative to the resistance to be measured. Secondly, a low inductance and low resistance short-circuiting device must be employed.

In the Type 280-A, circuit component contact resistance is basically the lower limiting factor in series measurements. This contact resistance usually becomes a function of the component shape and may require a special machined fixture for a given component.

A short cut to solving the multiple computations of the real component of parallel impedance measurements is illustrated in Figure 7. Curves for a given work coil, with Q_1 and frequency held constant, are plotted as a function of Q_2 and R_P. If the work coil is stable, well designed, rigid, well plated, etc., these curves, or a group of curves, can be used for general measurements over long periods of time.

SPECIAL OR NONCONVENTIONAL MEASUREMENTS

The basic parameters of L, C, and Q are often affected when brought near, or in contact with, a component to be tested. Let us consider some specific instances and determine what measurements may be made.

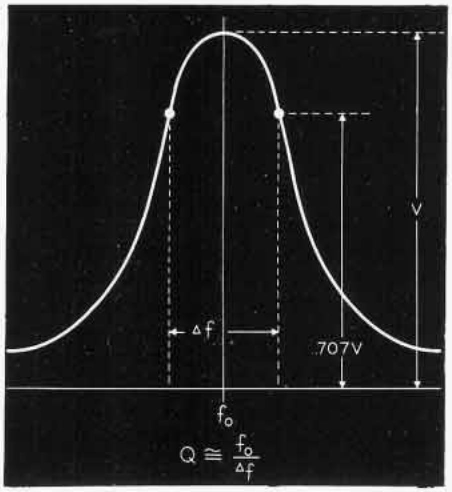


Figure 3. Q Resonance Curve

Measurements Involving Change in Inductance and Resistance

Iron cores, shells, toroids, and rods may now be tested simply, at higher frequencies, with the UHF Q Meter. It has been found that some defects are detectable in the resistive or Q_2 indication at these frequencies (210 to 610 Mc) that do not show up at the lower operating frequencies.

The ferro-resonant frequency of some ferro-magnetic components may be detected on the resonance indicating meter, if this resonance falls within the instrument frequency range.

Figure 9 suggests a possible jig design for coupling these and other components, liquids, and materials into the inductive field of a test coil. The plastic plug can be machined to precisely position the specimen so that the change in C, L, or Q falls within the range of the instrument. A change of inductance indicates a change in effective permeability and a change in Q indicates a change of specimen resistivity. A high degree of precision can be achieved in these measurements, since both the work coil and plug can be fabricated on precision machines.

A work coil and two plastic plugs, patterned after those shown in Figure 9, were made and attached to the Q capacitor terminals on the UHF Q Meter, and a few experiments were performed which produced some interesting results. In the first experiment, a group of small shell cores were inserted in the plastic plug and tested at 400 Mc. Q_1 was determined to be within 5% of 630, and Q^2 was within 5% of 284 for all cores. Inductance increased by 5%, indicating permeability greater than unity, even at 400 Mc. Core #4 showed a 5% decrease in inductance, with a drop to 135 in Q_2. This core was obviously of low-frequency material acting like a poor short circuit. This experiment indicates a technique for evaluating inductive tuning or adjustment devices and their effects upon circuit Q at ultra-high frequencies.

The author has long been curious about the effects of liquids on circuit Q. This curiosity led to the second experiment, performed to determine the effect of tap water on circuit Q, with and without a few salt crystals added. Q_2 measured for the clear water was 610. Low losses, very little change in inductance, and approximately 1% increase in distributed capacitance were noted. A pinch of salt (NaC1) was then added and the effects noted. Q_2 dropped to 255, with no inductance change apparent. It can be concluded

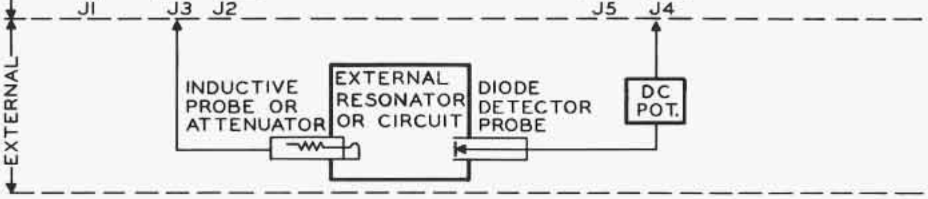


Figure 4. Block Diagram of UHF Q Meter Showing External Resonator Connections

then, that the RF resistivity or losses only change in a positive direction with the addition of salt.

