MICROWAVE TRANSMISSION LINE FREQUENCY DISCRIMINATORS

Hong Goo Cho* and Choong Woong Lee**

* Dept. of Electronic Engineering
Kookmin University, Seoul, Korea

**Dept. of Electronic Engineering
Seoul National University, Seoul, Korea

ABSTRACT

New types of microwave frequency discriminators are proposed for the narrow band as well as wide-band applications. An example of branch-line hybrid type with 5% operation bandwidth is presented at 4.94 GHz. A bridge type wide-band frequency discriminator is realized using microstrip lines and slot-lines. An experimental discriminator has 50% bandwidth, which shows good agreement with the theory.

INTRODUCTION

Conventional microwave frequency discriminators usually employ resonators for narrow band operation and hybrids (1-4) for wide-band applications. We propose new types of microwave frequency discriminators for both narrow and wide-band applications. For narrow band operations(up to 20% bandwidth), such devices as the branch-line hybrid, the $\lambda/4$ parallel coupled line, the rat-race ring hybrid or the binary power divider can be used together with an open and a shorted stub.

To obtain frequency discrimination over 50% bandwidth, a bridge circuit is employed. Lee and Seo (5) have proposed a bridge type wide-band frequency line discriminator and obtained 40% bandwidth performance in the VHF band (6). The bridge circuit can be realized using microstrip lines and slotlines in microwave frequencies.

NARROW BAND DISCRIMINATORS

The proposed discriminator circuits consist of a microwave device N_C and stub circuits N_L as shown in Fig. 1(a). For the device N_C which serves as power dividing as well as impedance matching section, a branch-line hybrid, a $\lambda/4$ parallel coupled line, a rat-race ring hybrid or a binary power divider can be used.

In the 3 dB branch-line hybrid coupler type as shown in Fig. 1 (a) and (b), the incident power through port 1 is coupled in equal measure to ports 2 and 3 with a 90° phase shift between ports 1 and 2, and a 180° phase shift between ports 1 and 3. If the reflection coefficients at ports 2 and 3 (Γ_1, Γ_2 in Fig. 1 (a)) are chosen to be equal, the reflected signals, respectively, split into two waves that arrive at port 1 with 180° out of phase and at port 4 in phase with one another. Therefore, this circuit is matched at the driven port 1 when ports 2 and 3 are terminated with arbitrary equivalent equal impedances and port 4 with matched termination. Input impedance of a shorted stub and that of an open stub are equal when the difference of the stub lengths is $\lambda/4$. The long stub is connected at port 2 so that the phase shifts between port 1 and each detecting position are equal at designed frequency. The detecting positions are located at $\lambda/8$ from the stub terminations (5). If port 1 is driven by a source V_s of 2 volts with an internal impedance Z_o, the incident voltage V_i at port 1 is 1 volt and the incident voltages upon the stubs at ports 2 and 3 are S_{21} and S_{31} respectively. The output voltage V_o

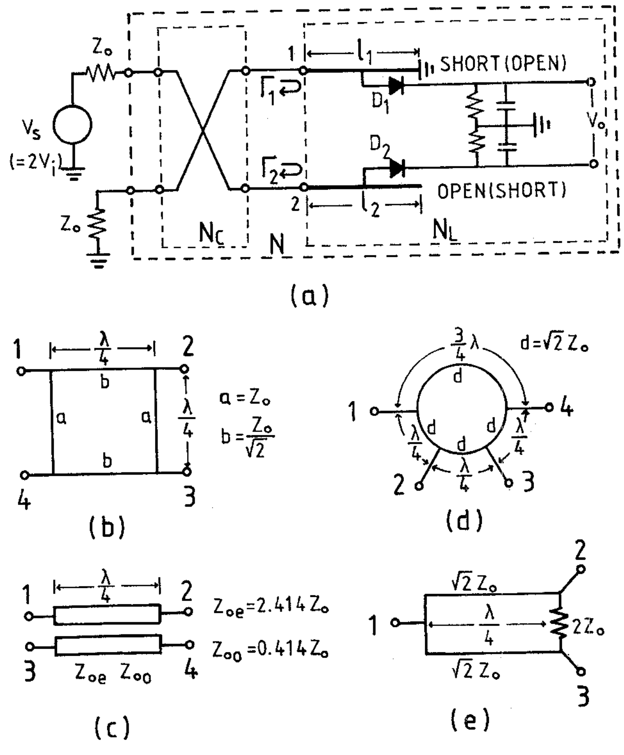


Fig. 1 Schematic of transmission line frequency discriminator and microwave devices. (a) Discriminator circuit using microwave device. (b) Branch-line hybrid. (c) $\lambda/4$ parallel coupled line. (d) Rat-race ring hybrid. (e) Binary power divider.

