An Analysis of the AC Bandwidth of Transmission Line Discriminators for FM Noise Measurement

Roy S. Brozovich and J. Robert Ashley

Sperry Corporation, Clearwater, Florida 33518 USA

ABSTRACT

An error in [1] motivated a derivation of the frequency response of transmission line discriminators. The derivation properly handles the limit as $f_m \to 0$. Experiments are reported which confirm the DC response of transmission line discriminators and the (sin x)/x shape of the frequency response characteristics.

This analysis was started when three different experiments failed to confirm a relationship for AC Bandwidth given by Ashley, et. al. [1]. The experiments indicated the bandwidth to be 4 times greater than our previous theory. In doing the derivation presented here, we found several misconceptions regarding transmission line discriminators. Clearing these required careful evaluation of the response at DC. Our derivation handles the limit $fm \to 0$ correctly.

If the attenuator 2 in Fig. 1 is set for greater than 40 dB, we have the simplest of transmission line discriminators. To study the AC bandwidth, we apply a frequency modulated sinusoid.

$$s(t) = \cos\left(2\pi\upsilon_c + \frac{\Delta\upsilon}{f_m}\sin(2\pi f_m)\right) \qquad (1)$$

where: t = time, sec.

υ_c = carrier frequency, Hz

$\Delta\upsilon$ = peak deviation, Hz

f_m = baseband modulation frequency, Hz

This signal is attenuated to the correct level and applied as a local oscillator signal to the balanced mixer which serves here as a phase sensitive detector. The mixer RF input is this signal as delayed.

$$s_i(\upsilon) = \sqrt{P_s Z_o}\; s\,(t - \tau_D) \qquad (2)$$

where τ_D = group delay time in transmission line, sec.

For the normal operation with the RF power to the mixer at least 10 dB below the LO power, the mixer output voltage is

$$v_o(t) = \sqrt{P_s\ Z_o}\; s(t)s(t-\tau_D) \qquad (3)$$

With much trigonometery and discarding the double frequency term, we have

$$\frac{2v_o(t)}{\sqrt{P_s Z_o}} = \sin(x \cos(2\pi fmt + \Theta) \qquad (4)$$

where

$$x = (2\pi\tau_D)(\Delta\upsilon)\,\frac{\sin(\tau_D f_m)}{\pi\tau_D f_m} \qquad (5)$$

Notice that we can use

$$\sin(x \cos\emptyset) = 2[J_1(x)\cos\emptyset - J_3(x)\cos 3\emptyset \ldots] \qquad (6)$$

and the approximation

$$x \ll 1$$

without requiring $\Delta\upsilon/fm$ to be small. The basic response has a (sin x)/x behavior and is flat down to DC.

$$\frac{v_o(t)}{\Delta\upsilon} = \sqrt{P_s\ Z_o}\,(2\pi\tau_D)\;\frac{\sin(\pi\tau_D f_m)}{\pi\tau_D f_m} \qquad (7)$$

If precision attenuator 2 and the Dumbell short are adjusted for carrier nulling as observed with the microwave spectrum analyzer, an additional wave is applied to the mixer. If the delay of this wave is the same as the delay of the reference wave, the same expression given above (7) is obtained.

The experiment to confirm the DC end of the curve was done by applying sinusoidal frequency modulation to the Transferred Electron Oscillator (TEO, Gun Diode). The response shown in Figures 2 & 3 confirms that both discriminators have response to DC. The experiment to confirm the results near the null of the (sin x)/x were done by using the inherently flat FM noise from any cavity oscillator. The failure of the points in Fig. 5 to equal the second lobe of the (sin x)/x is attributed to not making the delay in the cancellation line equal to the delay in the reference line.

REFERENCES:

1. J. R. Ashley, T. A. Barley, and G. J. Rast, Jr., "The Measurement of Noise in Microwave Transmitters," (Invited Paper) IEEE Trans. MTT, 1977 April.

