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APPLICATION OF RF MICROPOTENTIOMETERS FOR CALIBRATION OF SIGNAL GENERATORS TO 1000 Mc

BY L. F. BEHRENT

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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JANUARY 1960

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ABSTRACT

With the RF Micropotentiometer, signal generator output voltage can be calibrated to 1000 Mc simply and accurately if the procedures outlined in this paper are carefully followed. The sources of error are discussed and methods for minimizing or eliminating them are described. Topics discussed include: rf shielding, selection of a suitable rf detector, impedance matching and the proper selection of voltage reference planes.

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SUMMARY

With the RF Micropotentiometer, signal generator output voltage can be calibrated to 1000 Mc simply and accurately if the procedures outlined in this paper are carefully followed. The sources of error are discussed and methods for minimizing or eliminating them are described. Topics discussed include: rf shielding, selection of a suitable rf detector, impedance matching and the proper selection of voltage reference planes.

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1. INTRODUCTION

The RF Micropotentiometer[1] is a simple and accurate standard for calibrating the rf voltage output of signal generators. However, from the inquiries received it seems that some precautions basic to high-frequency measurements are being overlooked or given insufficient consideration. By discussing in detail some difficulties which have been brought to the attention of the RF Voltage Measurement Standards Group at the National Bureau of Standards, and describing the necessary corrective measures, it is hoped that this material will help improve techniques so that higher accuracies will be obtained.

2. CALIBRATION PROCEDURE

The block diagram of Figure 1 illustrates how the RF Micropotentiometer is used. G_1 is the rf generator to be calibrated (the unknown); G_2 energizes the reference standard - the RF Micropotentiometer S - and D is the detector, usually a sensitive receiver, for comparing the rf output voltage of the unknown with the reference standard.

The usual procedure in calibrating the unknown is to preset its output level to an arbitrary indicated value. This output is compared with the standard by switching the detector alternately between them.

The level of the standard is adjusted until the detector shows its amplitude is equal to the unknown. Since the rf resistance of the RF Micropotentiometer output is known from previous comparison with the Primary Standard, and the rf current flowing in it can be determined from a d-c calibration of the thermoelement, the magnitude of the rf voltage may now be calculated.

One possible combination of thermoelements and RF Micropotentiometer resistance elements which will provide standardized rf microvoltages at any level between 1 and 100,000 microvolts is presented in Appendix I. This combination of units permits a ready check of each RF Micropotentiometer against those covering adjacent ranges.

3. PRECAUTIONS

Stray radiation is the most serious source of error in low level measurements and the most difficult to eliminate. Even at rf levels as high as 10 kμv errors greater than 100 percent have been traced to this cause, with even greater errors at lower rf levels. In the circuit illustrated in Figure 1 there are several possible sources of radiation. Between the rf input and output of the RF Micropotentiometer there is sometimes as much as 100 db of attenuation. Therefore, the metal box containing the reference standard must be well constructed to prevent leakage. One very satisfactory and economical design is illustrated in Figures 2 and 3. Heavy-walled construction is used to provide large contact surfaces between the box and the removable cover, the body of the coaxial rf input connector, and the outer electrode of the RF Micropotentiometer resistance element. The most effective by-passing of the thermoelement's d-c leads can be obtained by mounting button type mica capacitors in recesses in the heavy side wall of the box. (See Figure 3.)

How extensively the signal generators and the detector must be shielded can best be determined by connecting an antenna to the detector and probing the system for radiation. Often it is necessary to place each of these pieces of equipment into individual double-screened boxes (Figure 4).

Commercial double-screened cabinets can be used to shield each of the signal generators and the rf detector. The shielding will be most effective if the inner screened box is grounded to the outer only where the coaxial rf cable connecting the rf equipment in the screened cabinct to the outside circuitry passes through the side of the screened boxes. All other connections into the cabinets required for energizing and controlling the enclosed equipment must be properly filtered to prevent rf leakage. There is ample published literature on this phase of the shielding problem[2]. The rf input cable to the detector and the cable connecting signal generator G_2 to the standard S should be double-shielded coaxial cables, preferably with an additional external shielding braid. With the equipment arranged as shown in Figure 4, the most effective shielding against rf leakage was obtained when external braid was placed over each of the rf cables, with the braid connected to the internal shield by clamping it tightly to the rf connectors at the cable ends with adjustable metal hose clamps.