of the discriminator, which is composed of a shorted stub at port 2 and an open stub at port 3, can be expressed as follows:

$$V_0 = 4\eta\,(|S_{21}|^2 \sin^2\theta - |S_{31}|^2 \cos^2\theta) \qquad (1)$$

where η=constant determined by the characteristics of diode circuits. $\theta = \pi f/(4f_0)$.

In the 3 dB $\lambda/4$ parallel coupled line type as shown in Fig. 1 (a) and (c), the incident power through port 1 splits equally toward ports 2 and 3 with 90° phase relationship between these two ports. Therefore, a long stub is connected at port 3, a short stub at port 2 and matched termination at port 4. The discriminator output voltage can be given as a similar expression in the equation (1).

The rat-race ring hybrid is the most common 0-180° phase response device. Therefore, the 3 dB rat-race ring hybrid type as shown in Fig. 1 (a) and (d), two stubs of equal length can be used. If the incident power is fed at port 2, the reflected signals at stub terminations connected at ports 1 and 3 arrive at the input port 2 180° out of phase and at the isolated port 4 in phase each other. The discriminator output voltage can also be given as a similar expression in the equation (1).

The relative output voltage for the three types of discriminators described previously is shown in Fig. 2. Referring to this Figure, discriminators with bandwidth of about 5% can be achieved with these circuits. The input impedances can be well matched over the frequency bandwidth.

In the binary power divider type as shown in Fig. 1 (a) and (e), since the binary power divider is a three-port structure, the fourth port externally terminated with Z_0 does not exist. The binary power divider has the advantages of excellent output port amplitude balance and in phase power division. Therefore, we can use two stubs of equal length. When driven at port 1 the input power splits equally between ports 2 and 3 and no power is dissipated in the internal termination $2Z_0$, since each end is at the same potential. On the other hand, the reflected signals at the stub terminations are dissipated in the internal termination and interfere destructively at the input port 1. The incident signals upon two output ports 2 and 3 are equal ($S_{21} = S_{31}$). The output voltage V_0 of the discriminator can be expressed as follows:

$$V_0 = 4\eta|S_{21}|^2(\sin^2\theta - \cos^2\theta) \qquad (2)$$

The relative output voltage for the binary power divider type discriminator is shown in Fig. 3. The linearity is acceptable over approximately 20% bandwidth. In that frequency range, the input impedance can also be well matched.

An example of the branch-line hybrid type discriminator has been designed at 4.94 GHz using microstrip lines as shown in Fig. 4. The stub circuits N_L shown in Fig. 1 (a) is composed of the $\lambda/2$ shorted stub and the $\lambda/4$ open stub of characteristic impedance Z_0. Experimental return loss and output voltage response for this circuit are shown in Figs.5 and 6. Referring to the Figures, a good linearity and impedance matching was obtained with this circuit over about 5 % bandwidth. In this case, measured transmission (from port 1 to port 4 in Fig. 1 (b)) loss was 0.40 dB at the designed frequency.

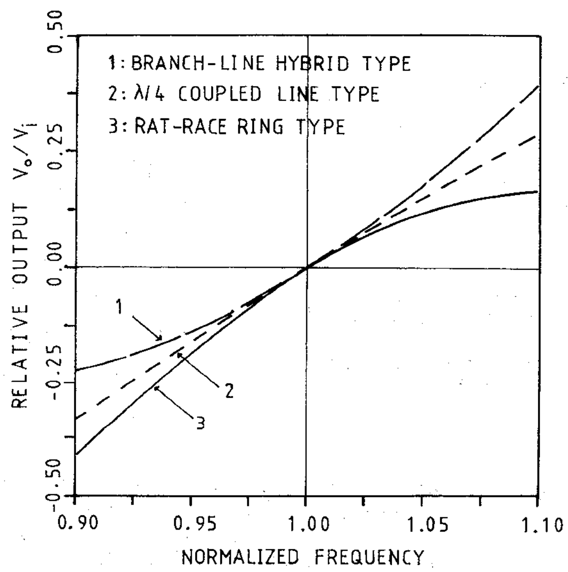


Fig. 2 Relative output voltage of the three type discriminators.

