LB-866

NOISE FACTOR CONSIDERATIONS AND MEASUREMENT TECHNIQUES AT UHF

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Approved

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Introduction

In the course of making noise-factor measurements on uhf television receivers, several precautions were found necessary in order to avoid error. As a result, an investigation of several phases of the problem was conducted, including a study of the operating levels required at the receiver video detector, an evaluation of the c-w and noise-diode methods of measurement, and a consideration of the less commonly used two-point noise-diode method.

Several charts which were prepared in the course of this investigation to simplify the required calculations, are included in this bulletin. The design data for the construction of two types of coaxial 50-to-75-ohm transformers are also included.

General Discussion

The two systems of noise-factor measurement commonly used are the c-w signal-generator method and the one-point noise-diode method,[1] the video detector of the receiver being used in both instances as the output device. The method of linearizing the detector differs for each method. When using a noise diode, linearization is obtained by the introduction of a c-w signal, so that the noise appears as modulation of this c.w. The a-c output then becomes a linear function of noise voltages at the detector input. In the signal-generator method, however, the detector must respond to a combination of c-w and noise, so that its exact behavior is dependent on the i-f and detector bandwidths.[2] This method requires an accurate knowledge of receiver bandwidth, and measurement of the d-c output of the detector, with the attendant error due to the presence of detector contact potential.

[1] LB-775, "Noise Factor and Its Measurement". LB-776, "A Television and FM Noise Generator".

[2] W. R. Bennett, "Response of a Linear Rectifier to Signal and Noise", *Bell System Technical Journal*, Vol. 23, p. 97, Jan. 1944.

Signal-Generator Method

Detector linearization is obtained for the signal generator method by increasing the receiver gain until sufficient noise voltage appears at the detector. Experience has shown that, for the conventional video detector to operate linearly, the d-c level due to noise alone must be approximately one volt (Fig. 1). Measurements made on vhf television receivers indicate that in some instances, because of low receiver noise factor and moderate i-f gain, this minimum d-c level necessary for linearization cannot be obtained. This is indicated by the low values of measured noise factor at the lower values of detector d-c output. In such instances the measured noise figure may be low by as much as 5 db from the correct value.

The dotted curve in Fig. 1 also indicates the possibility of error in the opposite direction. Thus the measured noise figure may increase at low detector levels if excessive bias is applied to the r-f tube. In this instance, the degradation of noise figure due to the increased mixer noise contribution overrides the apparent improvement in the noise figure due to detector non-linearity. Fig. 1 also shows the rise in measured noise figure at high detector noise levels because of receiver overload.

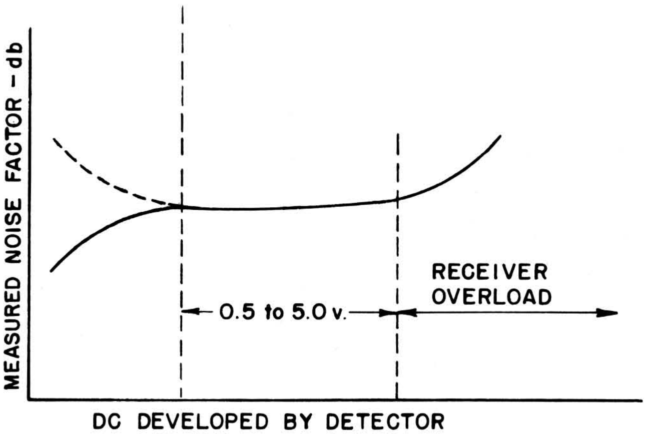


Fig. 1 – Noise factor vs d-c detector output level for the c-w method.

If the forward resistance of the detector is independent of level and frequency, the presence of a c-w input power equal to that of the receiver noise will increase the d-c output of the detector to a value 45 per cent greater than that due to receiver noise alone.[2] Then, for an equivalent c-w generator open-circuit voltage of e_o, a receiver input impedance of R_a and a noise bandwidth of Δf, the noise factor is given by the familiar relation:

$$F \text{ (in db)} = 10 \log 62 \frac{e_o^2}{R_a \Delta f}$$

where e_o is in µvolts

R_a is in ohms

and Δf, the noise bandwidth, is in megacycles.