For some calibration work a crystal rectifier and microammeter or an electronic rf millivoltmeter will be an adequate detector, but in most instances a radio receiver sensitive to 1 microvolt or less will be required. In any case, there must be enough sensitivity to resolve incremental changes in the rf input of 1 percent or less.

Any receiver so used should be tested to determine the optimum operating conditions and maximum rf input level for which maximum resolution is obtained. For rf voltages above this, the receiver must be decoupled to prevent loss of sensitivity due to receiver overloading.

The amplitude of the voltage output from an rf source depends upon how the external load impedance, whether an rf voltmeter, radio receiver or other impedance, is connected to it. With a perfect transmission line terminated in its characteristic impedance connected to the output, the amplitude of the rf voltage would be the same at all points along the line and it would be immaterial how long a line section was used. However, because of imperfections in practical rf cables and connectors, discontinuities will exist which will introduce voltage variations along the line. At very-high and ultra-high frequencies large changes in the amplitude of the output voltages may result from changing the length of the coaxial connection between the output and the load even by a fraction of an inch. The plane through the rf connection at which the voltage output is measured should be properly identified. In using the rf source as a reference standard, the magnitude of the voltage is accurately known only at this Voltage Reference Plane. The ideal reference plane for the RF Micropotentiometer would be the plane in which the resistive annular ring lies, a-a Figure 3. However, because it was necessary to provide a coaxial output connection, the best practical reference plane is essentially at b-b Figure 3. The rf voltage at b-b is compared with the Primary Voltage Standard at all frequencies when determining dc-rf characteristics of the RF Micropotentiometer.

The output voltage of a signal generator should be measured at the output connector provided. Where this connector is similar to that of the RF Micropotentiometer, the recommended voltage reference plane would pass through the connector essentially at the tip of the female center pin (b-b Figure 5). Where other types of output connectors are found on the generator output, an adaptor should be used which henceforth should be considered a part of the generator.

The output of the unknown must be terminated with an accurately known rf impedance connected at the voltage reference plane. The detector can be used as the termination by adjusting its input impedance with a suitable matching network. (See Figure 6) However, it is not safe to assume that impedance measurements of the input to the detector made with an impedance bridge will be valid at low rf levels. Such bridges impress from 0.1 to 1 volt or more across the unknown impedance. For a radio receiver, such a level would result in complete saturation, causing the input impedance to change greatly from what it would be at relatively low levels. Moreover, the impedance is a function of the tuning of the receiver. One method of adjusting a receiver's input impedance to 50 ohms with a matching network is to connect the input of the matching network to an rf source through a 20 db, 50 ohm pad of high quality. With only a few microvolts applied to the receiver input, and the receiver tuned to the source frequency, adjust the network for maximum receiver output indication. Once the matching is completed, the receiver tuning must not be changed. Where the sensitivity of the detector permits, a high quality attenuator pad may be used in place of the matching network, thus terminating the unknown in an impedance essentially that of the attenuator pad.

4. CONCLUSIONS

Observance of the precautions described in the text cannot be overemphasized. In a recent case brought to the attention of the RF Voltage Standards Group, insufficient attention to these details resulted in measurement errors of approximately 14 db at 1000 Mc.

