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MEASUREMENT TECHNIQUES USING A COAXIAL SWITCH

Since the genesis of the electronic age, hundreds of measurements have relied upon a system of comparison. In this system the desired information is obtained from the unit to be measured, and then compared to a known reference. This technique is capable of considerable accuracy in that it provides for the virtual elimination of test "set-up" errors.

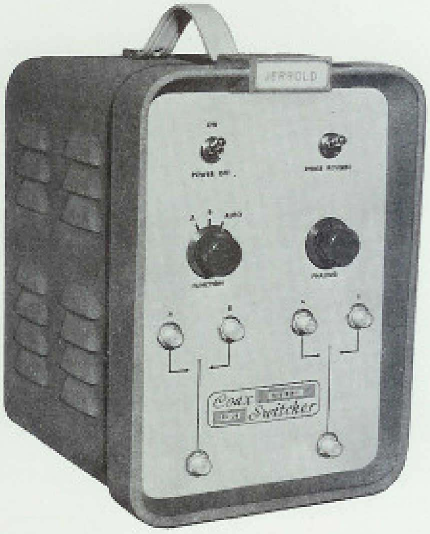
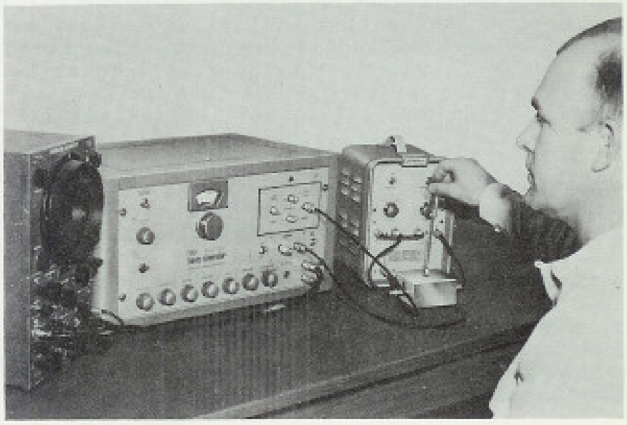


FIGURE 1 – ELECTRONIC COAXIAL SWITCH

An important disadvantage to the comparison method of test, however, is that it is generally quite time consuming. Manually operated coaxial switches have provided some degree of improvement insofar as the time consuming criticism is concerned, and electronic "hard-tube" switching has considerably improved measurements in the video and audio spectrums. Since electronic "Hard-tube" switching devices are limited to the video spectrum of 10 mc. and below, they are not applicable to direct R.F. measurements.



Indirect R.F. measurements can be accomplished however, by using the video switch to display alternately, the output of two R.F. detectors; one installed in the test circuit and the other in the reference circuit. Although this method is useful, its accuracy is limited by the requirement that the characteristics of the detectors and amplifiers must be balanced and precisely matched.

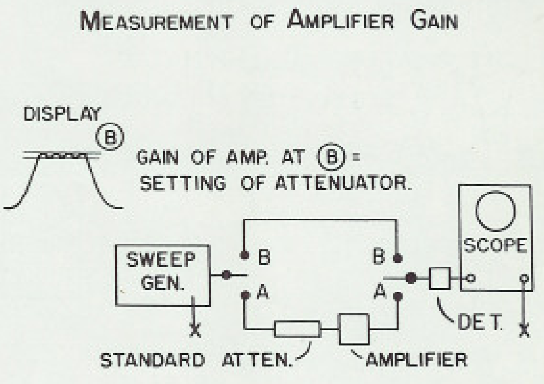


FIGURE- 2

The Jerrold Coaxial Switcher, Model FD-30, was specifically designed to apply the comparison method of measurement in the frequency range from D. C. to 250 mc., without the need for costly, time consuming test "set-ups" and "take-downs", and without the problems of detector and amplifier balancing.