These experiments point up the application of the UHF Q Meter in the UHF inductive heating field (cooking of foods, curing of adhesives and resins, etc.) where it is important to know the frequency of optimum energy absorption.

Jigs similar in theory to the one discussed above, but more sophisticated, may be constructed to detect, test, and measure more complex components and materials and to solve more exacting problems. For example, a capacitance-loaded or "end-tuned" coaxial resonator could be adapted to check toroidal behavior under truly inductive conditions and with the flux lines in a specific plane.

Measurements Involving Change in Capacitance and Resistance

The measurement of the dielectric loss factor of Teflon, Polyethlene, etc., is one of the most difficult measurements to make with any degree of accuracy. For example, high-grade Teflon is known to have a loss factor of approximately 0.00014.

The Type 280-A UHF Q Meter, with its frequency range of 210 to 610 Mc and Q range of 10 to 25,000, makes this equivalent high shunt resistance more readable. Further, since the Type 280-A employs a bandwidth measuring system; i.e., $\triangle f$ is measured between the half-power points, permitting the use of frequency counting techniques; calibration and readability of the Q dials can be eliminated as a source of error and $\triangle Q$ becomes more readable, limited only by our ability to measure $\triangle f$. Let us consider the order of $\triangle f$ or frequency changes that will be encountered for such a measurement.

Conditions:

1. The specimen capacitance (C_x) should be about 10pf.
2. If a plate area of 0.6 inches is used, material thickness should be 1/32 inch for approximately 10 pf C_x.
3. C_1, under these conditions, should be approximately 15pf.
4. Q_1 should be at least 500.
5. Operating frequency is 300Mc.

Solving for $\triangle Q$: We can now solve for the expected $\triangle Q$ for a 0.0001 dissipation factor. In this case:

$$D = \frac{1}{Q_x}, Q_x = 10{,}000.$$

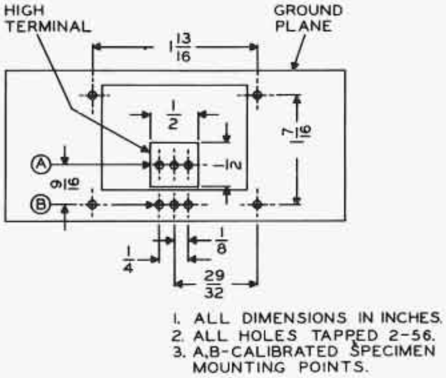


Figure 5. Q Capacitor Terminal Dimensions

Using the standard equation for Q:

$$Q_x = \frac{Q_1 Q_2}{\triangle Q} \text{ x } \frac{C_x}{C_1}. \qquad (3)$$

Let $C_x/C_1 = K = 0.66$ which is a practical ratio adjustable by manipulation of inducance or frequency and specimen thickness. Then:

$$Q_x = K \frac{Q_1 Q_2}{\triangle Q} \qquad (4)$$

since

$$Q_2 = Q_1 - \triangle Q; \qquad (5)$$

and

$$\triangle Q = \frac{KQ_1{}^2}{Q_x + KQ_1}. \qquad (6)$$

Example (for above conditions):

$$\triangle Q = \frac{.66\ (500)^2}{10{,}000 + .66 \text{ x } 500}$$

$$= \frac{.66\ (25 \text{ x } 10^4)}{10{,}330}$$

$$= 16$$

Calibrated dial divisions at this Q value are 10 units. This means that estimates from the dial reading can be within approximately 20% of this $\triangle Q$ value. With a $\triangle Q$ of 16 at a frequency (f_r) of 300 Mc, what is the frequency bandwidth change? Let us refer to this change as $\triangle f_3$. The derivation of the equation used is as follows:

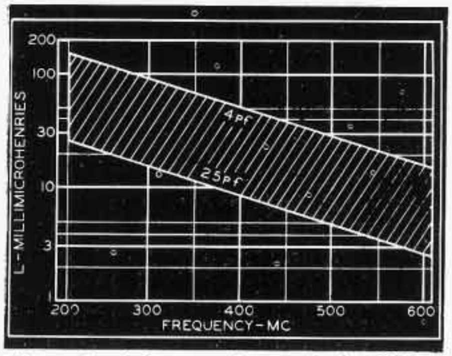


Figure 6. Inductance Range of the UHF Q Meter (Direct Reading)

$$Q_1 = \frac{f_r}{\triangle f_1}, \triangle f_1 = \frac{f_r}{Q_1} \qquad (7)$$

$$Q_2 = \frac{f_r}{\triangle f_2}, \triangle f_2 = \frac{f_r}{Q_2} \qquad (8)$$

$$\triangle Q = Q_1 - Q_2, Q_1 > Q_2$$

$$\triangle f_3 = \triangle f_2 - \triangle f_1 \qquad (9)$$

$$= \frac{f_r}{Q_2} - \frac{f_r}{Q_1}$$

Clearing:

$$\triangle f_3 = \frac{Q_1 f_r - Q_2 f_r}{Q_1 Q_2}$$

$$= \frac{f_r\ (Q_1 - Q_2)}{Q_1 Q_2}$$

$$= \frac{f_r\ (\triangle Q)}{Q_1 Q_2} \qquad (10)$$

To compute the above example:

$$\triangle f_3 = \frac{300 \text{ Mc x } 16}{500 \text{ x } 484}$$

$$= .0198 \text{ Mc or } 19.838 \text{ kc}$$

From the above example, two factors stand out as important to the accuracy of measurement: First, the value of the ratio K in equation 4, especially if the Q dial readout is to be used, should approach as close to unity as possible to optimize readability. Secondly, equations 7, 8, 9, and 10 indicate that a frequency measurement technique can be used to measure Q_1, Q_2, and $\triangle Q$.

Use of an Auxiliary Frequency Counter to Measure Loss Factor

Fortunately for those with dielectric loss measurement problems, the art of frequency measurement is highly refined and is really a simple solution to the loss-factor measurement problem. A popular frequency measuring device found in most laboratories is the frequency counter. This instrument, with a suitable transfer oscillator, has more than sufficient accuracy and resolution for this application. The frequency counter is connected to jack J1 at the

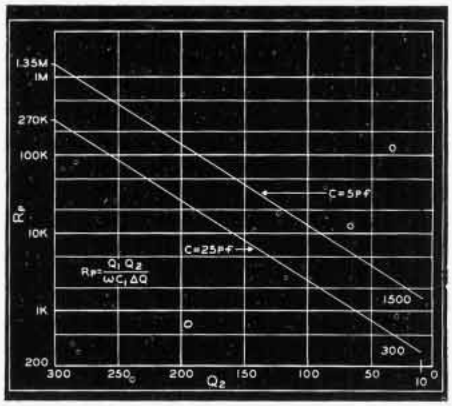


Figure 7. R_p versus Q_2 and C_x

rear of the Type 280A (Figure 4) which is provided especially for monitoring the UHF Q Meter frequency. With this technique the accuracy of measurement is determined by the short-term frequency stability of the Type 280-A and the stability of the half-power indicator in its most insensitive position (position of maximum stability). In this mode of operation, 0.5 kc per minute per 100 megacycles can be resolved with good repeatability. For this method of dielectric measurements, it is convenient to derive the equations for Q_x and D_x (dissipation factor) in terms of frequency. Considering the relationships of equations 7 and 8, equation 3 can be written:

$$Q_x = \left[\frac{\frac{f_r}{\triangle f_1} \times \frac{f_r}{\triangle f_2}}{\frac{f_r}{\triangle f_1} \times \frac{f_r}{\triangle f_2}}\right] \times \frac{C_x}{C_1}$$

$$O_x = \frac{f_r^2}{\triangle f_1 \times \triangle f_2} \times \frac{\triangle f_1 \times f_2}{\triangle f_2 \times f_r - \triangle f_1 \times f_r} \times \frac{C_x}{C_1}$$

$$= \frac{f_r^2}{f_r\,(\triangle f_2 - \triangle f_1)\,C_1} \times \frac{C_x}{}$$

$$= \frac{f_r}{(\triangle f_2 - \triangle f_1)} \times \frac{C_x}{C_1} \qquad (11)$$

$$D_x = \frac{\triangle f_2 - \triangle f_1}{f_r} \times \frac{C_1}{C_x} \qquad (12)$$

Dielectric loss factor measurements in this range, were heretofore obtained by refined techniques and extreme skill. The Type 280-A △f technique can achieve ±10% accuracy (or one part in the fifth place) with considerable simplification of the measurement procedure in this frequency range.