For convenience, this relation has been plotted in Fig. 2 for several bandwidths and input impedances.

Noise-Diode Method

The noise-diode method has proven generally more satisfactory than the signal-generator method. The advantages of this method are that the receiver bandwidth need not be known, that the detector is required to handle noise signals only, and that an a-c voltmeter is employed thus removing the problem of contact potential. The detector is linearized by the injection of a c-w carrier of such amplitude that the noise voltages appear effectively as modulation of that c.w. For this condition, when the noise-diode power (as read from the instrument) is made equal to the noise power originating in the receiver, the a-c output of the detector is increased by 3 db. If there are spurious responses of appreciable magnitude, the measured noise factor will appear lower than the actual noise factor. Normally, this is a second-order effect. Thus for an image response down as little as 10 db, the measured noise figure will be degraded by 0.5 db.

Fig. 3 indicates that some caution must be used in choosing an operating point. The indicated a-c output range of 10 to 50 millivolts is representative, although this will vary with receiver design. Below this range, the measured noise figure may increase if excessive bias is applied to the r-f tube.

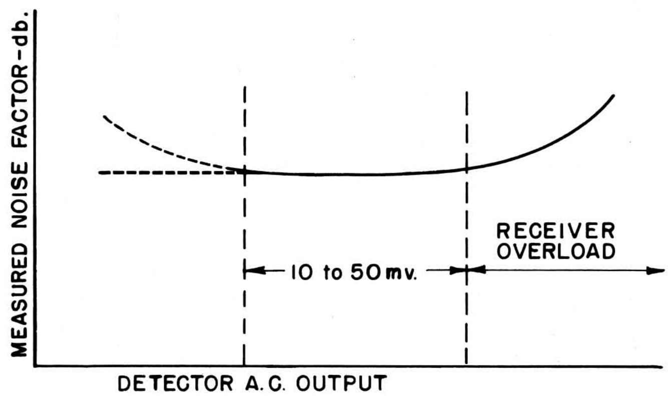


Fig. 3 – Noise factor vs detector a-c output level for the noise-diode method.

Two-Point Noise-Diode Method

When uncertainty exists as to linearity of the detector, the two-point noise-diode method may be used (LB-775, page 13). This method consists basically of calibrating the detector at two a-c output levels using a noise diode, and then using these same detector levels for making the actual measurement (see Fig. 4). Because the calibration is dependent upon the receiver noise factor, an appreciable