2. R. S. Brozovich, "Improved Transmission Line Discriminators for Phase Noise Measurement," MSE Thesis, Univ. So. Fla. 1983 April.

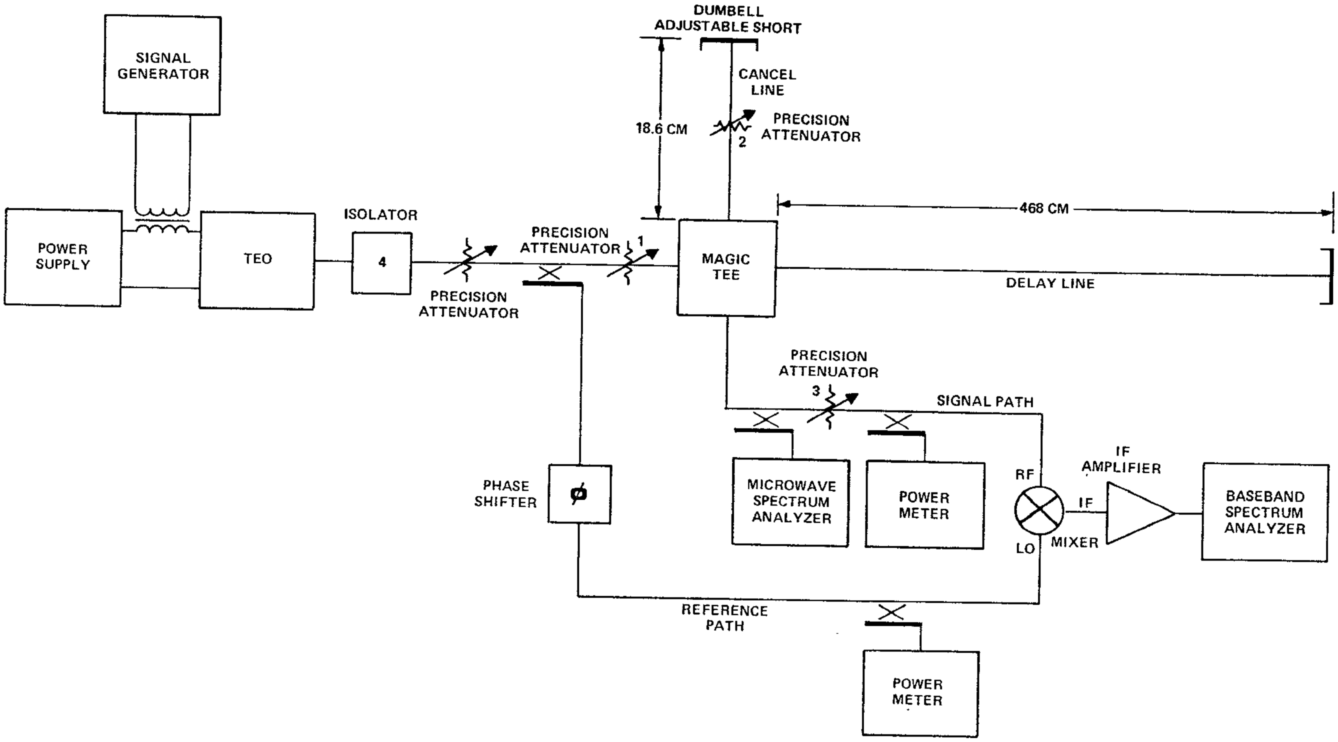

FIG. 1. A SIMPLE TRANSMISSION LINE FM NOISE MEASURING DISCRIMINATOR WHICH CAN BE USED WITH OR WITHOUT CARRIER NULLING

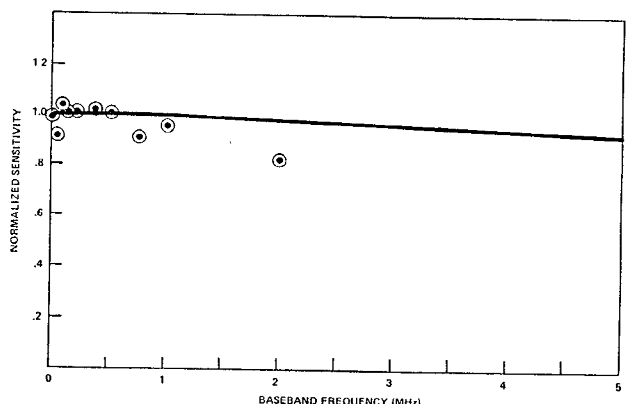

FIG. 2. MEASURED & THEORETICAL SENSITIVITY AT LOW BASEBAND FREQUENCIES FOR THE SIMPLE TRANSMISSION LINE DISCRIMINATOR

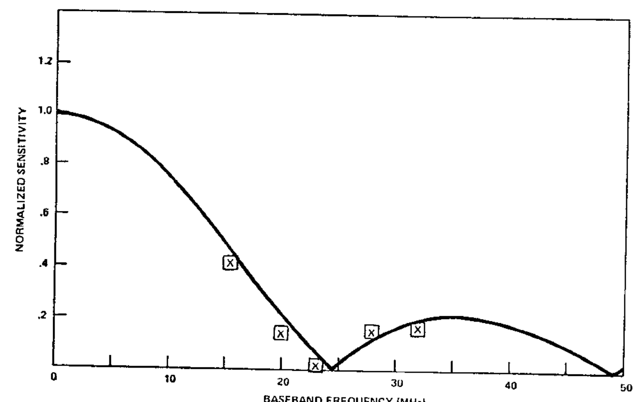