Measurement of Semiconductor Components and Materials

Since one of the key features of the new UHF Q Meter is high detector gain, low RF levels are available across the component to be tested. The level can be selected by the front panel SENSITIVITY control from 25 to 250 millivolts. Of the many components measurable in this RF voltage range, the variable-capacitor diode is one of the best examples. Here, one is most concerned with the behavior of Q and capacitance as a function of bias and frequency. With 0.025 volts RF across the diode, investigations to almost zero bias (0.1v dc) can be made. RF impedance of detector and mixer diodes can be determined using standard Q Meter equations[7]. A suggested design for a diode jig, with provisions for biasing, is shown in Figure 1. Other parametric and nonlinear components, including h_{ie}, h_{oe}, and h_{ob} of some UHF transistors, may be measured in a similar manner. Semiconductor material resistivity can be measured in the electrostatic manner previously described under "Measurements Involving Change in Capacitance and Resistance", or relative resistivity can be obtained using the inductive jig previously described under "Measurements Involving Change in Inductance and Resistance."

External Resonator and "In Circuit" Measurements

One of the most interesting phases of the new UHF Q Meter application is the measurement of external resonators and "in circuit" measurements. Referring to Figure 2B and 4, observe that there is really no direct connection to the injection and detection circuits. The RF signal is actually magnetically coupled or induced into the Q capacitor by a piston-type inductive attenuator. This device is a tubular probe, with a single turn of wire at its end. The detector circuit is similar to a conventional diode probe used on many RF vacuum tube voltmeters and is coupled to the Q capacitor by merely bringing one end of it near the electrostatic field of the stator structure.

The fact that there is actually no conductive connection to the circuit under test suggests many possible configurations for making measurements. As shown in Figure 4, connections to the Q capacitor assembly have been made through a series of jacks and jumpers located at the rear of the instrument. This means that the oscillator and high-gain amplifiers may be disconnected from the Q capacitor.

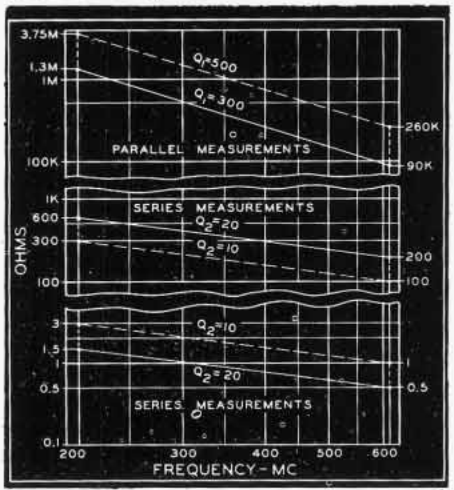


Figure 8. Approximate Resistance Range of the UHF Q Meter

External Resonators

First, let us assure that we have a coaxial resonator and need to know its Q and resonant frequency. Due to the physical size of the component, it can not be mounted on the Q capacitor terminals. Even if it could be mounted, the minimum capacitance of 4pf would prohibit uncorrected measurements. The Type 280-A, with appropriate accessories, can make these measurements on the bench rather than on the instrument. Figure 4 shows the connections for a typical resonator circuit. The piston attenuator and diode probes shown in Figures 1 and 4 will be made available as optional accessories for the Type 280-A.

The procedure for making this measurement is basically the same as for making conventional measurements, except that the "Level Set" controls (Q capacitor piston attenuator and Q capacitor controls) are no longer operative. The motion of the attenuator probe and adjustment of the dc potentiometer serve as the "Level Set" control once the detector probe has been positioned. The frequency or CIRCUIT Q dials are then tuned to obtain the resonant peak. The resonant frequency is read directly on the frequency dial, or by means of external frequency measuring equipment if desired. The Q measuring procedure is the same as described above for inductors.

Care must be taken to avoid unexpected loading of the resonator. Prevention of this loading is one function of the coupling block and is also the reason that an adjustment is provided on the attenuator probe. Two Q readings, at different detector probe and attenuator probe settings, will establish the extent of loading. If there is any loading, Q_2 will be different than Q_1.

