Letters

Comments on Discriminator Theory

J. ROBERT ASHLEY, THOMAS A. BARLEY, AND GUSTAF J. RAST, JR.

Abstract—**The error in our analysis detected by Knochel *et al.*, and several other errors are acknowledged. The corrected analysis is abstracted and compared with the results by Knochel *et al.* Experimental verification is given for the new results. Some practical considerations regarding the implementation and use of the TEM resonator discriminator are given.**

I. Errors

We wish to thank Knochel, Schunemann, and Schiek [1] for their careful reading of our papers which led to the detection of a significant error in our analysis which will be further discussed in this communication. Other errors in [2] which have been found include [2, fig. 10], which has the photograph upsidedown, and the discussion regarding [2, fig. 5]. The width of the line γ/π is determined by the value of the FM noise at zero (baseband) frequency. An experiment to prove the theory was successfully performed by Lawler [3].

II. Corrected Analysis

The essence of the comment by Knochel *et al.* [1] is that our analysis does not apply to the circuit given in [2, fig. 13] ([1, fig. 1] with the slide screw tuner inserted). We neglected the signal recirculating between the slide screw tuner and the short. Our analysis [4] does apply to [2, fig. 14] and we still believe it is correct. This circuit was used to verify the theory and obtain [2, fig. 18]. A hybrid junction version is shown in Fig. 1.

To extend the analysis given by Knochel *et al.* [1], we compare the resonator discriminator with a delay line discriminator of the type which utilizes carrier nulling to reject AM on the test signal and to allow additional signal power to be inserted to lower the effective measurement threshold. We have found these last two considerations to be most important in the laboratory.

The insertion of the slide screw tuner and adjustment as we outlined in [2] makes the combination of tuner and transmission line a resonant circuit. If the adjustment is perfect, then the reflection is zero at $\Delta\nu = 0$. For the perfect match case, we prefer to write [1, (3)] in the form

$$r_r = \frac{|\sin(2\pi n\Delta\nu/\nu_c)|}{2\sinh(2\alpha L)}\exp[j(\pi/2+\mathrm{sgn}(\Delta\nu)]. \tag{1}$$

The $\mathrm{sgn}(\Delta\nu)$ in the phase angle points out why early workers referred to the balanced mixer as a "sign detector" [5].

In general, the analysis should allow for a less than perfect match. If the transformer action of the slide screw tuner makes the impedance at resonance (at a point just in front of the tuner) very nearly Z_0, we can write

$$\hat{Z} = Z_0\zeta\left[1 + j\frac{\sin(2\pi n\Delta\nu/\nu_c)}{\sinh(2\alpha L)}\right] \tag{2}$$

Manuscript received March 23, 1982; revised February 17, 1983.
J. R. Ashley is with Sperry Electronic Systems, Clearwater, FL 33518.
T. A. Barley and G. J. Rast, Jr. are with the U.S. Army Missile Command, Redstone Arsenal, AL 35898.

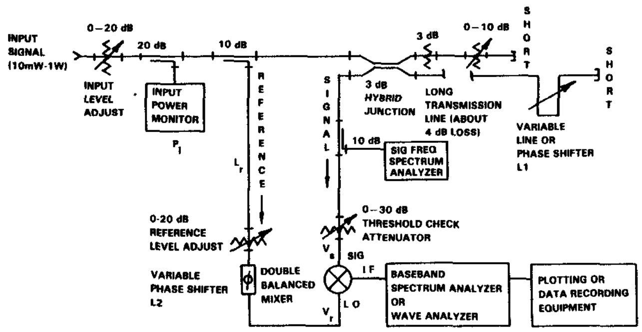

Fig. 1. A wide operating frequency range transmission line discriminator.

where

$$\zeta = K_T\frac{\sinh(2\alpha L)}{\cosh(2\alpha L)+2} \tag{3}$$

and K_T is set by the slide screw tuner to make $\zeta = 1$. By analogy to cavity resonator theory, we can write (2) as

$$Z = Z_0[\zeta + j2Q_0\Delta\nu/\nu] \tag{4}$$

where

$$Q_0 = \frac{2\pi}{\alpha\lambda_c\left(1+\dfrac{n^2\alpha^2\lambda^2c}{3!}\right)} \tag{5}$$

$$\lambda_c = U_0/\nu_c = \text{wavelength in the line.} \tag{6}$$

Here we have replaced the sine by the first term and the hyperbolic cosine by the first two terms of their respective power series. As we might expect from cavity resonator theory, Q_0 does not depend on n for a small number ($n < 5$) of half wavelengths in low-loss line.

With this analogy, we can apply in general the previously developed cavity discriminator theory to show that this discriminator has the desirable properties of rejecting AM on the signal being tested and allowing much of the power available in the test signal to be applied to the discriminator. It allows a simple verification of [1, (7)] for the $n = 1$ case.

To experimentally verify the theory Knochel *et al.* [1] have given for the resonator discriminator, we tried to build the resonator type at 300 MHz. Using a slide screw tuner, we could not get sufficient capacitance in shunt with a 50-Ω coaxial line for $\alpha L = 0.1$ to null the carrier; therefore, we substituted a single tuning stub. Also, we did not have a circulator at 300 MHz so we again used the 3-dB hybrid junction as shown in Fig. 2. (This circuit would be about 6 dB more sensitive with the circulator.) This circuit is easy to compare with the delay line discriminator of Fig. 1.