Figure 2 illustrates the use of an FD-30 in measuring the gain of an R. F. amplifier by the comparison technique. In switch position A the generator signal is fed to the amplifier to be tested through a variable attenuator and the amplifier output is connected to an R. F. detector. In switch position B, the generator signal is fed to the same R. F. detector through both switches. The Model FD-30 switches between positions A and B at a rate adjustable to 10, 15 or 30 cycles per second, so that the two detected outputs are seen super-imposed on the scope. Measurement is accomplished by adjusting the attenuator until the two traces coincide showing equality of the detector inputs in positions A and B. At this point, the gain of the amplifier equals the insertion loss of the attenuator.

The accuracy of the measurement is unaffected by variations in the generator's output, variations in the oscilloscope gain settings, or by the frequency and square law characteristics of the detector. Neglecting the attenuator accuracy, the only errors in the system are; VSWR or loss differences in paths A and B, and the "cross-talk" between the A and B switch sections.

To keep these errors at a minimum, the Model FD-30 was designed to provide for a VSWR of less than 1.1 up to 250 mc. The insertion loss of the switch elements is well below 0.5 db, and the "cross-talk" path has been designed not to exceed the coupling provided by 1.0 uuf or capacity, into a 50 ohm load at 250 mc. These specifications provide for accuracy capabilities - without refinement efforts - in the order of ± 0.2 db.

Improved accuracy can be accomplished, in any test procedure using the Model FD-30, by balancing the A and B paths for correction of the VSWR and insertion loss differences. This is accomplished by observing the oscilloscope presentation with the item to be tested replaced by a jumper, but utilizing all other cables and fittings. Attenuation differences in paths A and B can be corrected by the insertion of small value, fixed pads.

MEASUREMENT OF EQUIPMENT LOSS

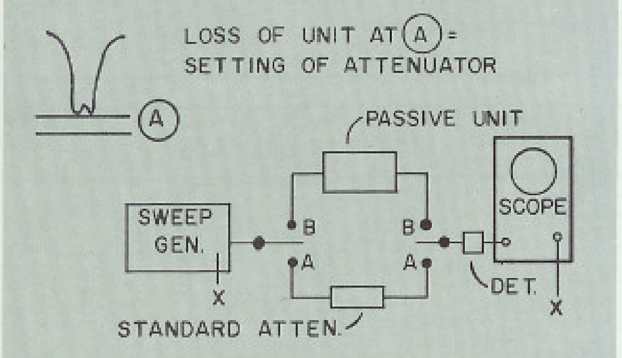


FIGURE-3

Illustrated in Figure 3 is a simple method of measuring the attenuation characteristics of filters, traps, coaxial cable and other passive networks. Here, the loss of the circuit is determined by inserting attenuation in the variable attenuator until the detected outputs of paths A and B are equal, as observed on the oscilloscope.

For circuits with losses as great as 40 db it may be necessary to use an oscilloscope preamplifier to improve the input sensitivity of the oscilloscope. The Jerrold Oscilloscope Preamplifier, Model SPR-100, is excellent for this purpose. The unit features a built-in detector that is flat from 500 kc. to 250 mc., an internal marker insertion amplifier-mixer. and an audio amplifier with a minimum gain of 40 db and good 60 cycle square wave response.

Fig. 4 illustrates a well-known and very useful sweep-frequency method of determining VSWR. A section of standard cable or "delay line" is connected to the output of a sweep-frequency generator, with a detector bridged across the junction. The detector supplies the scope with an input corresponding to the RF voltage at the line input.

Under these conditions the detector input voltage is the resultant of two components. The first component is E(m), the main wave, which is the only voltage when the delay line is terminated at the other end in its characteristic impedance. With a well-designed sweep this voltage is constant with frequency, and the scope displays a horizontal line.