A plot of two or three Q readings as a function of coupling will show that Q approaches a limit, asymptotic to the Q value, at which the Type 280-A injection and detection circuit reflected losses are negligible. This Q value is the actual unloaded Q of the resonator under test.

In resonators of this type, Q is important as a method of determining bandwidth in receivers. The effects of circuit loading can be determined and optimized.

As a power handling device, Q is related to efficiency (E) as follows:

$$E = 100 \left(1 - \frac{Q_L}{Q_{UL}}\right) \%, \quad (13)$$

where $Q_L = Q$ loaded and $Q_{UL} = Q$ unloaded.

"In Circuit" Measurements

A distinct advantage of the UHF Q Meter is its ability to measure the Q of resonant circuits (resonators) as they are connected and mounted in actual use; i.e., "in-circuit" measurements. This is extremely important, since the behavior of most resonators is a function of many things. Resonators may take many forms; i.e., coaxial, cavity, open lines, strip lines, butterfly tanks, etc. An example of a typical "in-circuit" measurement problem is shown in Figure 1. Here, flat strips are used to form a resonator for a developmental RF amplifier. It is important to know the Q_L and Q_{UL} of the resonator to determine the optimum efficiency versus bandwidth compromise. Coupling was achieved as illustrated, and the following example readings were made at 400 Mc: $Q_{UL} = 400$, $Q_L = 40$, $E = 100\ (1 - 40/400) = 90\%$. It was found that due to radiation losses, Q_{UL} dropped to 300 with the shield removed, resulting in an efficiency of $100\ (1 - 40/300)\ \% = 84\%$. These efficiencies were adequate, but a different tube type and aluminum shields resulted in a Q_{UL} of 100. Efficiency was 60% under these conditions and, therefore, this may prove to be an unusuable configuration.

An extension of this type of measurement can be applied to mating components, or may be used to determine Q at the self-resonant frequency of an inductor. The components are placed on a small ground plane in the vicinity of the probes, or in a convenient shield, to limit radiation losses and body capacitance effects. By this means, any tuning or fixed capacitor desired may be employed.

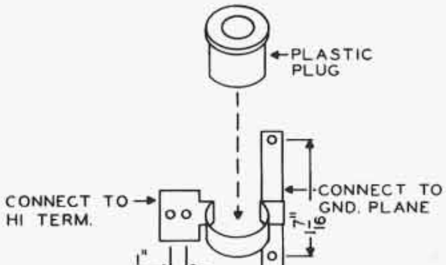


Figure 9. Suggested Design for an Inductance Jig

It is important to realize that measurements made in the manner described in this section yield Q_e; i.e., the effective Q of the component and associated circuit inperceptably influenced by the Q Meter, if care is used to determine sufficient probe decoupling. This is the actual "in-circuit" Q and can be used directly in circuit computations. The Type 280-A UHF Q Meter is the only Q Meter in existance that can measure, directly, the Q of a circuit that is resonant at the frequency of measurement.

To measure circuit "stray" capacitance, a coil may be calibrated on the Q capacitor and then soldered into the circuit at the desired points. The circuit capacitance can then be computed from the relationship for resonance:

$$f = \frac{1}{\omega\sqrt{LC}}$$

or

$$C = \frac{1}{f^2 \omega^2 L} \qquad (14)$$

The same technique can be applied to circuit inductances.

CONCLUSION

We have attempted to describe some of the applications of the new UHF Q Meter Type 280-A, but realize that there will be many more jobs for this versatile instrument; some of which are not apparent at this writing. These will provide worthwhile subject matter for future articles in The Notebook.

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7. "The Nature of Q," Moore, W.C., BRC Notebook #1, Spring, 1954.