Quickly, we found that a simple stub with the sliding contacts very near the high current point at the short was very erratic and hard to tune. We substituted a fixed short and adjustable length

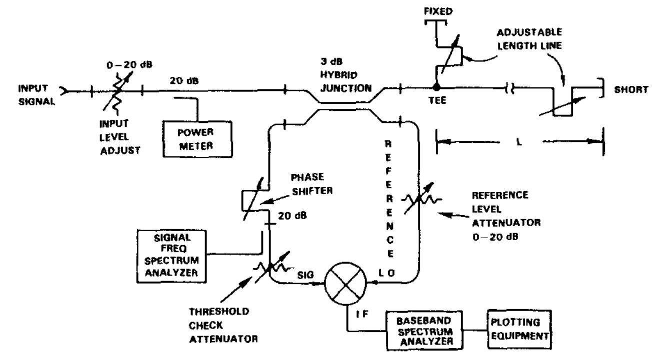

Fig. 2. A practical resonator discriminator assembled from transmission line components [7].

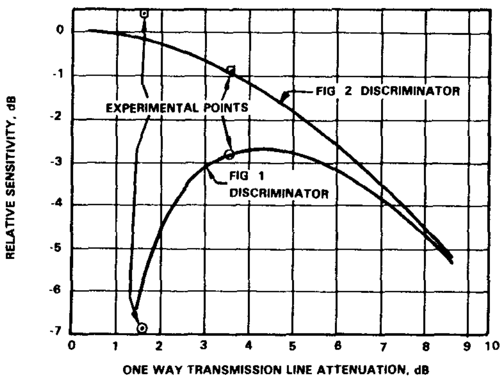

Fig. 3. A comparison of discriminator sensitivities.

line to put the sliding contacts somewhere between $\lambda/8$ and $3\lambda/8$ from the fixed short (as illustrated in Fig. 2). After this modification, we were able to obtain the experimental points shown in Fig. 3. We did not attempt to verify the absolute sensitivity of [1, (7)].

Comparison of [1, fig. 2] and Fig. 3 will show that we have changed the scales to quantities more appropriate to our laboratory equipment. Notice that a line with several dB of attenuation can be used without serious loss of sensitivity. The longer line does make the system easier to tune. In choosing the kind of transmission line, do not lose sight of the fact that the lower loss line will yield higher sensitivity as shown in [1, (7)] or as the higher Q_0 of (5). In light of this discussion, a given length of coaxial cable can be used through a surprisingly large range of carrier frequencies.

For the resonator case, the upper modulation frequency limit can no longer be estimated by [2, (43)]. Instead, one must estimate Q_0 from [2, (5)] and then use the theory given by Ondria [6].

References

[1] R. Knochel, K. Schunemann, and B. Schiek, "Comments on 'The measurement of noise in microwave transmitters'", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-27, Jan. 1979.

[2] J. R. Ashley, T. A. Barley, and G. J. Rast, Jr., "The measurement of noise in microwave transmitters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-25, pp. 294–318, Apr. 1977.

[3] C. E. Lawler, "The power spectrum of a carrier frequency modulated by Gaussian noise," M.S.E.E. thesis, Univ. of Colorado, Denver, 1979.

[4] G. J Rast, Jr., T. A. Barley, and J. R. Ashley, "Automated measurement of transmitter noise at HF through microwave frequencies," U.S. Army Missile Command, Rep. TR-RE-7T-8, Sept. 1976.

[5] S. B March and J. D. Clare, "Microwave frequency discriminator," U.S. Patent 3 079 563, Feb. 1963.

[6] J. G. Ondria, "A microwave system for measurement of AM and FM noise spectra," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-16, pp. 767–781, Sept. 1968.

[7] J. R. Ashley, T. A. Barley, and G. J. Rast, Jr., "Single hybrid junction frequency discriminator," U.S. Patent Application Serial no. 315 328.

Corrections to "New View on an Anisotropic Medium in a Moving Line Charge Problem"

MASANORI KOBAYASHI, MEMBER, IEEE

In the above paper[1], the following corrections should be made. The part, $A'_{x'} = A'_{y'} = A'_{z'} = 0$ in this problem, shown between equation (9) and equation (10) should read as

$$\phi'/c = \left(1 - \epsilon_y^* \mu^* \beta^2\right)\gamma\phi/c, A'_{x'} = A'_{y'} = 0, A'_{z'} = \left(\epsilon_y^* \mu^* - 1\right)\beta\gamma\phi/c$$

in this problem.

Equation (11) should read as

$$\phi = \frac{\phi'}{\gamma\left(1 - \epsilon_y^* \mu^* \beta^2\right)}. \tag{11}$$

Equation (13) should read as

$$\epsilon_{y'}^* = \frac{\epsilon_y^*\left(1 - \beta^2\right)}{1 - \epsilon_y^* \mu^* \beta^2}, \qquad \epsilon_{z'}^* = \epsilon_z^*. \tag{13}$$

Manuscript received March 1, 1983.

The author is with the Department of Electrical Engineering, Ibaraki University, 4-12-1 Nakanarusawa-Machi, Hitachi, Ibaraki, Japan.

[1]Masanori Kobayashi, *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, pp. 2046–2048, Nov. 1982.