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A General Purpose Precision Signal Generator

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Design Considerations

The primary purpose of a signal generator is to simulate, acurately, some part or parts of a transmission system which are not conveniently operated at a test area or in a laboratory. Most important among the design considerations of such a device are its size, the precision with which it simulates test signals, and the stability of the simulated signals. Because test and laboratory space is usually limited, the signal generator is required to cover, in one small package, a band of frequencies wide enough to test an entire system, usually many times the size of the signal generator itself. As electronic systems have become more precise, the precision requirements placed upon the signal generator designed for use with these systems have become more stringent. A natural companion to precision is stability: the generated frequency, in particular, must not vary under the influence of the power line or amplitude modulation. In simulating weak signals into a high-sensitivity receiver, it must be possible to set the output of the signal generator to provide signals as low as 0.1μv with the knowledge that the results are not being clouded by leakage from the generator enclosure. Therefore, the design of the enclosure is very important along with all of the circuit design considerations.

Oscillator

The range chosen for this design is 10 to 500mc, the area of most intensive use in equipment development. Covering such a range with a single oscillator, implies that some changes in the parameters of the frequency determining elements will have to be made at periodic intervals through the range. It is impractical to imagine that varying one element, or varying both L and C for that matter, could possibly permit coverage of the 10 to 500-mc range in one band. At lower frequencies one can often choose from several different coils with a selector switch, but in the UHF range, leads and connections must be short, precluding the use of simple switching.

Figure 1. Type 225-A Signal Generator

In common use today is the concept of the turret, a device which actually removes the inductive element of the resonant circuit and replaces it with another element. This would seem to suit our purpose, because in such a device, lead length can be controlled. However, positioning must be very accurate and very stable. Providing a means for contacting these coils as they come into position requires careful consideration. The contacts must have low inductance and stray capacitance as well as a stable

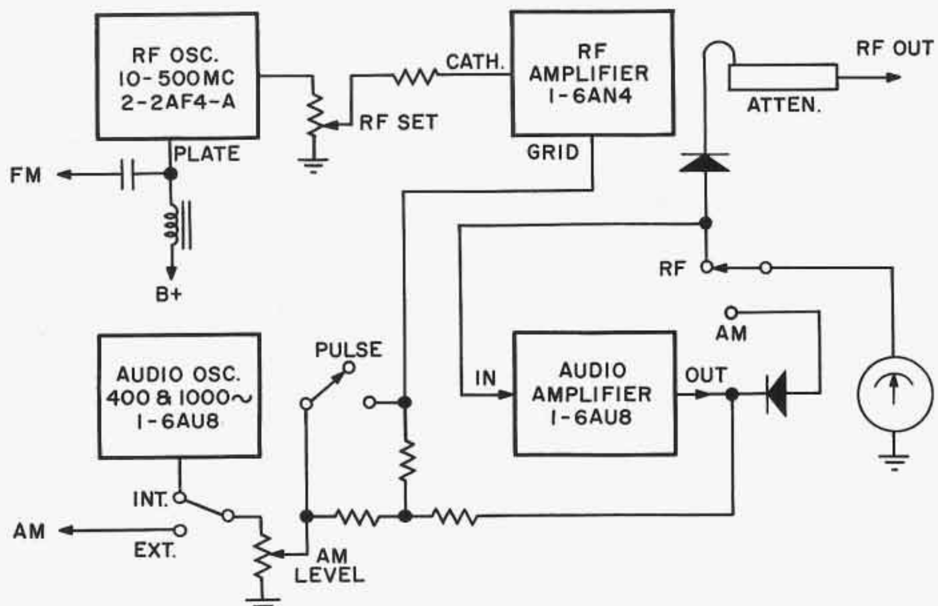

Figure 2. Functional Block Diagram

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low resistance. The physical structure of the turret is very important also, as any tendency of the basic structure to change dimensions or warp would result in frequency instability.

Use of the turret imposes certain limitations on the actual oscillator circuitry. The preferred circuit is one which employs a minimum number of moving contacts. It would be desirable then to design an oscillator with a feedback network which could be fixed for all frequencies so that additional switch contacts would not be required. A circuit which fits the turret requirements quite well, with a minimum number of contacts in the frequency determining network, is shown in Figure 3. The feedback is accomplished with a capacitive divider from one plate to the opposite grid, using the grid capacitance of the tube to cathode together with a fixed mounted capacitor from the other plate. This two-tube oscillator is particularly adaptable to our requirements for several reasons. First, it gives more power than a single tube of the 2AF4-A class; an important factor because good isolation from the modulator will be a requirement of the overall system and the more power there is to dissipate in isolation, the less reaction there will be. Second, the feedback is simple and fixed. Third, the two-tube oscillator works very well with a split-stator capacitor which requires no wiping contacts. This is important because wiping contacts on an oscillator capacitor would introduce noise and instability. In this oscillator, the center of the tank is at ground potential and therefore the rotor of the capacitor is also at ground potential for RF frequencies. With this arrangement the capacitance to ground of the capacitor drive is noncritical. Since the center of the oscillator coil is also roughly at the neutral or ground plane; plate power can be injected at this point from a common supply ring on the turret. This ring may be a simple slip ring rather than a switchable contact. Actually the oscillator turret is so constructed that the center of each coil is permanently tied back to this common slip ring through individual 100-ohm resistors. These resistors serve to break up undesirable RF paths, but do not introduce any appreciable plate voltage or radio frequency loss.