5. REFERENCES

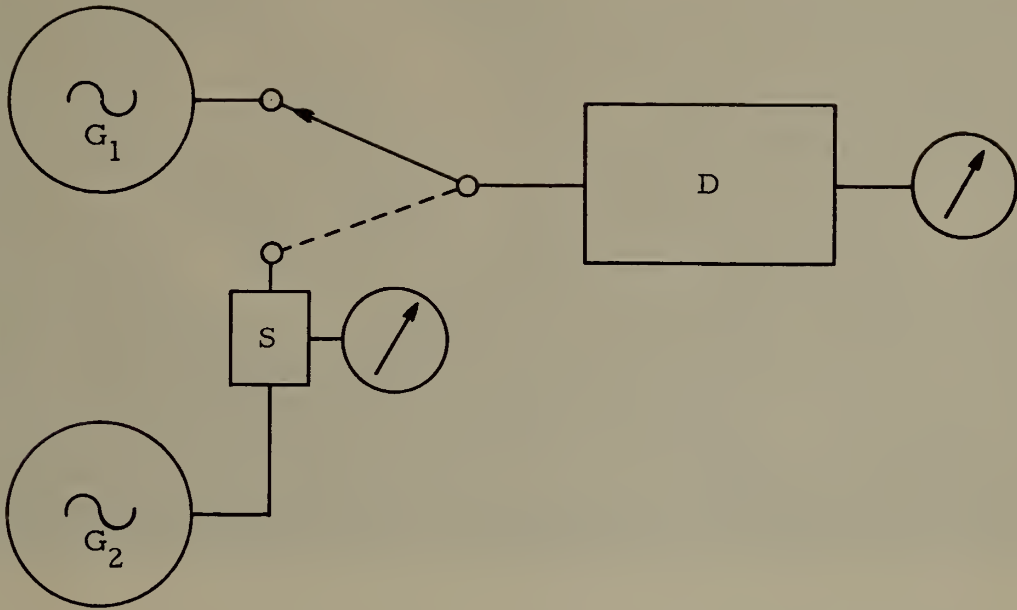
(1) M. C. Selby, Accurate radio-frequency microvoltages, Communications and Electronics, AIEE 6: 158-164 (May 1953)

(2) E. E. Zepler, The technique of radio design, 240-264 (John Wiley & Sons, Inc., New York, 1949)

APPENDIX I

Typical Values of RF Micropotentiometer Components for the Range of 1 to 100,000 Microvolts

Thermoelement rating, ma	Resistance (RF Micropotentiometer), milliohms	Standardized rf voltage, microvolts
5	1	1 - 5
25	1	5 - 25
100	1	20 - 100
50	10	100 - 500
50	50	500 - 2500
50	100	1000 - 5000
25	1000	5000 - 25000
100	1000	20000 - 100000



G_1 is the rf generator to be calibrated.

S is the transfer standard, the RF Micropotentiometer.

G_2 is the signal generator energizing the RF Micropotentiometer.

D is the rf detector.