SERVICE NOTE

RX Meter Null Indicator

Proper operation of the Type 250-A RX Meter is dependent upon the correct balancing of the bridge circuit, and the bridge circuit cannot be correctly balanced if the NULL INDICATOR is not functioning properly. To check the operation of the NULL INDICATOR, proceed as follows:

1. Select the desired measuring frequency by means of the OSC RANGE and OSC FREQ controls.
2. Set the C_p dial to "O" and the R_p dial to ∞.
3. Unbalance the bridge by shorting the two binding posts and adjusting the DETECTOR TUNING knob until maximum deflection is obtained on the NULL INDICATOR. The meter pointer should indicate about 35 scale divisions. A peak of substantially less than this amount is usually an indication of an unusuable harmonic response instead of the desired fundamental. At higher frequencies, two fundamental frequency peaks will be observed, either of which represents satisfactory tuning of the detector. Several secondary or harmonic peaks, which may be recognized by their relative sharpness and low amplitude, will be observed between the fundamental peaks. Care should be taken not to tune to one of these harmonics, since this will produce erroneous readings or make bridge balance impossible. When maximum meter deflection has been obtained, remove the short from across the binding posts and tighten the binding posts nuts.
4. Balance the bridge by adjusting the three ZERO BALANCE controls, alternately, until a minimum deflection is obtained on the

NULL INDICATOR. The indication should not be more than 3 scale divisions on the meter. At frequencies above 100 Mc, the COARSE R control should be adjusted to its approximate midpoint position before null is sought. Since a slight interaction exists, at high frequencies, between the FINE R and C controls, it is important to use all three controls to obtain final balance. When an apparent null has been obtained, the circuit should be tested for true balance by slowly rocking the R_p dial above and below the setting, and observing the NULL INDICATOR. If a deeper null is observed at some R_p value other than ∞, the R_p dial should be returned to the latter indication and a new balance obtained with the ZERO BALANCE controls.

NOTE: When the measurement frequency is changed, steps 2 through 4 above should be repeated.

5. After the bridge is balanced as described above, set the frequency controls for 0.5 megacycles and change the R_p dial setting from ∞ to 100K. The NULL INDICATOR pointer should deflect upscale and indicate approximately 7 to 12 divisions.

A 10–500 Mc Signal Generator Power Amplifier

ROBERT POIRIER, *Development Engineer*

An increasing demand has developed for higher RF power output levels, in the 0 to 10 dbw maximum output range, over the frequency range from 10 to 500 Mc, for the testing of communications systems and for general laboratory measurements. The need for higher power output signal sources results mainly from strong signal and cross modulation requirements of certain receiver tests and the large input signal requirements of bridge type devices. Because of the large number of existing signal generators in the 0 dbm maximum output category, BRC has developed a tunable signal generator power amplifier for use with these instruments. The signal generator power amplifier is to be an accessory for use with any signal generator having a maximum output in the vicinity of 0 dbm to provide a maximum output level in the vicinity of 4 dbw.

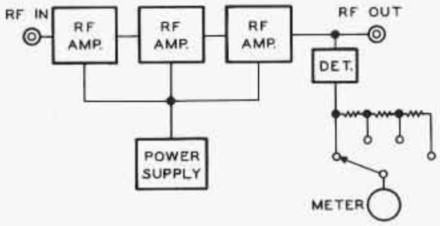


Figure 1. Block Diagram of Signal Generator Power Amplifier Type 230-A

The new Signal Generator Power Amplifier Type 230-A conceived by the Boonton Radio Corporation, consists essentially of three tracked tuned, cascaded stages of grounded-grid amplification. The choice of grounded-grid triode amplification was established primarily by a desire to provide a maximum operating frequency of 500 Mc. Two other advantages which are accrued for grounded-grid triode amplification as compared with grounded cathode tetrodes are: a low untuned input impedance which can be made nominally in the vicinity of 50 ohms, and a gain and maximum power output which are less sensitive to variations in load impedance. A minimum of 34 db power gain is to be provided for a frequency coverage of 10-500 Mc which will be continuously tuned in six slightly overlapping ranges. The gain will be linear within 9.0% up to 10 volts output in a 50-ohm termination. This provides that a maximum of 91% AM of a 5-volt carrier level, with 10% distortion of the modulation envelope, will be obtained for a 100% modulated (with no envelope distortion) input signal for which the carrier level approaches 0.1 volt or —7 dbm. The changes in percentage of modulation and envelope distortion which may be developed in the Signal Generator Power Amplifier at the maximum output levels, become negligible for modulation crests of 0.5 watt (5.0 volts rms in 50 ohms) or less. The linearity characteristic of the Signal Generator Power Amplifier is such that, in general, if the outgoing modulation crests exceed 0.5 watt, the modulation index will always be less than the incoming modulation by an amount not exceeding 9.0% of the incoming modulation. Whether, and in which direction, the envelope distortion may be affected at the maximum output levels, depends on the magnitude and phase of the incoming envelope distortion components, if any. The effect should be within ±10% for modulation crests of 10 volts rms in 50 ohms, diminishing to 2% or less for modulation crests of 5 volts rms in 50 ohms or less. The absolute maximum power output over most of the frequency range is 4 watts or 6 dbw (14.14 volts rms in 50 ohms), but the linearity (and gain) is not specified beyond 2 watts or 3 dbw. The overall bandwidth of the three-stage power amplifier is not less than 700 kc and is considerably greater over much of the frequency range.