Coupling from the oscillator is accomplished by a pickup coil wrapped on the same form as the oscillator tank. Its output is picked up by two wiping contacts (similar to the contacts in the tank circuit) on the side of the turret.

Mechanical considerations in this part of the circuit have been very carefully thought out. The contact buttons on the turret are of coin silver and the mating spring fingers are of beryllium copper with a rolled-on coin silver overlay of 0.0025-inch thickness. (Silver plating can not be depended upon to withstand wear.) The turret itself is cast in an unmodified Epoxy Resin made by CIBA known as Araldite 6060 casting resin. This material has a reasonably low coefficient of expansion (50 ppm/°C and contains no filler material. The result is a very stable casting with no internal stresses and good machinability. Araldite resin is used to cement the silver button contacts into the casting. The circuit itself is mounted on a silver-plated brass chassis in a way which minimizes lead lengths and maintains the fundamental circuit symmetry. The basic enclosure tying the entire assembly together is a heavy aluminum casting mounted on a 1/4" silver-plated aluminum base plate. Positioning of the turret is accomplished by means of a stainless steel shaft which mounts a heavy hardened steel detent plate. The detent plate is restrained by an arm and roller assembly which is substantially spring loaded for positive positioning.

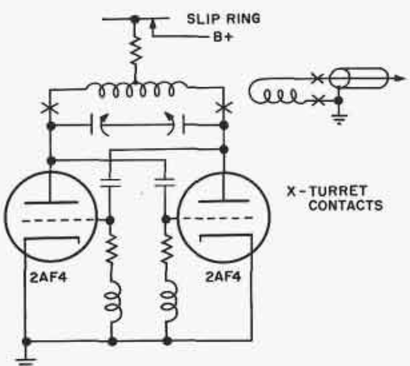

Figure 3. Oscillator Circuit

Modulator

There are many ways to modulate an RF signal once it is produced and it was necessary to evaluate these various methods in order to make the wisest choice. It was thought, at first, that it would be best if the modulator did not require tuning. This would immediately simplify the job by eliminating one tuning capacitor. It developed however, that this approach would create a problem in the output system. The piston attenuator in the output system operates with a rather large insertion loss; around 30 db over our frequency range. What is more, at least 20 db of attenuation is required between the modulator and the oscillator to prevent spurious frequency modulation as a result of amplitude modulation. An untuned modulator would impose an additional insertion loss. The output requirements of 0.1 volts is db below a milliwatt. With 20 db required for isolation, 10 db for modulation, and 30 db for the attenuator, there is a total loss of 60 db between the oscillator and the output. This means that a ridiculously high figure of roughly 500 watts would be required to provide the desired output. The oscillator discussed previously, puts out about 500 milliwatts lightly loaded.

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Diode Modulator

Another approach worthy of consideration is some form of diode modulator following the piston attenuator. There seem to be two objections to this approach. First, the noise generated in the diodes would be objectionable at low levels such as 0.1μv. Second, the high levels of voltage necessarily applied in order to produce a 0.1-volt output would necessitate operation of the diodes in a more linear operating range and thereby destroy the modulation capabilities. Typical low-level diode modulators of this type have about 50K μv maximum input and about 10 db insertion loss, meaning that the maximum modulated RF output would be around 15K μv. An advantage of this type modulator would be that the piston attenuator could couple directly to the oscillator and eliminate the second tuned stage. However, the poor low-output capabilities make it unsuitable for our purpose.

Tuned Grounded-Grid Trode Amplifier

If the modulator could be designed to provide a 20-db gain, instead of the 10-db loss introduced by an untuned modulator, there would be only a 30-db loss beyond the oscillator and the oscillator output requirement would need to be only 500 milliwatts. A tuned grounded-grid amplifier, utilizing a 6AN4 UHF triode, will provide this 20-db gain. The gain drops as 500 mc is approached, but improved attenuator coupling at the higher frequencies compensates for this effect.

There are several ways to modulate a tuned grounded-grid triode amplifier; by means of the plate, grid, or cathode. Both plate and cathode modulation require power. Grid modulation does not require power, but requires careful selection of operating point for reasonable linearity. Since this stage would not be operating as a class C amplifier, linear plate modulation would not be possible. Therefore, in the interest of simple low-powered amplitude modulation, a grid-modulation system was chosen.