Figure 1

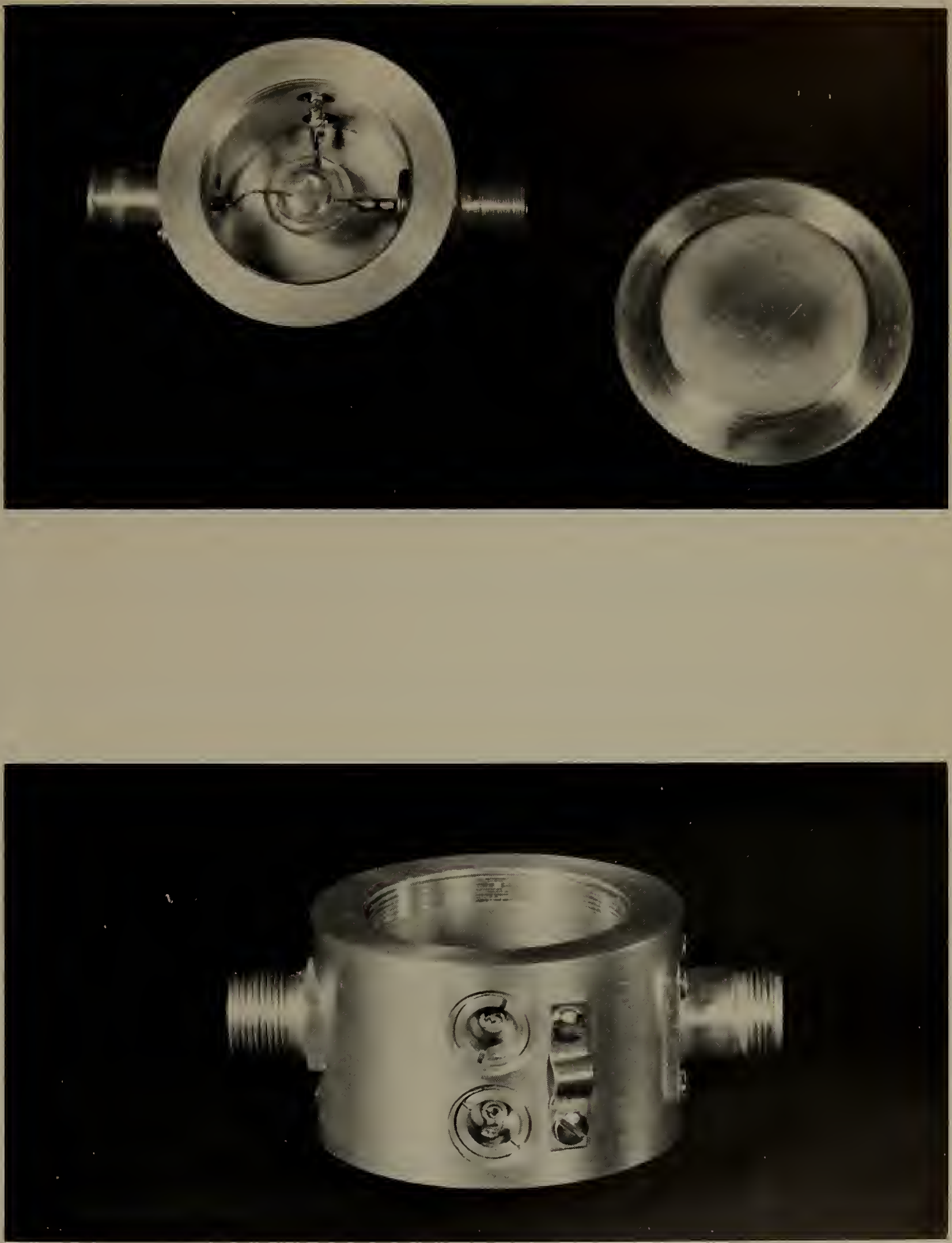