BASIC VSWR TEST SET-UP

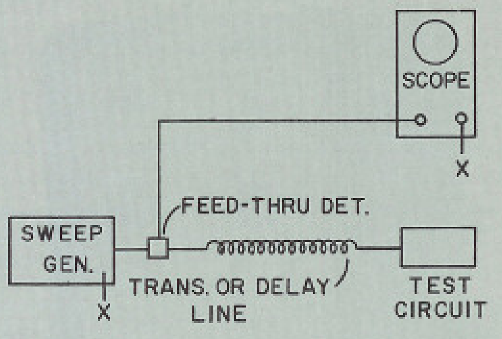


FIGURE-4

The other component is E(r), the reflected wave; this is present only when the far end of the line is mismatched, and its amplitude measures the degree of mismatch. When E(r) is in phase with E(m) they add to produce a voltage maximum; when it is 180° out of phase they subtract to a minimum. Due to the time delay in the line the phase of E(r) changes as the sweep frequency changes, so it alternately adds to and subtracts from E(m), producing a ripple pattern on the scope. At frequencies where the match is good, the reflection is small, and the ripple pattern has small amplitude; where the match is poor, there is a large reflection and the ripple has large amplitude.

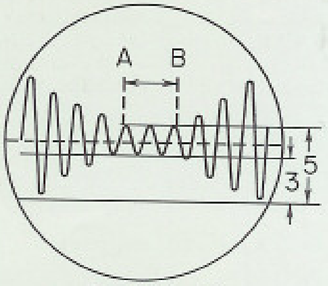


FIGURE-5

Figure 5 illustrates a typical scope display, showing the ripple pattern caused by a band-pass circuit which has a fair match between frequencies A and B and a poor match elsewhere. The horizontal dashed line shows where the trace would fall for a terminated line (E(m) only).

There are several well known methods of obtaining a VSWR measurement using this type of display. A common, but somewhat inaccurate method is to measure the relative height of Emax, and Emin as indicated on the oscilloscope. In Figure 5 Emax is indicated as 5 divisions and Emin as 3 divisions over the frequency range A-B.

Since **VSWR** $= \frac{Emax}{Emin}$ *Then* **VSWR** $= 5/3 = 1.66$

The use of the divisions on the oscilloscope screen for a true voltage relationship does not allow for the square law characteristics of the detector. This would not normally be a large source of error when the VSWR approaches unity, but become an increasing source of error as the VSWR increases. Also, as the VSWR approaches unity it becomes increasingly difficult to use the oscilloscope face as a measurement of Emax and Emin, as these voltages are nearly identical and the difference between them is relatively small. The use of additional oscilloscope gain is limited by the need for the zero base line, and therefore, this method will not provide accurate VSWR measurements of small ratios.

VSWR TEST SET-UP USING AN ATTEN.

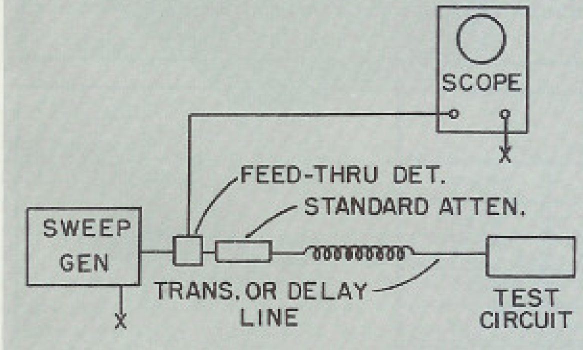


FIGURE-6

A more accurate method of VSWR measurements utilizes a calibrated attenuator as shown in Figure 6. First, all attenuation is removed from the attenuator and the unit to be measured is connected to the end of the transmission line. The height of the reflected voltage as shown on the oscilloscope is recorded. The unit is now removed from the line and the line is left opened to provide 100% reflection. Attenuation is inserted in the attenuator until the height of the reflected voltage equals the reflected voltage from the circuit under test, as previously recorded. The amount of attenuation inserted, now provides us with the relationship between E(m) and E(r). If 10 db insertion was required in the attenuator we may then say that the "return loss" of the circuit is 20 db, since the reflected voltage has to make two trips through the attenuator. If a VSWR relationship is required, we have:

$$\text{VSWR} = \frac{E(m) + E(r)}{E(m) - E(r)}$$

AND: $E(r)$ = 20db below $E(m)$
OR: $E(r) = 1/10\ E(m)$
AND: $E(m) + E(r) = 1 + .1$ or 1.1
$E(m) - E(r) = 1 - .1$ or $.9$
THEREFORE: $\text{VSWR} = \frac{1.1}{.9}$ or **1.23**