In such a system, the grid must be well grounded for the RF signals but not for audio signals. This requires that a suitable capacitor be placed from grid to ground. A common failing of a high-frequency, grounded-grid stage is instability caused by the existance of inductance in the grid circuit. This results in positive feedback and possibly oscillation. Therefore, the grid capacitor selected must be a very low-inductance device.

The RF ground of the stage is established by a large silver-plated brass shield closely contoured to the tube socket and passing directly through the center of the tube socket and the grid pins which are located 180° apart. This shield not only establishes ground but shields the plate from the cathode. The grid leads are soldered to a sheet of silver-plated copper which covers the entire surface of the shield. A thin sheet of reconstituted mica separates the copper sheet from the shield. The copper sheet, covers both sides of the shield and acts as a very low-inductance bypass capacitor of 1500 $\mu\mu$f. This arrangement imposes a maximum RF reactance of 10 ohms at 10 mc; the lowest generated frequency. The maximum audio frequency to be passed by the modulator is 20 kc. At this frequency, the bypass capacitor is not less than 5000 ohms. To enable good pulse modulation, this capacitance would require 15 ma in order to permit the grid voltage to rise from 0 to 10 volts in 1 μs. The 15-ma current is based on the fact that a 10-volt pulse will cut off the amplifier. This is easily accomplished in the average pulse generator as long as there is no large series impedance between the generator and the grid.

Maximum isolation between the oscillator and the amplifier was given previously as a criterion for minimizing spurious frequency modulation. For this reason, as well as in the interest of maintaining the operating point of the modulation at an optimum level, the output level control was incorporated in the coupling between the oscillator and the modulator. This is merely a variable resistive voltage divider into which the oscillator output is fed. Only enough voltage to drive the modulated amplifier to the level which produces 0.1-volt output is taken from the divider. If a fixed attenuator were used it would have to be made small enough to insure full output at all frequencies under the limits imposed by tube parameter variations. The amplifier gain would then have to be reduced under these conditions to match this fixed attenuator. The result would be that, under many conditions, the stage gain would be reduced unnecessarily to match the fixed attenuator and, although the resulting spurious FM would be within the advertised specifications, it would not be as low as the tubes were capable of making it if they were allowed to perform at their optimum capabilities.

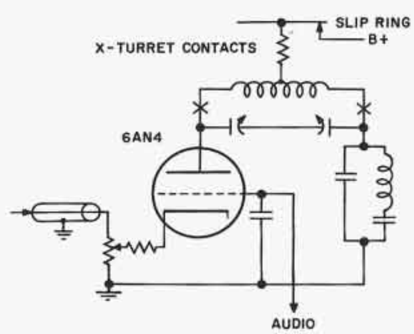

Figure 4. Modulator Circuit

Another reason for not changing the anode potentials in some uncontrolled manner is that, as previously stated, control-grid modulation requires careful selection of the stage operating point. The bias level is quite critical if low distortion is desired. Because the attenuator coupling decreases with decreasing frequency, the average level of drive to the final stage increases as the frequency decreases. The impedance of the modulator's tuned load also is higher for each lower band because the same tuning capacitor is used on all six bands. These factors result in a different optimum grid bias being required for each range. This is accomplished by means of a switch, coupled to the range knob, which selects the proper bias for each range. The distortion is further reduced by overall inverse feedback which will be described further on in this paper.

To maintain maximum isolation between the amplifier and oscillator, the amplifier is housed in a separately shielded casting, very similar to the oscillator casting. The energy passing between the two castings is fed through a coaxial cable which is enclosed in copper tubing to prevent leakage. This coaxial cable couples directly into the variable resistive attenuator which in turn couples to the cathode of the amplifier. This construction prevents stray fields or circulating currents which might cause sudden unpredictable increases in spurious FM at discrete frequencies.

The grounded-grid amplifier circuit tank (Figure 4) is similar to a push-pull tank except that one tube has been replaced with a reactive network. A true push-pull stage utilizes a complex driver transformer and would furnish more power than is required. This one tube arrangement was used in order that the amplifier circuitry would be similar in design to the oscillator, with the same design of turret and tuning capacitor, so that the two circuits would track naturally. The turret is the same as the turret used in the oscillator except that there is no pickup winding. (The attenuator pickup coil couples directly to the tank coil.)

The tuning capacitor is the same capacitor used in the oscillator except that several plate sections have been omitted. The oscillator and amplifier tanks are necessarily of slightly different design because, in the oscillator, the feedback capacitors add to the minimum tank capacitance. In the amplifier, the connections from the turret to the tuning capacitor are slightly longer to accomodate the attenuator. Therefore, this tank has a somewhat higher inductance and a lower capacitance than the oscillator tank. In order to assure reasonable tracking with these unequal tank parameters, fewer plate sections were used in the amplifier tuning capacitor. The reduced $\triangle$C in the amplifier, in combination with the lower residual capacitance, results in a frequency range which closely tracks the oscillator.