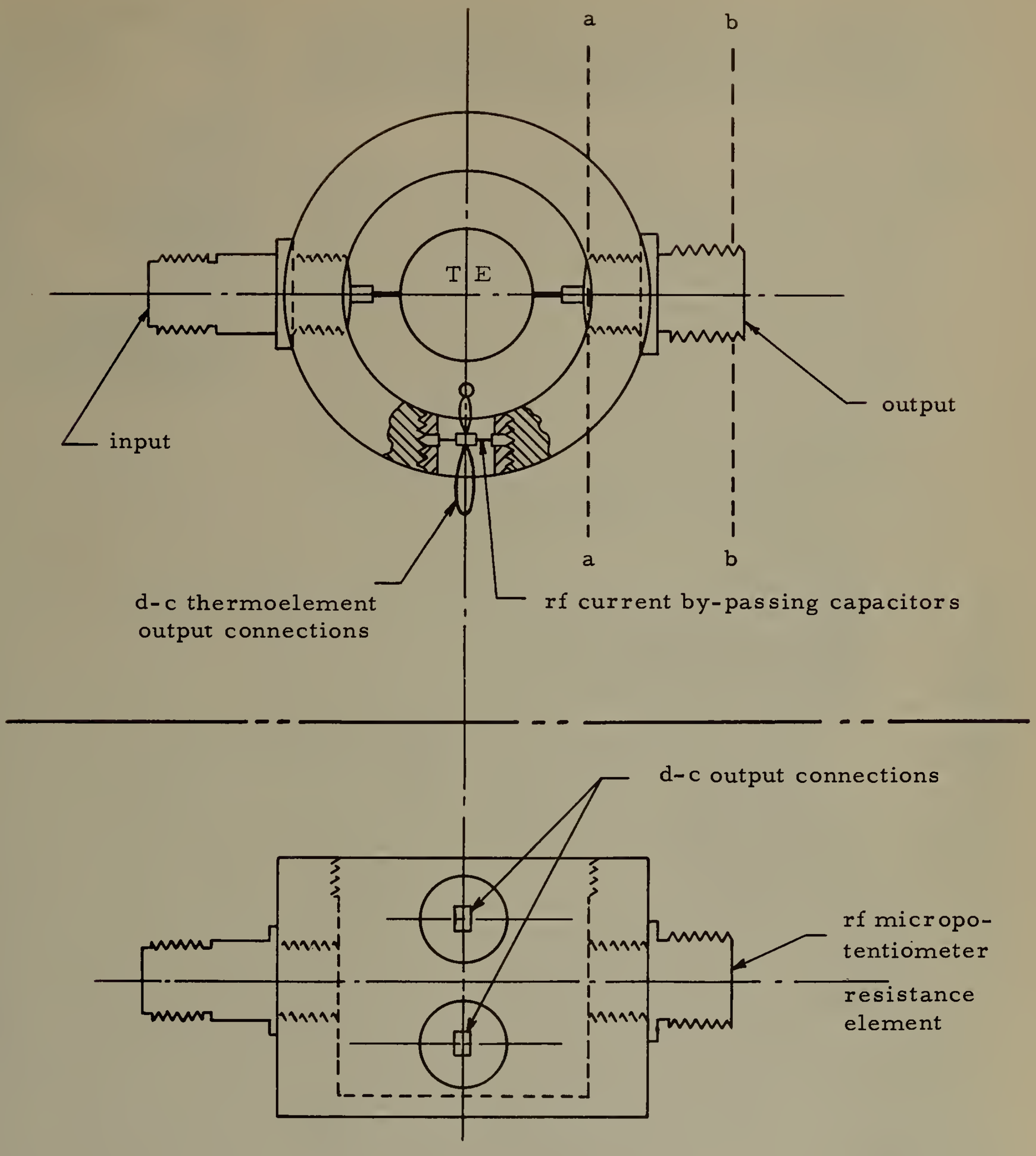