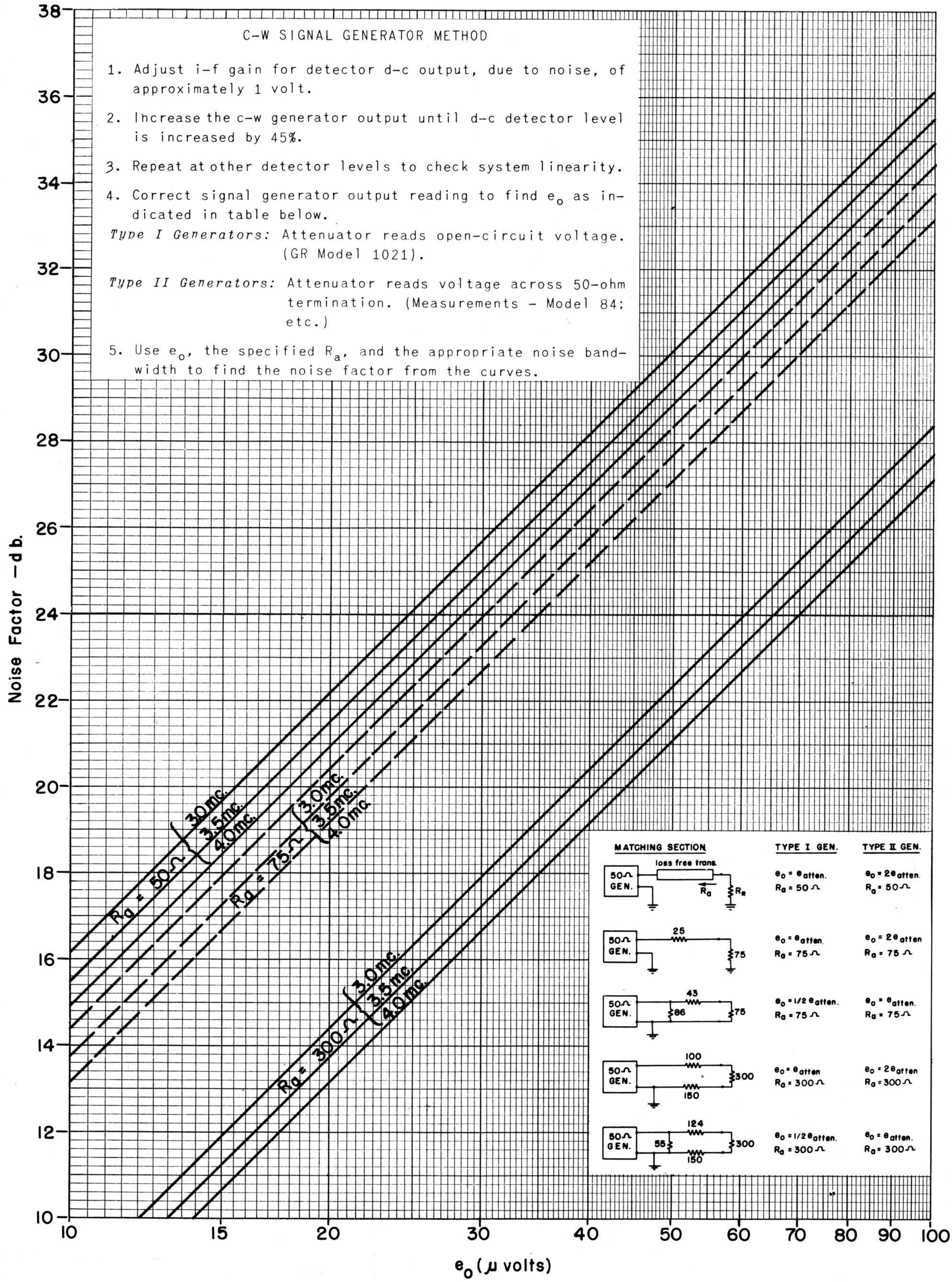


Fig. 2 - Chart for conversion from e_o to noise factor for common receiver impedances and bandwidth.

correction factor is required when the receiver noise figure is of the same order of magnitude as the noise-diode levels used for calibrating.

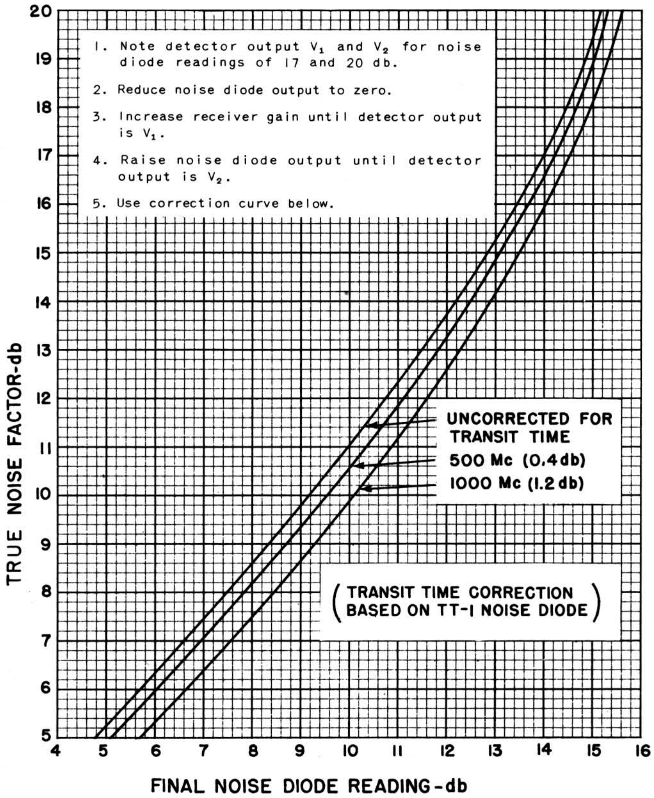


Fig. 4 - Two-point noise-diode correction curve.