The turret is cast with one flat side

so that it can be positioned closely to the flat attenuator pickup coil. Between the attenuator tube and output tank, on either side of the plane occupied by the attenuator pickup coil, are two parallel monitor wires about $\frac{3}{16}$ inch apart. One end of each of these is grounded and the other ends are tied to a IN82A diode monitor. This monitor system, therefore, intercepts the same field that enters the piston attenuator tube and performs the monitor function for all ranges. In a narrow-range, one-band generator, output monitoring is accomplished by feeding some energy from the tank through a small coupling capacitor. This system provides more usable energy, but would not be satisfactory in a wide-range, multi-banded unit. The two pickup conductors also serve as a Faraday shield, allowing only the TE_{11} mode to propagate into the tube. Any mode which is propagated into a wave guide significantly below its cutoff frequency decays at a rate which is exactly logrithmic with distance along the waveguide. This rate is exactly related to guide diameter in a circular waveguide. However, there are various modes which can be introduced into a waveguide which have differing rates of decay. The presence of more than one mode would tend to distort the ideal attenuation law. The attenuator is based on the TE_{11} mode because this mode decays at a rate which is less than any of the other propagation modes. The TM_{01} mode is shorted out by conductors arranged in the same manner as the monitor loop, because the attenuation rate of the TM_{01} mode is only 4.9 db per radius more than the TE_{01} mode and could cause errors in the attenuator output. The TE_{02} mode, at an additional 17.3 db per radius, is also an annoyance. This problem is solved by arranging the pickup and tank coils symetrically around the axis of the tube.

The attenuator pickup coil itself is a single loop of wire in the same plane as the center turns of the tank coil. A 50-ohm carbon film resistor in series with the loop provides a 50-ohm source impedance. At the point where the loop connects to the output coaxial cable, there is an impedance compensating circuit composed of a 50-ohm resistor and a capacitor in series to ground. This tends to draw current of a leading phase when the loop phase is lagging, resulting in the maintenance of a good low VSWR source impedance from the attenuator output. This results in a VSWR of less than 1.2.

In order to accurately measure the amplitude modulation percentage, as well as the RF output, the 1N82A monitor diode is by-passed for RF only. Amplitude modulation at an audio rate remains as an audio voltage imposed on the diode dc output. To monitor RF, diode output is fed directly to a 20 μa meter on the panel through suitable calibrating resistors. For AM monitoring, the diode output is connected to an ac-coupled amplifier which builds up the audio envelope, then feeds it to a cathode follower. The cathode follower in turn drives a diode voltmeter which is fully bypassed for frequencies as low as 20 cps. This dc output is then switched to the same 20 μa meter through suitable calibrating resistors. The meter is marked both in % AM and an RF Calibrate position. It normally reads RF but by means of a momentary contact switch can be made to read % AM.

The output of this AM metering amplifier is used in another related manner. A certain percentage of the voltage from the cathode follower outputs returned out of phase with the incoming modulation voltage. This tends to further reduce the AM distortion and provdes a high degree of stability for the entire modulation system. Since this places a resistive network between the input terminals and the RF amplifier grid which would tend to slow down pulses fed into this point, a switch at the full-clockwise position of the AM LEVEL control removes the inverse feedback, providing direct connection from the input terminals to the RF amplifier control grid for pulse modulation.

In the pulse position, the instrument continues to operate as described. A 10-volt negative pulse will turn the amplifier off. The amplitude modulation terminals are dc coupled to the grid of the RF amplifier and thus it is not desirable to swing this point in a positive direction. All that lies between the AM posts and the grid is an RF filter which prevents RF leakage. This had to be appropriately damped to prevent ringing or extreme overshoot and therefore limits the minimum rise time to 2 μs.

Frequency Modulation

Frequency modulation has been included in this instrument in its most elementary form. Means have been provided for amplitude modulating the plate of the oscillator from an external post. This provides low deviation frequency modulation which, though uncalibrated, is somewhat predictable in magnitude and will be useful in the range above 100 mc where sufficient deviation for the narrow-band FM communications channels is present.

Shielding

The instrument has been thoroughly shielded against RF leakage. Where flat cover plates engage the RF shield castings, a mating tongue and groove joint lined with silver-plated brass mesh assures perfect sealing. The aluminum cover plates are silver plated and join the casting in a similar manner. Where shafts protrude from the enclosure, double circular wiper fingers are used, one over the other. Every joint is carefully sealed by some resilient, highly conductive device which will retain high pressure and good electrical contact. The RF filters employ very low-inductance discoidal ceramic capacitors which have a resonant frequency well above the range at which they are used in the generator. The series elements in the filter are toroidal coils wound on ferrite cores, providing the maximum series loss in the smallest package possible.