FIG. 4. MEASURED AND THEORETICAL SENSITIVITY AT BASEBAND FREQUENCIES FOR THE SIMPLE TRANSMISSION LINE DISCRIMINATOR

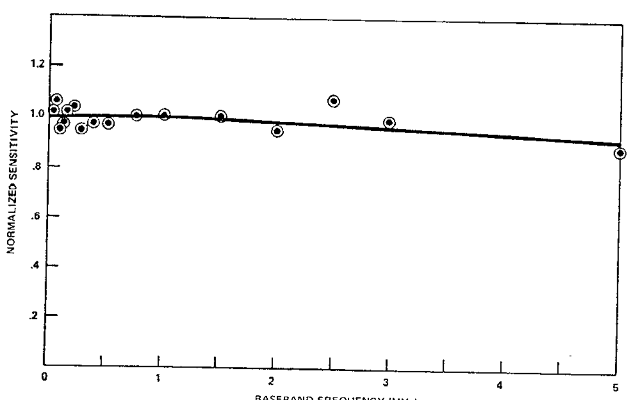

FIG. 3. MEASURED AND THEORETICAL SENSITIVITY AT LOW BASEBAND FREQUENCIES FOR THE CARRIER CANCELLING TRANSMISSION LINE DISCRIMINATOR

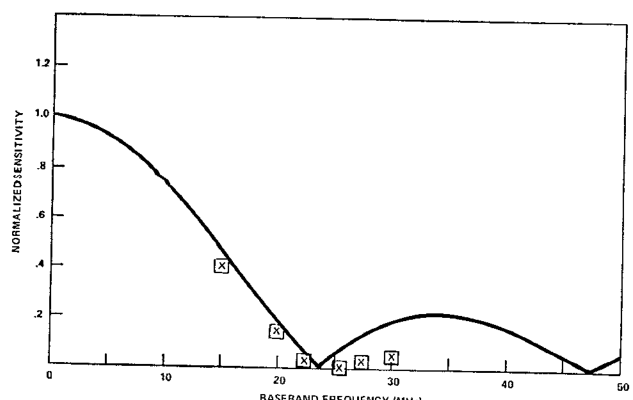

FIG. 5. MEASURED AND THEORETICAL SENSITIVITY AT BASEBAND FREQUENCIES FOR THE CARRIER CANCELLING TRANSMISSION LINE DISCRIMINATOR