As can be seen in Fig. 4, if the noise-diode output levels used for calibration were 20 and 17 db and the noise figure indicated by use of these calibration points was 15 db, the true value would be 19.4 db, a difference of 4.4 db. For convenience, a suitable procedure is outlined in Fig. 4.

Matching Sections

Since currently available signal generators and noise diodes are designed for a 50-ohm impedance and television receivers for 75 or 300-ohm input impedances, a matching section is required between generator and receiver. This section can be either of the loss-free or resistive type. For a 50 to 75-ohm transformation, some form of multiple-quarter wavelength coaxial transformer is suitable. A coaxial tapered line gives good results but is more difficult to construct and is physically larger since it must be at least one wavelength long at the lowest frequency of interest.

Single quarter-wavelength transformation sections provide a theoretical standing-wave ratio of up to 1.25 over the required 2-to-1 frequency range. For two cascaded sections this calculated value drops to 1.1. On the other hand, with a triple-section transformer[3] the theoretical performance is comparable with a tapered line. A transformer of this type was built as shown in Fig. 5b. The SWR of this unit measured less than 1.15 over the frequency range of 450 to 900 Mc, the departure from theoretical performance being caused largely by its connectors.

The tapered line shown in Fig. 5a gave the same results, although the additional complexity is apparent. Diameter values for each step are indicated in Table I.

Table 1

Step Diameters for Tapered Line

S	diameter	S	diameter
1	0.261	14	0.212
2	0.257	15	0.208
3	0.253	16	0.205
4	0.249	17	0.202
5	0.245	18	0.199
6	0.241	19	0.195
7	0.237	20	0.192
8	0.233	21	0.188
9	0.229	22	0.186
10	0.226	23	0.183
11	0.222	24	0.179
12	0.219	25	0.177
13	0.215		

Dissipative matching sections generally have the configuration of Fig. 6a where a match is made both to the generator and to the receiver. Thus, at either AA' or BB' the same impedance is seen when looking in either direction. The result obtained is the elimination of standing waves on both the generator and

[3] W. Dallenbach, "Transformation Section with Transformation Ratio Independent of Wavelength", abstract No. 1511, *Wireless Engineer*, May 1944, p. 231.