Power Requirements

The power requirements of the instrument have been kept low; in the order of 70 watts. This gives the instrument a good degree of stability due to the freedom from excessive heating. What is more, it has permitted the use of a very effective, but simple, power supply. The power transformer is a resonant circuit type, regulating transformer which provides excellent stabilization of plate and heater voltages. In addition, the dc output to the oscillator plate is gas-discharge tube regulated and the filaments are regulated by a hot-wire, series-regulating ballast. This regulation results in a frequency stability-vs-line voltage of much better than 0.001% total frequency change for a 5-volt line shift.

Internal Modulation

The instrument has an internal modulating oscillator operating at 400 or 100 cycles, as well as provision for external amplitude modulation.

Frequency Variation Controls

It has been previously stated that the oscillator and amplifier were designed in such a way as to track together as the frequency is changed. However, some adjustment is necessary to peak the amplifier output for optimum performance at a specific frequency. This is accomplished by means of a small trimmer knob which is coaxial with the large coarse frequency control knob. This control provides differential motion between the oscillator and the amplifier tuning capacitors. Friction in the system is such that the oscillator shaft does not turn when this knob is operated, permitting tuning of the amplifier through a 6 to 1 reduction with negligible frequency change. The shafts are coupled together with a spring-loaded, phosphor bronze drive cable so that, when the large frequency knob is turned, both oscillator and amplifier tuning shafts operate in unison.

The main frequency dial, which is over 6 inches in diameter, is directly attached to the oscillator capacitor drive shaft. Gear teeth on the perimeter of the oscillator dial are driven by a vernier dial which is divided into 100 parts. The vernier dial turns 10 times throughout the full oscillator dial range. This provides a logging scale which divides any range into 1000 parts. Backlash is negligible because the main dial is a spring-loaded, split-gear assembly.

Rack Mountable

As a package the instrument is on a standard 19-inch rack mountable panel. End bells provided with the instrument cover the protruding panel ends in case rack mounting is not desired.

Conclusion

The BRC Type 225-A Signal Generator is a compact, highly stable, useful signal generator free from the spurious effects which can make life unpleasant for the engineer or technician. The following published specifications speak for themselves in demonstrating the degree of success achieved.

Specifications

RADIO FREQUENCY CHARACTERISTICS

RF Range
Total Range: 10 to 500 mc.
No. Bands: 6
RF Accuracy: ±0.5% (after two hour warmup)
RF Settability: ±0.05%
RF Calibration
Main Dial: Increments of approximately 1%
Vernier: 1000 divisions through each range.
RF Stability (after 2 hour warmup)
Short Term: ±0.001% (5 minutes)
Long Term: ±0.01% (1 hour)
Line Voltage: ±0.001% (5 volts)
RF Output
Range: 0.1μv to 0.1 volts
(across external 50 ohm load.)
Accuracy: ±10% 0.1 to 50 k μv, 10 to 250 mc.
±15% 0.1 to 50 k μv, 250 to 500 mc.
±20% 0.05 to 0.1 v, 10 to 500 mc.
Impedance: 50 ohms
(25 ohms at terminals of Type 501-B Output Cable)
VSWR: 1.2
RF Leakage: Sufficiently low to permit measurements at 0.1 μv.

AMPLITUDE MODULATION CHARACTERISTICS

AM Range
Internal: 0 to 30%
External: 0 to 30%
AM Accuracy: ±10% at 30% AM, 10 to 250 mc.
±15% at 30% AM, 250 to 500 mc.
AM Calibration: 10, 20, 30%
AM Distortion: 5% 10 to 250 mc.
7% 250 to 500 mc.
AM Fidelity: ±1 db 40 cps to 20 kc.
Incidental FM: 0.001% or 1000 cps, whichever is greater, at 30% AM
External AM Requirements: 10 volts RMS into 4000 ohms for 30% AM

FREQUENCY MODULATION CHARACTERISTICS

FM Range: (External)
0 to between 5 kc and 60 kc, depending upon frequency in the range 130 to 500 mc.
FM Calibration: Deviation sensitivity vs. frequency nomograph
Incidental AM. 10%
External FM Requiremerlts: 10 volts RMS into 1000 ohms

PULSE MODULATION CHARACTERISTICS

PM Source: External
PM Rise Time: 5 μsec 10 to 40 mc.
3 μsec 40 to 80 mc.
2 μsec 80 to 500 mc.
PM Overshoot: 10% 10 to 100 mc.
25% 100 to 500 mc.
External PM Requirements: 10 volts peak negative pulse, 20 ma. peak short-circuit capability.

MODULATING OSCILLATOR CHARACTERISTICS

MO Frequency: 400 and 1000 cps.
MO Accuracy: ±10%

POWER REQUIREMENTS

225-A: 105-125 volts, 60 cps, 80 watts.
225-AP. 105-125 volts, 50 cps, 80 watts.

