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THE MEASUREMENT OF RECEIVER NOISE FIGURE

A. INTRODUCTION

The noise figure of a receiver may be defined as follows:

$$F = \frac{\text{Signal-to-Noise Power Ratio of Ideal Receiver}}{\text{Signal-to-Noise Power Ratio of Actual Receiver}}$$

By an ideal receiver is meant one which generates no noise. Thus the only noise source for an ideal receiver is the thermal agitation noise of the antenna. Hence the ideal receiver must have an infinite input resistance, since otherwise thermal agitation noise in the input resistance would constitute an additional noise source. This definition of an ideal receiver therefore specifies the conditions for the highest possible signal-to-noise ratio.

Fig. 1 shows the equivalent circuit for the ideal receiver. The only noise source is the antenna radiation resistance, which generates an open-circuit thermal agitation noise voltage given by the well-known relationship

$$\overline{e_n^2} = 4kTBR_a$$

where

k = Boltzmann's constant, 1.374×10^{-23} joules/deg K

T = effective temperature of radiation resistance in deg K, commonly taken as 290 degrees

B = bandwidth of receiver in cycles

R_a = radiation resistance in ohms

Since the ideal receiver itself generates no noise, the signal-to-noise ratio at the output terminals must be the same as at the input terminals. Furthermore the input t rminals present an infinite resistance to the antenna. Hence the signal-to-noise ratio of the ideal system is simply the signal-to-noise ratio at the output of the open-circuited ant nna, or

$$\text{Signal-to-noise power ratio of ideal receiver} = \frac{(E_s)^2}{\overline{e_n^2}}$$

B. MEASUREMENT PROCEDURE

The above relationship suggests a method for experimentally determining the noise figure. Fig. 2 shows the set-up. The procedure is as follows:

(1) With the signal generator output at zero, note the reading of the output indicator. This is a measure of the noise power output of the receiving system.

(2) Increase the signal generator output until the output indicator shows a condition of signal power plus noise power equal to twice noise power alone.

a. If the output indicator indicates power directly, this condition occurs when the reading due to signal plus noise is twice the reading due to noise along.

b. If the output indicator indicates voltage, the criterion is that the reading due to signal plus noise be $\sqrt{2}$ times the reading due to noise alone.

(3) Note the reading E_o of the signal generator output voltage indicator.

C. INTERPRETATION OF RESULTS

By making signal power plus noise power equal to twice noise power alone, we have actually obtained a unity signal-to-noise power ratio for the receiver under test. The expression for the noise figure of the receiver then becomes

$$F = \frac{\text{Signal-to-Noise Power Ratio of Ideal Receiver}}{1}$$

$$= \frac{E_s^2}{4kTBR_a}$$

It is important to note that E_s represents the open-circuit voltage of the signal generator. In general this is not the voltage at the output terminals of the generator. In terms of the output voltage E_o of the signal generator, E_s becomes

$$E_s = E_o \left(\frac{R_a + R_{in}}{R_{in}}\right)$$

where R_{in} is the resistance looking into the input terminals of the receiver with the signal generator disconnected. The noise figure then becomes

$$F = \frac{E_o^2 \left(\frac{R_a + R_{in}}{R_{in}}\right)^2}{4kTBR_a}$$

In the usual case the receiver is matched to the signal generator. For the matched case, $R_{in} = R_a$ and the noise figure is given by

$$F = \frac{E_o^2}{kTBR_a}$$

In practice the noise figure is generally expr ssed in decibels. The noise figure is given in decibels by the relationship

$$F_{db} = 10 \log_{10} \left(\frac{E_o^2}{kTBR_a} \right)$$

Fig. 3 is a family of curves showing the variation of noise figure with signal generator output voltmeter indication for signal power plug noise power equal twice nois power at the receiver output. A 50-ohm matched input system is assumed and several representative bandwidths are considered.