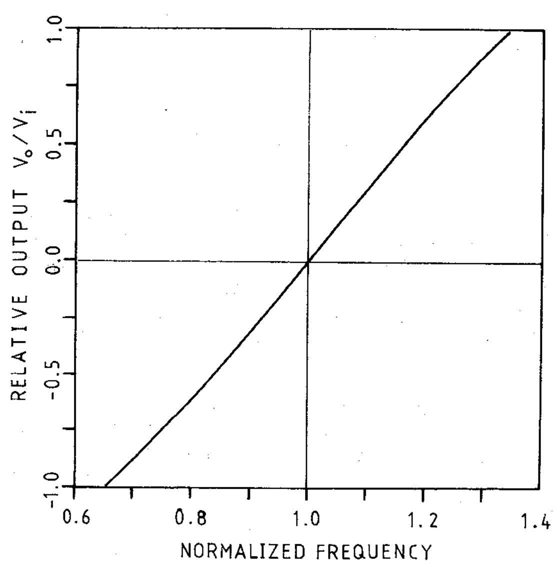


Fig. 3 Relative output voltage of the binary power divider type discriminator.

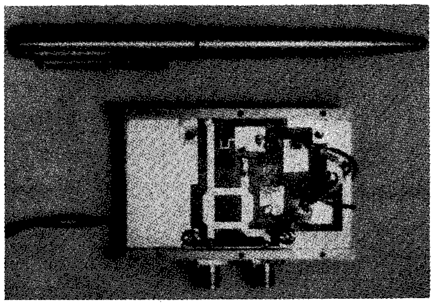


Fig. 4 3 dB branch-line hybrid type discriminator.

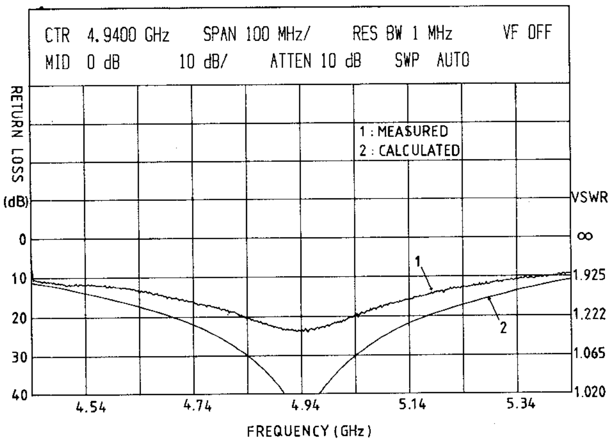


Fig. 5 Return loss of 3 dB branch-line hybrid type discriminator.

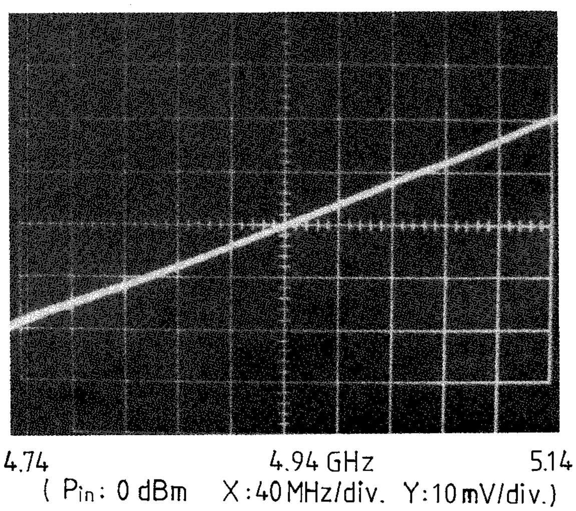


Fig. 6 Output voltage response of 3 dB branch-line hybrid type discriminator.

SUPER WIDE-BAND DISCRIMINATOR

The bridge type wide-band frequency line discriminator suggested by Lee and Seo consists of a shorted stub, an open stub, two coupling resistors and detecting circuits. When the coupling resistor constant is 1 (6), the input impedance of discriminator is independent of frequency and always equal to the transmission line characteristic impedance Z_o. The bridge circuit can be realized using microstrip lines and slotlines as shown in Fig. 7. In the experimental discriminator designed at 3.2 GHz as shown in Fig. 8, the bridge circuit has been constructed on the Cuflon substrate $42 \times 40 \times 0.254$ mm with a relative dielectric constant of 2.065, and matched detectors are used in place of the coupling resistors and detecting circuits. Measured return loss and output voltage from 2.4 GHz to 4.0 GHz are shown in Figs. 9 and 10. The 50 % bandwidth operation confirmed by the experiment is in good agreement with the theory.