Figure 2



a-a is the plane in which the standardized reference voltage exists.

b-b is the plane in which the rf voltage is compared with the primary rf voltage standard.

Figure 3

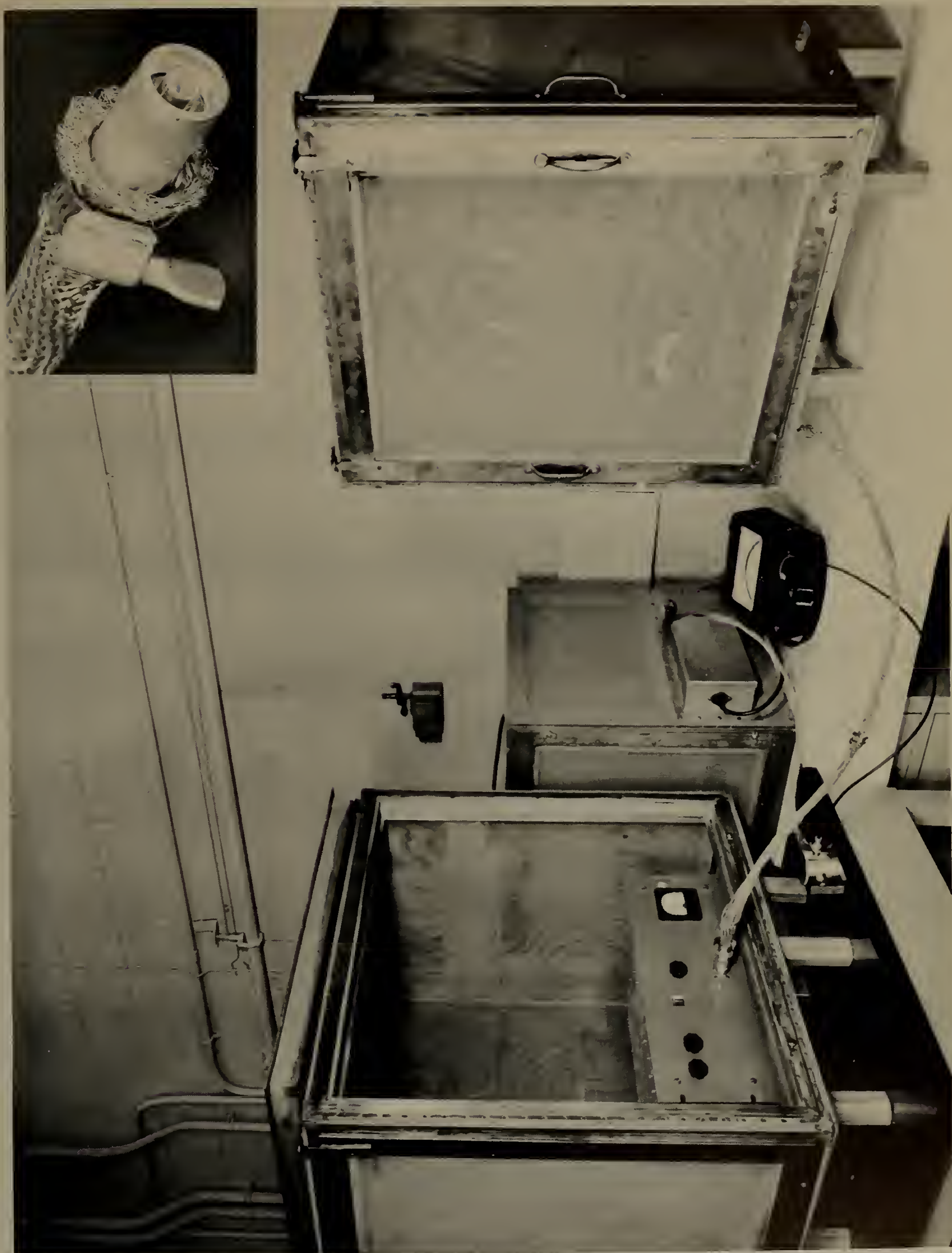


Figure 4

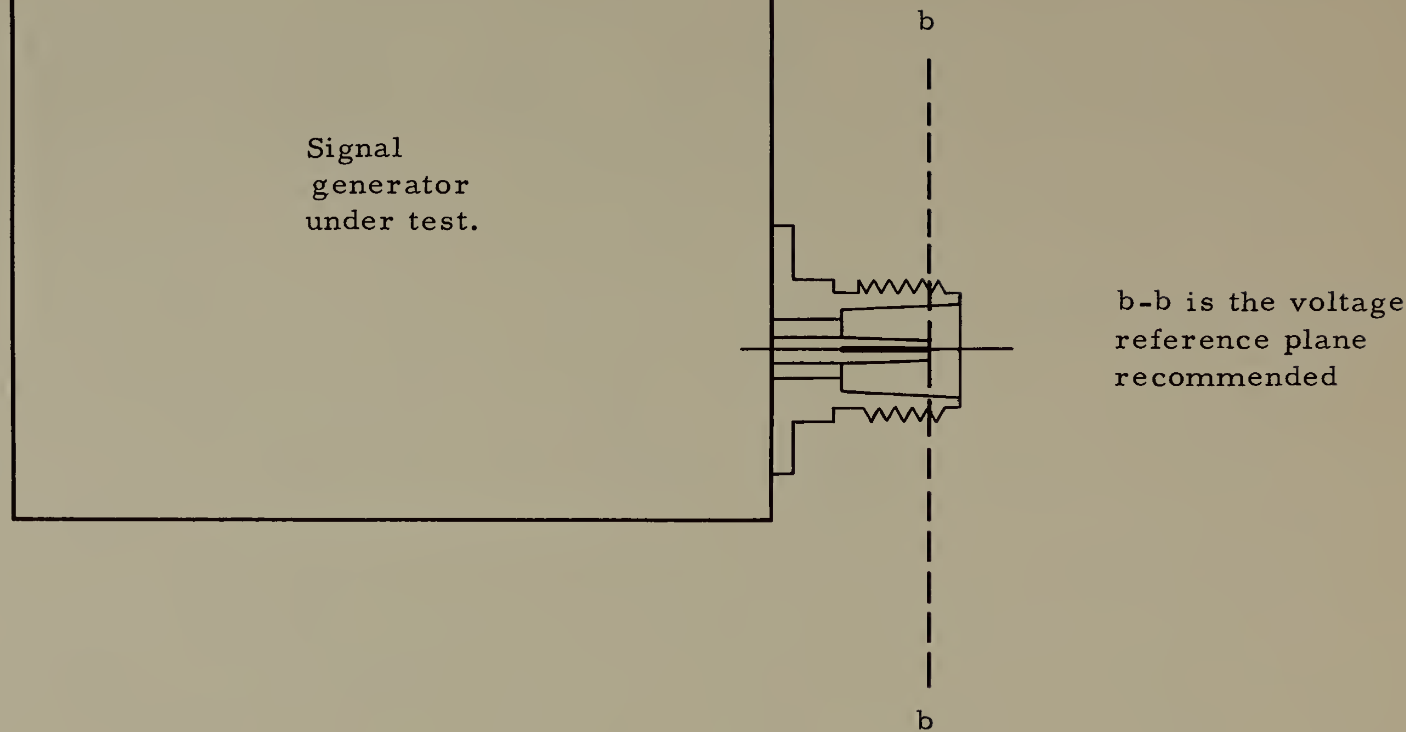