A block diagram, Figure 1, shows that a self-contained power supply and an output RF voltmeter are included with the Signal Generator Power Amplifier. The RF output voltage is metered from 0-15 volts in four convenient ranges. The detector and the metering circuit will withstand the high voltages which can be developed at the RF output jack when it is unterminated, or terminated in a load having a very high VSWR. The accuracy of the RF output voltage indication is specified at the output jack to be ± 1.0 db of full scale over a frequency range of 10 to 250 Mc and ±1.5 db from 250 Mc to 500 Mc for a 50-ohm termination having a VSWR of 1.0 (0 db) in each case.

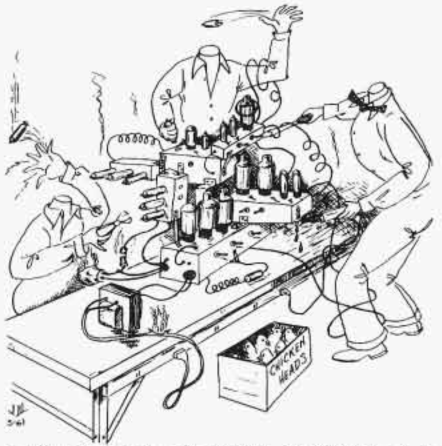
An electronically-regulated power supply is incorporated in the Signal Generator Power Amplifier to maintain a constant final amplifier plate voltage against the large variations in final plate current which occur over the range of 0.5 to 4 watts RF output. Other features include 50 ohms input and output impedance with a VSWR of 2.0:1, or less, over the frequency range of 10-500 Mc. RF leakage is sufficiently low to permit measurements at 0.1 volt.

Since the demand for higher power signal generators comes almost exclusively from sources already supplied with low-power signal generators, it is felt that the Signal Generator Power Amplifier will conveniently and readily fulfill this demand, offering up to 2 watts output for AM applications, or or up to 4 watts output for CW and FM, where amplitude linearity is unimportant.

EDITOR'S NOTE
New Look for BRC at IRE

The few weeks preceding the IRE show in March are pandemonium at BRC. Engineering and Sales are steeped in the problems of readying new instruments for showing and assuring that enough advance information is disseminated to stimulate customer interest. Many last-minute details are being attended to and the loose ends are being gathered and knotted .The last days before the show are tumultuous, but those in the midst of the turmoil are aware of the impact of the job they are doing, and in this there is solace.

This year, BRC will show its instrument line in a new display booth; designed not only to provide an attractive setting for instrument display, but to make it easier for BRC engineers in attendance to handle demonstrations and inquiries.



EACH YEAR, IN THE MONTH OF MARCH, A HIGHLY COORDINATED EFFORT IS MADE......!

Of particular interest at the show will be the UHF Q Meter Type 280-A (the subject of the lead article in this issue), the Navigation Aid Test Set Type 235-A (described in Notebook Number 24), and the new Signal Generator Power Amplifier Type 230-A (described in this issue).

Another "guess the Q" contest will be featured for those friends of BRC who welcome the challenge of a perplexing problem. Our engineers have, true to form, devised a resonant circuit which will be on display at the BRC booth. Contestants will be asked to estimate the Q of the circuit, enter this estimate on a contest card, and drop the entry into a special, locked receptacle. After the show, the Q of the resonant circuit will be measured on the UHF Q Meter Type 280-A, by means of the "in circuit" technique. Several measurements will be made and averaged. The entry which is closest to this average measured Q will be awarded a factory-reconditioned Q Meter Type 160-A. In case of a tie, a drawing will be held to determine the winner.

Plan to visit the IRE show at the Coliseum in New York City and stop at the BRC exhibit (Booths 3101 and 3102). Our engineering personnel on duty will be grateful for the opportunity to help you with your test equipment problems.

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