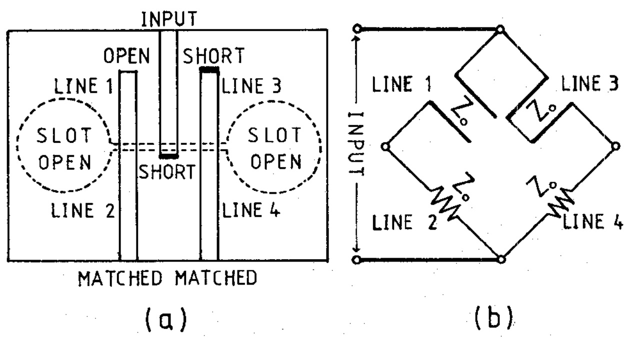


Fig. 7 (a) Configuration of bridge circuit.
(b) Equivalent circuit of (a).

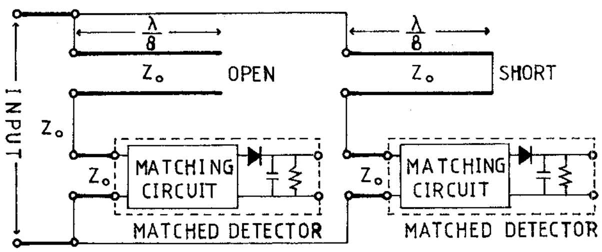


Fig. 8 An equivalent circuit of bridge type discriminator.

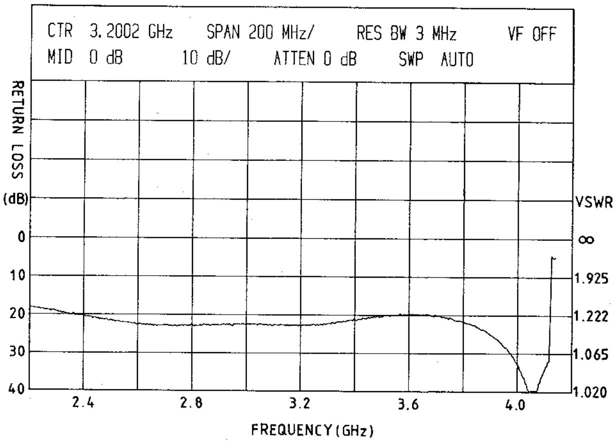
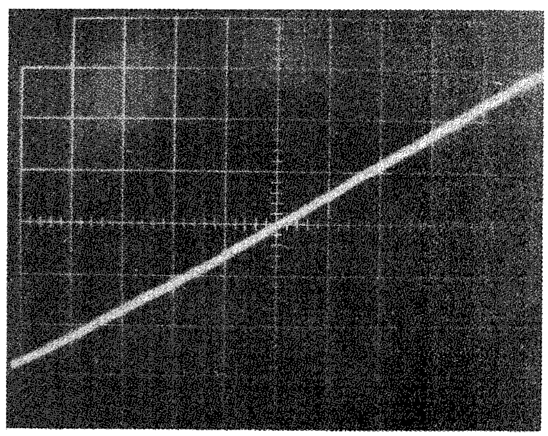


Fig. 9 Return loss of bridge type discriminator.



2.4 3.2 GHz 4.0

(P_{in}: -10dBm X:160 MHz/div. Y:10 mV/div.)

Fig. 10 Output voltage response of bridge type discriminator.

CONCLUSION

New types of microwave frequency discriminators have been presented for the narrow band as well as wide-band applications. The ordinary microwave devices have been used as power dividing and impedance matching section in the frequency discriminators which utilize an open and a shorted stub. An example of the branch-line hybrid type was constructed using microstrip lines. Its experimental results show that these circuits are well matched and have good linearities. The discriminators having the externally matched port may be suitable for frequency stabilization circuit of microwave oscillators.

It is also shown that the bridge type super wide-band frequency discriminator can be realized using microstrip lines and slotlines in microwave frequencies. It has over 50% discriminating bandwidth. Return loss is more than 19 dB over that frequency range.

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