Signal
generator
under test.
b
b
b-b is the voltage
reference plane
recommended

Figure 5

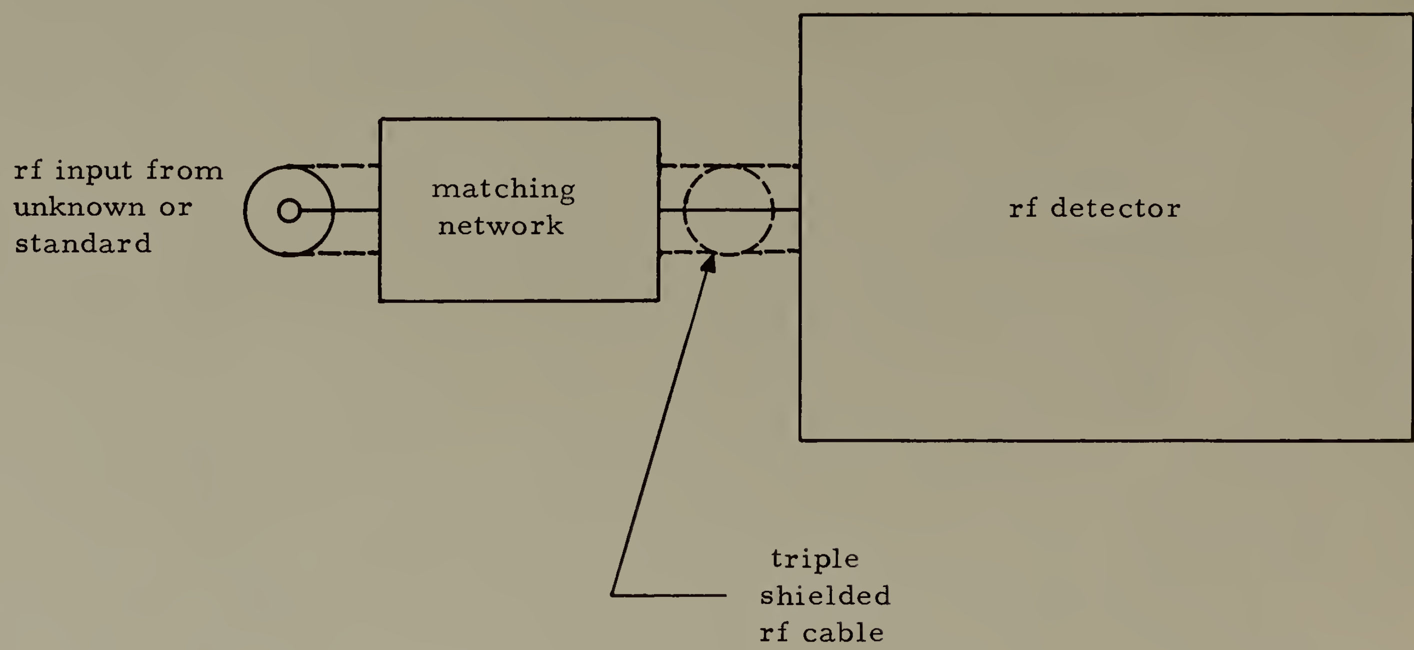

rf input from
unknown or
standard
matching
network
rf detector
triple
shielded
rf cable

Figure 6

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