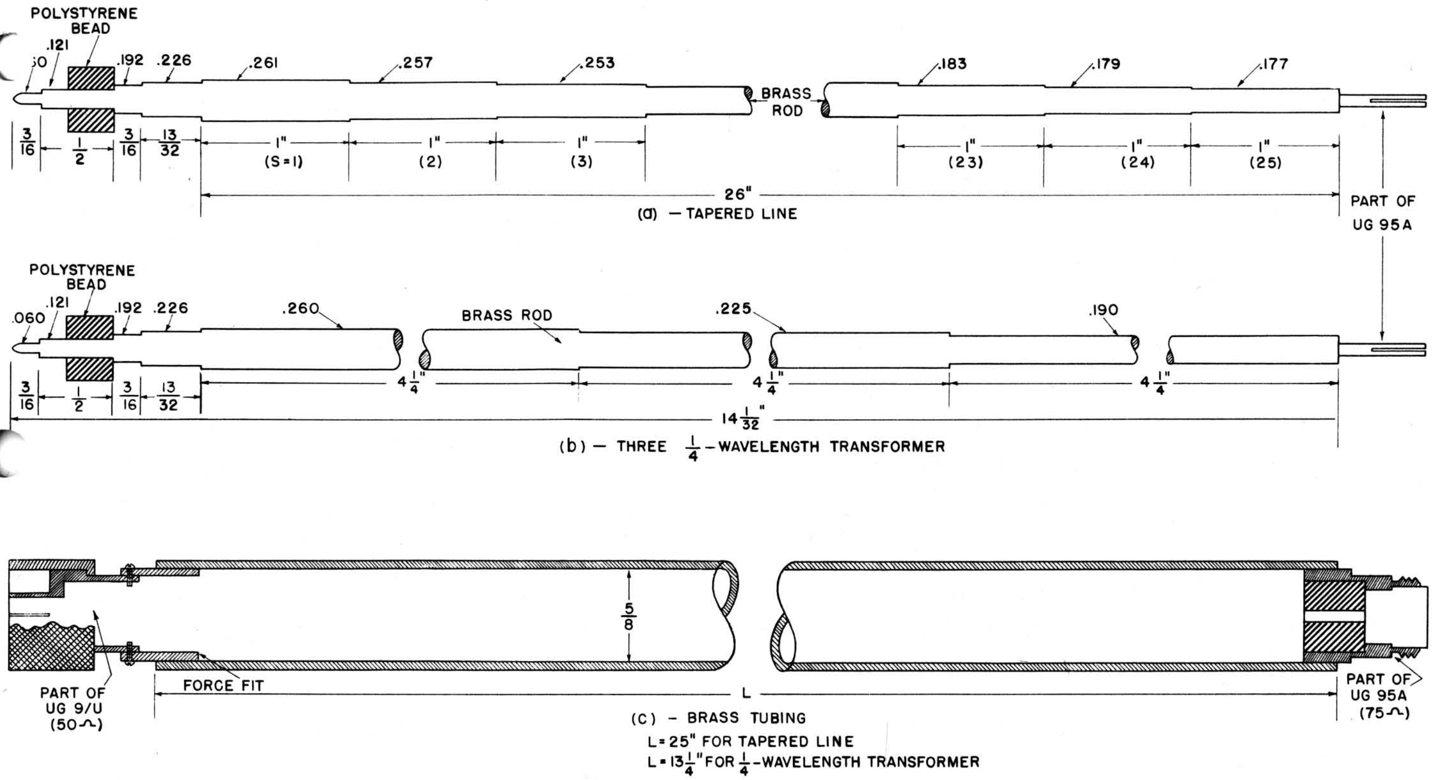
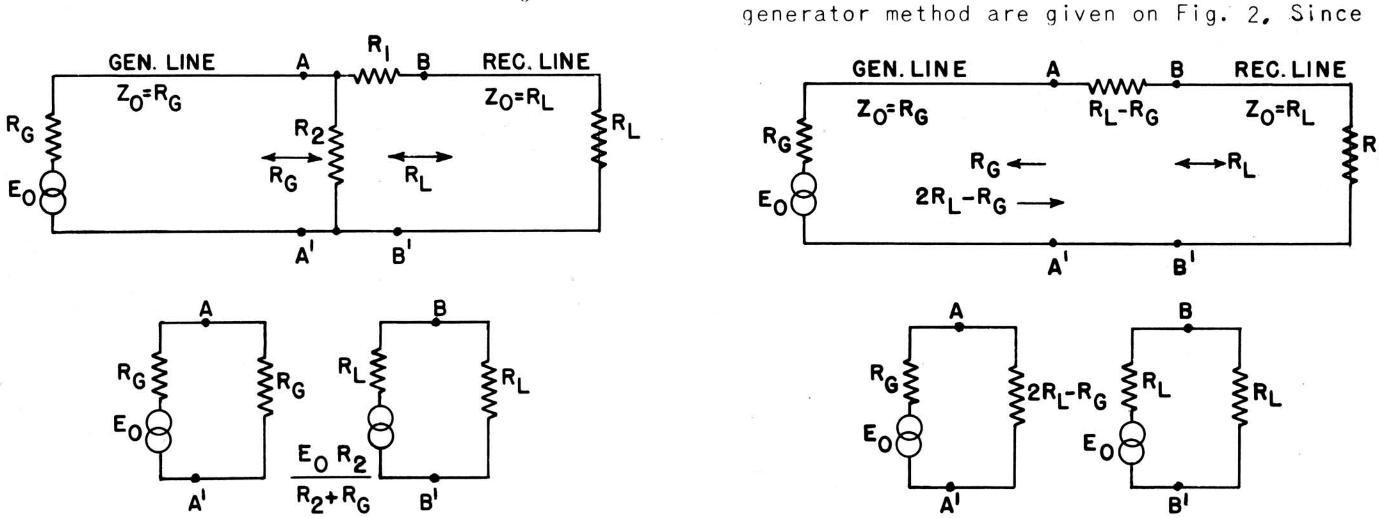


Fig. 5 - Two types of 50-75 ohm coaxial transformer.

receiver transmission lines when the receiver is matched to its transmission line.