A Signal Generator Calibrator for RF Level and Per Cent AM

ROBERT POIRIER, *Development Engineer*

In response to consumer requests for slightly higher output voltages the type 245-B RF Voltage Standard which initially was designed to provide accurately calibrated RF output voltages (supplied by an external source) of 0.5, 1.0, and 2.0 microvolts for the purpose of checking receiver sensitivity and low-level calibration of signal generators has been modified to greatly enhance its usefulness. The modified instrument, which supersedes the 245-B RF Voltage Standard, is known as the Signal Generator Calibrator. It is available in two models, types 245-C and 245-D. Added features include: 1) a choice of calibrated RF output voltages; vis., 5, 10, and 20 microvolts or 0.5, 1.0 and 2.0 microvolts; 2) direct reading of three calibrated, unmodulated RF input voltages; viz., 0.025, 0.05, and 0.1 volt, and 3) direct reading of the per cent amplitude modulation of the RF input voltage to 100%. With the exception of attenua-

Figure 1. Type 245-C/D Signal Generator Calibrator

tion, the types 245-C and 245-D are identical. The Type 245-C is the high output instrument providing 5, 10, and 20 microvolts calibrated output voltage and the Type 245-D is the low-output instrument providing 0.5, 1.0, and 2.0 microvolts calibrated output voltage.

Principles of Operation

In order to provide for slightly higher output voltages of the same accuracy as obtained from the Type 245-B RF voltage standard, it was considered expedient to change the shunt resistance element of the micropotentiometer[1] from 0.0024 ohms, as used in the 245-B, to 0.024 ohms for the 245-C. Output voltages of 5, 10, and 20 microvolts are thereby obtained for the same nominal input voltages of 0.025, 0.05, and 0.1 volt respectively, without changing the physical structure of the attenuator. All other methods of increasing the output of the Type 245-B micropotentiometer, such as decreasing the input impedance to 6 ohms (in lieu of changing the shunt resistance element) or increasing the input voltage requirement are inappropriate to the desired result. The problem of changing the resistance of the shunt element without appreciably affecting its physical dimensions is largely a matter of finding a suitable material from which to make the element; noting that the thickness of the resistance element is closely restricted at one end by the size of the individual molecules which influences the mechanical stability of the resistance, and at the other end by the depth of penetration of the RF current which influences the electrical fidelity of the attenuator. The effort which has recently been given to the search for new materials and new methods of fabricating the shunt resistance element has yielded an improved element for both the 245-C and 245-D Signal Generator Calibrator. The RF Voltage monitor and attenuator system, described in previous Notebook articles [2,3,4,] is shown in Figure 2. The value of the disc resistor used is different for the Type 245-C and 245-D as indicated.

The measurement of unmodulated RF input voltages of 0.025, 0.05, and 0.1 volt will be more fully exploited in the Types 245-C and 245-D than it was in the 245-B. Two innovations bearing directly on this function are: 1) a meter function switch to provide correct calibration of either the RF input voltage or the RF output voltage, and 2) frequency compensation of the RF monitor to eliminate the need of a frequency correction curve. Both the meter function switch and the frequency compensation permit greater accuracy of input voltage measurement than is attainable with the Type 245-B. The meter function switch precludes the ±6% maximum error of input voltage measurement which in the Type 245-B results from the tolerances of the nominal low frequency values of the resistors in the micropotentiometer. Frequency compensation is accomplished by means of a low-Q inductive network in series with the input to the RF voltmeter which reduces the input VSWR due to capacitance of the RF monitor circuit.

A completely new function of the Signal Generator Calibrator is the direct reading of per cent amplitude modulation of a modulated RF input signal around the 0.1-volt input level. Operation of the % AM feature requires an initial calibration of the unmodulated carrier at the 0.1-volt input level using the input voltage measuring function of the instrument. The meter function switch is then set to % AM and reads the full wave average of the detected modulation envelope. The additional gain required is developed in a two-stage transistor amplifier with inverse feedback to stabilize the gain and improve the linearity of the %AM scale. Although the RF detector operates

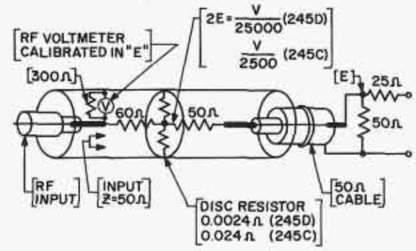

Figure 2. Attenuator and Voltmeter

nearly square law, the % AM indication is nearly linear because the AM detector is biased to be always forward conducting. [2, 4] The waveform of the detected modulation versus the modulation envelope is represented in Figure 3. The output polarity of the diode is negative. Referring to Figure 3, any peak-to-peak limits of the detected modulation are represented as $(y_1 - y_2)$ and the corresponding peaks of the modulation envelope are represented as $(x_2 - x_1)$.