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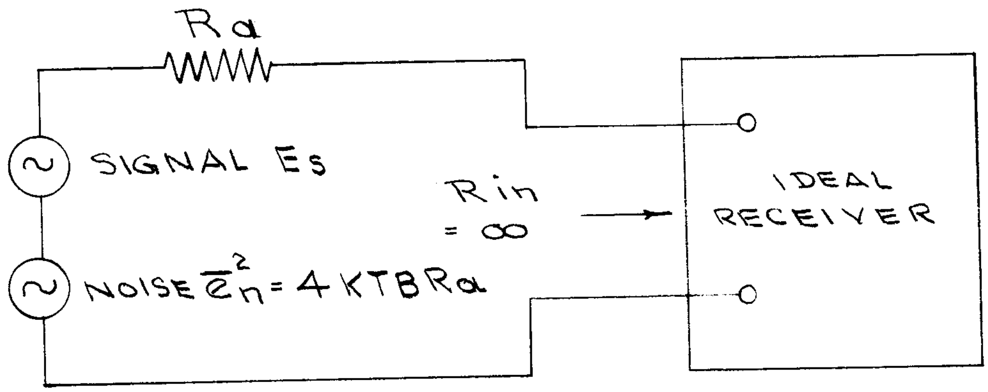

FIG. 1 - SCHEMATIC REPRESENTATION OF IDEAL RECEIVING SYSTEM. THE IDEAL RECEIVER IS ONE GENERATING NO NOISE.

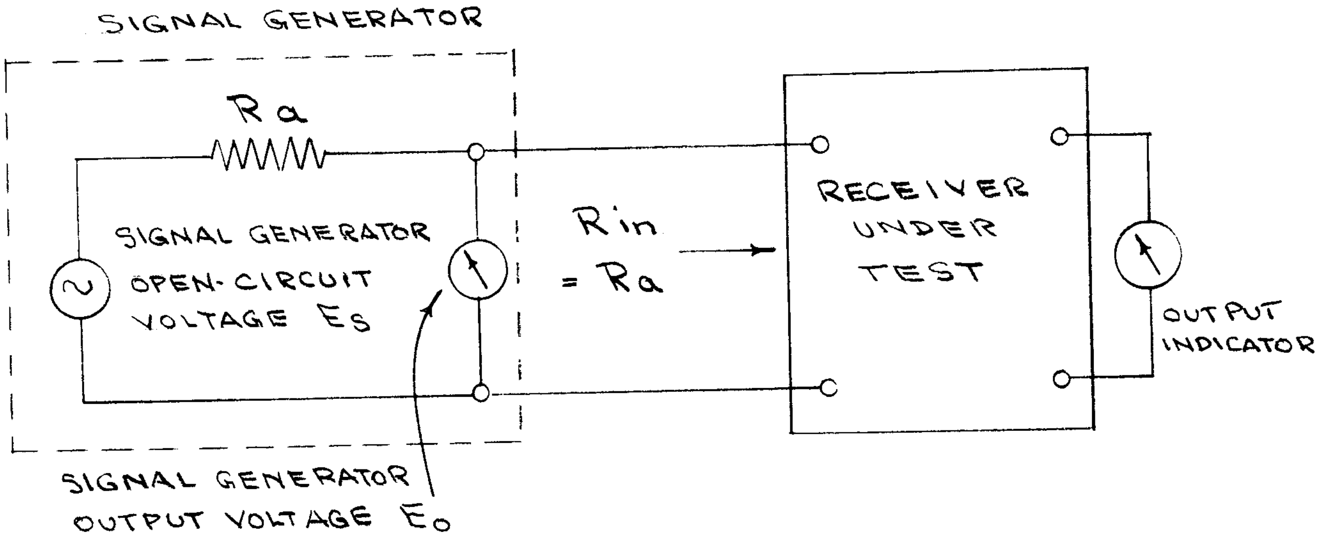

FIG. 2 - CIRCUIT FOR MEASURING NOISE FIGURE. RECEIVER MATCHED TO SIGNAL GENERATOR.