NOTE: See nomograph of VSWR, Figure 8

The advantage of this method over the previous method is that the result is not affected by the square law characteristics of the detector, and all of the oscilloscope gain may be utilized since we no longer require the base line to determine the relationship between E(m) and E(r).

The delay line losses are also of no consequence (except for sensitivity) in that the calbriated attenuator was adjusted to supply the same reduction of E(r) as the test unit provided and the line losses were identical in both indications.

MEASUREMENT OF VSWR

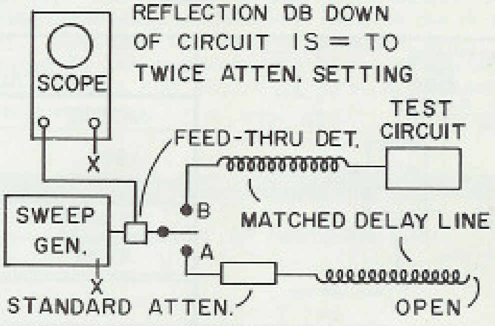


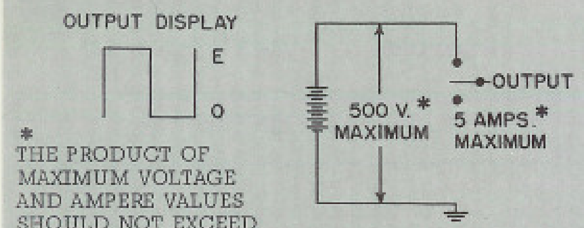
FIGURE-7

To further simplify the test procedure, the Model FD-30 may be used to simultaneously display both the reference and the test circuit. This basic test set-up is shown in Figure 7. All that is required in this procedure is that we provide identical transmission lines for the reference and test circuit. This can be accomplished by cutting both lines from the same reel of cable while making the test circuit line slightly longer than the reference circuit line. The lines can be adjusted for identical characteristics by leaving both unterminated while observing them simultaneously on an oscilloscope, and cutting the line that displays the greater electrical length to match the shorter line.

Figures 9 and 10 show two other interesting applications for the Jerrold Model FD-30.

If measurement is required of match that exhibits return losses in excess of 35 db, improvement in display indication can be obtained by utilizing a high pass audio filter between the detector and the oscilloscope. The filter is designed to pass the audio frequencies of the ripple voltage while providing 20-30 db of attenuation for the 60 cycle and lower frequency components of the E(m) signal. This feature emphasizes the E(r) component and thus faciltates the measurement. The required filter section is an integral part of the Model SPR-100 Oscilloscope Preamplifier. The filter can be switched in or out of the circuit as needed. Figure 11 illustrates the complete equipment package required for VSWR measurements.

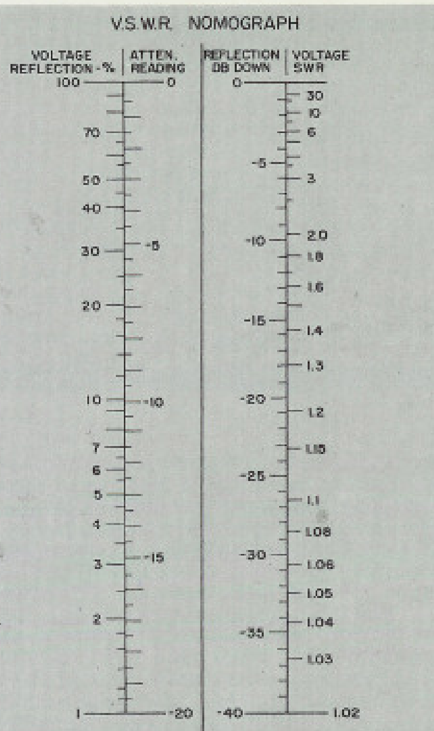
SQUARE WAVE GENERATOR



* THE PRODUCT OF MAXIMUM VOLTAGE AND AMPERE VALUES SHOULD NOT EXCEED 250 V.A.