From

$y = -x^2$ (for the square law diode)

$$y_1 - y_2 = x_2{}^2 - x_1{}^2 =$$

$$(x_2 - x_1)(x_2 + x_1)$$

For any given operating point x, y, $(x_2 + x_1)$ is a constant, 2x since $x + \triangle x + x - \triangle x = 2x$

$$\therefore (y_1 - y_2) \propto (x_2 - x_1)$$

for either distortionless or odd harmonic modulation distortion. Some even harmonic distortion of the modulation envelope is produced in the instrument as the AM detector law changes near the crests of 100% modulation. Experimentally, this has been found negligible and is anticipated in the calibration of the %AM meter scale.

Since the % AM readout is in terms

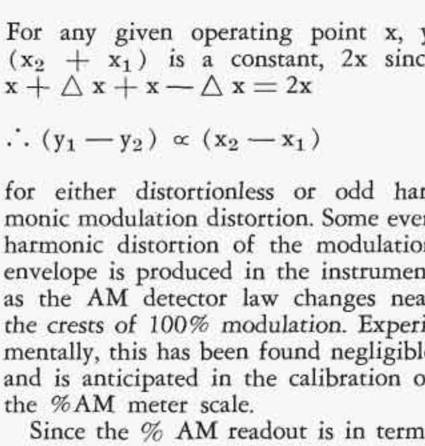

Figure 3. Approximate AM Detector Characteristic

of the full-wave average of the detected modulation, the % AM indication is subject to the usual errors resulting from interpreting peak-to-peak information from an average readout. The instrument is provided accurately calibrated for undistorted sinusoidal modulation. Users of this instrument should be cognizant of a source of error which is not necessarily related to distortion of the modulation envelope; viz., RF carrier shift of the initial unmodulated calibrated level which accompanies the modulation. Nonlinear modulation is, of course, a common cause of this carrier shift; an uncommon cause (which may become increasingly common) is inverse feedback regulation of the output power level of a signal generator. The Signal Generator Calibrator will be offered with the % AM indication calibrated for no shift of the carrier power level with modulation.

Uses of the 245-C and 245-D

The Signal Generator Calibrator retains the originally conceived function of providing accurate, low-level RF output voltages. Uses for this and the new features are enumerated as follows:

1. Accurate spot checks can be made of receiver sensitivity over the range of 500kc to 1000 mc and 0.5 microvolt to 20 microvolts.
2. By associating the precision fixed attenuator (74 db in the 245-C or 94 db in the 245-D) with a precision piston attenuator the range of calibrated low-level output voltages can be extended well below 0.5 microvolt, for receiver sensitivity and noise figure measurements, subject only to limitations in shielding the receiver from the signal source.[5]
3. Accurate spot checks can be made of unmodulated signal generator output voltages from 500kc to 1000mc at high-output levels between 0.025 and 0.1 volt inclusive, at low levels (with a suitable receiver) between 0.5 microvolt and 20 microvolts inclusive, or at a level less than 0.5 microvolt with precision fixed attenuators.
4. Fast, accurate measurement can be made of % amplitude modulation to 100% for modulating frequencies from 20 cps to 20 kc.

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4. Gorss, C. G., "Calibration of An Instrument for Measuring Low-Level RF Voltages," BRC Notebook No. 14, Summer, 1957.

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NEW BRC INSTRUMENTS TO BE SHOWN AT IRE SHOW

Booths 3101 — 3102

Boonton Radio orporation will offer three new instruments to the electronic industry in 1959. The instruments, which will be on display in the BRC exhibit at this year's IRE Show in New York, include: the new Type 225-A Signal Generator, the new Types 245-C and D Signal Generator calibrators, and the new Type 202-G Telemetering Signal Generator.

Designed for operation in the 10 to 100-megacycle range, the Type 225-A Signal Generator embodies circuit and structural design innovations which provide a new standard of precision and stability.

The Types 245-C and D Signal Generator Calibrators, for the first time, provide a convenient portable instrument for measuring and calibrating the RF level and percentage AM on Signal Generators in the range from 500KC to 1000MC. They may also be used to provide a calibrated source of low-level RF voltage for the precision testing of receiver sensitivity.

The Type 202-G FM-AM Signal Generator is an improved generator for the testing and calibration of FM telemetering systems offering RDB modulating frequencies and complete coverage of the recently extended 215 to 260 MC telemetering band.

Visit booths 3101 and 3102 at the IRE Show during March 23 to 26 where BRC personnel will be on hand to give you more facts about these and other BRC instruments.