Since the generator line is usually of the unbalanced coaxial type, reflections in this line can be tolerated. Should a single resistive element be used as indicated in Fig. 6b, the receiver line will be matched and no trouble from reflections will arise, provided the receiver matches its line and the generator matches the generator line. The main advantages of this arrangement are its lower attenuation, a factor of importance when using a noise diode, and the smaller number of resistors required, a significant consideration at uhf where the reactive components of resistors become important. The resistance values required for typical configurations and the corresponding corrections when using the signal-generator method are given on Fig. 2. Since the



(a) Pad matches both transmission lines.

(b) Pad matches load transmission line only.

Fig. 6 - Two types of resistive matching section and equivalent circuits.

noise diode is calibrated for a 50-ohm load, a different correction is required. These are indicated in Fig. 7 for the non-terminated pads. No correction is needed when using a loss-free transformer.

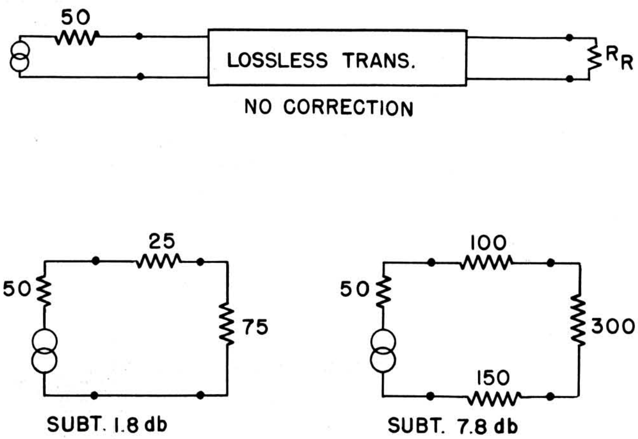


Fig. 7 – Matching section losses when using a noise diode.

If a mismatch loss occurs because the actual receiver impedance differs from its nominal value, the noise figure measured is indicative of receiver operation under typical conditions. This noise figure is independent of line length between generator and receiver, assuming that the generator matches its line. Some indication of the order of magnitude of the receiver mismatch can be obtained by inserting an adjustable shorting-stub into the receiver input line. By adjusting this stub both in position and length so that the minimum input signal for a given detector output is determined, the ratio of the squares of the generator voltages required with and without the stub will give the mismatch loss. A larg input signal should be used during the measurement so that the noise originating in the receiver is only a small part of the total output voltage. Fig. 8 enables conversion from the mismatch loss (in db) to SWR.

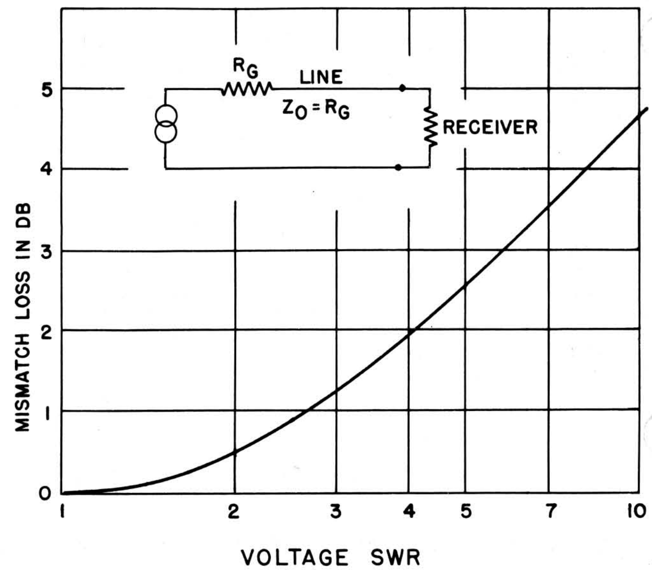


Fig. 8 – Mismatch loss vs voltage SWR caused by receiver mismatched to line.

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