FIGURE-9

V.S.W.R. NOMOGRAPH



NOTE: $SWR = \frac{E\ MAX.}{E\ MIN.}$ AND % REFLECTION = $\frac{(SWR)-1}{(SWR)+1} \times 100$

FIGURE-8

CALIBRATING SCOPE DISPLAY OF DIODE OR TRANSISTOR CHARACTERISTICS

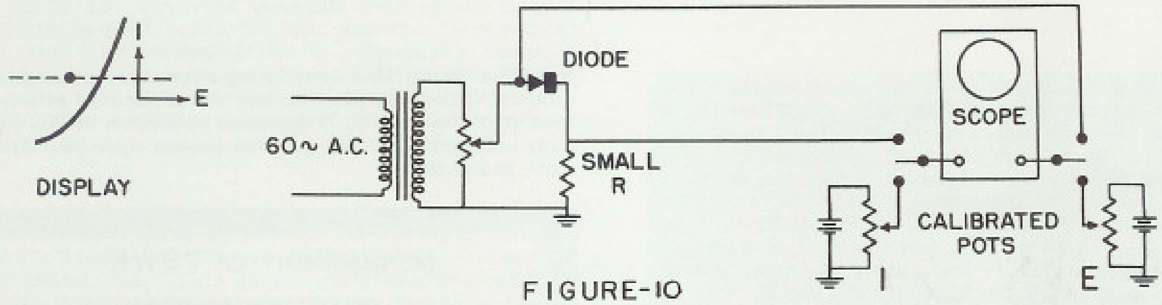
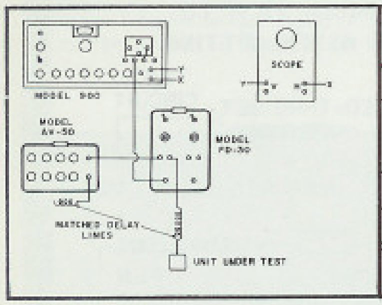


FIGURE-10



FREQUENCY RANGE	200 KC to 250 mcs	
MODEL	DESCRIPTION	PRICE
900	SWEEP GENERATOR (0.2 - 1,000 MCS) OSCILLOSCOPE PREAMPLIFIER (included in Sweep Generator)	$1260.
FD-30	COAXIAL SWITCH	$ 250.
AV-50	VARIABLE ATTENUATOR	$ 150.
	TOTAL COST	$1660.

FREQUENCY RANGE	12 mcs to 225mcs.	
MODEL	DESCRIPTION	PRICE
601	SWEEP GENERATOR	$390.
FD-30	COAXIAL SWITCH	$250.
SPR-100	OCILLOSCOPE PREAMPLIFIER	$200.
AV-50	VARIABLE ATTENUATOR	$150.
	TOTAL COST	$990.

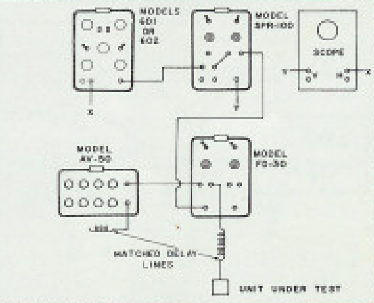


FIGURE-11

Prices Subject To Change Without Notice

Export: Rocke International, New York 16, New York. Cable—ARLAB. Canada: Jerrold Electronics (Canada) Ltd., Toronto, Canada.