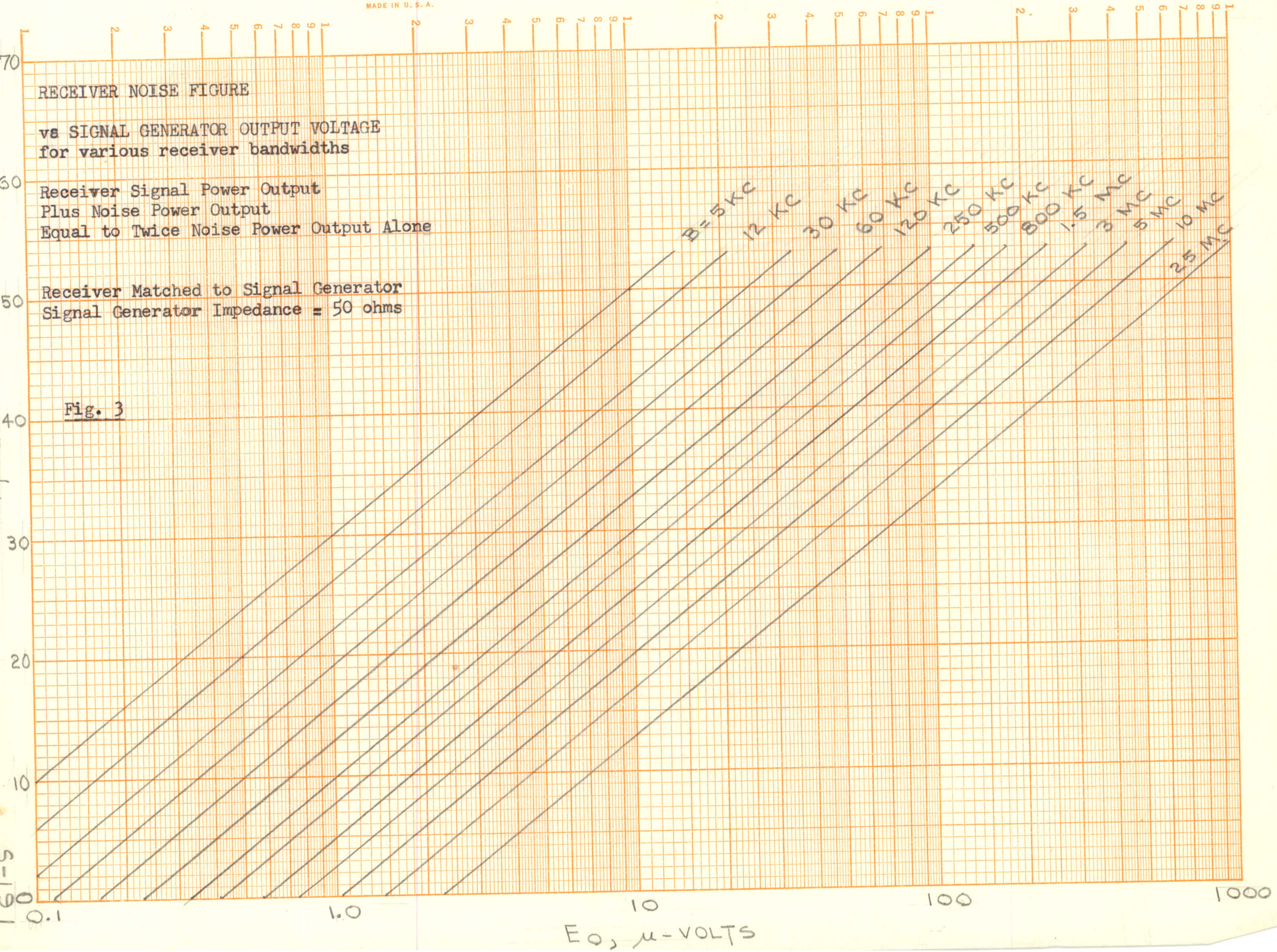
RECEIVER NOISE FIGURE
vs SIGNAL GENERATOR OUTPUT VOLTAGE
for various receiver bandwidths
Receiver Signal Power Output
Plus Noise Power Output
Equal to Twice Noise Power Output Alone
Receiver Matched to Signal Generator
Signal Generator Impedance = 50 ohms
B = 5 KC
12 KC
30 KC
60 KC
120 KC
250 KC
500 KC
800 KC
1.5 MC
3 MC
5 MC
10 MC
25 MC
F, db
E_o, μ-VOLTS
0.1
1.0
10
100
1000
0
10
20
30
40
50
60
70

Fig. 3