A Telemetering FM-AM Signal Generator

FOR COVERAGE OF THE RECENTLY EXTENDED TELEMETERING BAND

HARRY J. LANG, *Sales Manager*

Type 202-G Telemetering FM-AM Signal Generator

With the rapid development of FM telemetering systems in the post-war period, BRC, as a pioneer manufacturer of FM Signal Generators, developed the Type 202-D Signal Generator in 1949 to provide FM-AM coverage of the then assigned 215-235 mc telemetering band. The 202-D, which was subsequently assigned military nomenclature SG-59/U, offered continuous RF coverage from 175 to 250 mc at output levels from 0.1 μv to 0.2 volt and was designed for both internal and external FM and AM. Frequency modulation was provided by a reactance-tube circuit, specially designed to maintain constant deviation, with carrier frequency. Controls provided continuously variable deviation from 0 to 240 kc Amplitude modulation, from the internal audio oscillator, was continuously variable from 0 to 50% and this range could be entended to 100%, employing an external modulating oscillator. Pulse modulation, from an external source, was also provided. The internal audio modulating oscillator provided a choice of eight fixed frequencies with nominal values between 50 cps and 15 kc.

Further development and expansion of FM telemetering, increased the applications of this type precision signal generator. Both military and commercial system requirements called for the incorporation of such a unit into the complete telemetering system. Recognizing this trend, BRC redesigned the 202-D and made available the Type 202-F Signal Generator in 1957. The 202-F was mounted in a new type of cabinet (which has now become standard on many of our instruments) that would provide for both bench and rack mounting. The instrument, as furnished, includes a complete cabinet and dust cover. By simple removal of the cabinet end bells, the instrument will mount in a standard 19″ relay rack, making it ideal for system applications. Several other circuit innovations were also incorporated which improved stability and modulation fidelity.

When the telemetering band was recently extended up to 260 mc, it became immediately apparent that a further redesign of the 202-F was necessary in order to provide complete RF coverage of the new band. The new Type 202-G Signal Generator offers continuous RF coverage from 195 to 270 mc completely blanketing the new 215 to 260 mc band. As a further aid to the convenient checkout of telemetering systems, the nominal audio modulating frequencies, provided in the earlier 202-D and F, were replaced with the following standard RDB values:

50, 400, 730 cps; 1.7, 3.9, 10.5, 30.0, and 70.0 kc.

All other mechanical and electrical characteristics are identical to the obsolete 202-F.

EDITOR'S NOTE

25th Anniversary for BRC

1959 represents a major milestone for BRC marking the completion of 25 years as a designer and manufacturer of precision electronic laboratory instruments. Befittingly, this anniversary closely follows the purchase of a new 70-acre plant site in the picturesque Rockaway valley and the announcement that plans have been formulated to erect a new, enlarged factory in the near future. Much progress and expanison has taken place in the electronics industry since the inception of BRC back in 1934 and as we reflect back over the years, we feel a certain amount of pride in the knowledge that we have made a direct contribution to this growth.

Founded in 1934 by William D. Loughlin, a pioneer in the industry, BRC, from its earliest years, concentrated its engineering skills toward the development of general-purpose precision laboratory tools for the electronic designer. The first product was the now famous Q Meter which still represents a basic tool and has been accepted as a standard throughout the industry. Improved versions of the Q Meter have since been designed and continue to form a major portion of BRC's product line.

With the development of frequency modulation techniques in the late thirties, the company's interests were focused in this area and resulted in the first commercial FM Signal Generator which made its debut at the Boston IRE meeting in 1940. BRC has since expanded its line of FM Signal Generators to cover all commercial and military applications in this field.

During World War II, BRC, like all U. S. industry, was directly engaged in the manufacture of critically needed products for the Armed Services. In addition to continuing the production of several versions of the Q Meter and Signal Generators, BRC, in cooperation with the M.I.T. Radiation Laboratory, developed microwave Signal Generators for the calibration of radar systems. These efforts won the company numerous awards and commendations and served to encourage a broadening of activities in the post-war period.

Boonton Radio Corporation in 1939

Beginning in 1946, an entirely new line of FM Signal Generators was introduced to serve the then embryonic television industry and several new instruments for general purpose RF impedance measurements followed shortly thereafter. With the introduction of the VOR aircraft navigation system and the ILS aircraft landing system, specialized Signal Generators for these systems were designed and introduced in the period from 1948 to 1953.

Boonton Radio Corporation as it appears today

Beginning in 1953, the basic Q Meters were redesigned and a Sweep Signal Generator, a self-contained VHF impedance bridge, Q Standards, and an RF Voltage Standard, as well as a Film Gauge for industrial applications, were added to the line. Last year marked the development of a unique Q Comparator which is now in production.

In partial celebration of its 25 years in the electronic instrument industry, BRC is introducing four new instruments at the New York IRE Show this month: the Type 225-A Signal Generator, the Types 245-C and D Signal Generator Calibrators, and the Type 202-G FM-AM Signal Generator. These new instruments are described in this issue.

WIN A Q METER

Visit the BRC exhibit (Booths 3101-3102) at the IRE show and enter the Q Meter Contest. A factory reconditioned Type 160-A Q Meter will be awarded again this year to the person whose Q estimate is closest to the actual measured Q of a special coil which will be on display in the BRC exhibit. Complete information will be furnished by BRC representatives in attendance at the exhibit.

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