AN INTEGRATED MICROWAVE FM DISCRIMINATOR

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Based on the recent advances in several technologies, a flurry of activity has been initiated in the field of microwave integrated circuits. Multifunction stripline circuits are now possible which compare favorably in quality with waveguide construction and offer the advantages of large reductions in cost and size. This paper shows the introduction of such microwave integrated circuit technology to an FM discriminator.

The discriminator is of the delay line type. It uses ferrite circulators and intentionally introduced variable mismatches to permit simple compensation for delay line loss and easy adjustment to the desired input carrier frequency. For the intended application, it is necessary to have the capability of tuning the device to any one of many carrier frequencies extending over the band from 5925 to 6425 MHz. The discriminator must have high sensitivity, excellent linearity (for frequency deviations up to ± 5 MHz), and low group delay.

The stripline circuitry in the discriminator is of two types. In the vicinity of the circulators and detectors, the circuitry contains a thin ceramic substrate suspended between two ground planes as shown in Figure 1a. Thin film technology with a photolithographic selective etch process is used to define the center conductors and resistive terminations. The conductors are titanium and gold, copper plated to a thickness of 0.3 mils. The resistors are tantalum nitride, trim anodized to value. A cross section through a circulator is shown in Figure 2. The delay line is in fully loaded stripline as shown in Figure 1b. The dielectric is 99.5% alumina and the center conductor is also defined by thin film techniques. Because of the length involved, the conductor thickness is increased to 0.8 mils to reduce the RF loss.

A layout of the discriminator is shown in Figure 3. The power splitting and combining network and the delay line are shown in a simplified schematic in Figure 4. The FM input signal is coupled through a circulator to the line on which the variable depth, variable position mismatch is located. Adjustment of the magnitude of this first mismatch controls the amount of signal transmitted through it and the amount reflected. Adjustment of its position controls the phase between the two signals. The signal reflected from this mismatch is coupled through several circulators to the second mismatch, which is set to 3 dB. Thus, half of the nondelayed signal is sent to each detector. Similarly, the signal transmitted through the first delayed signal also reaches each detector. For highest sensitivity the delayed and nondelayed signal levels should be equal. Since the delay line has some loss, this condition is achieved by making the transmitted signal at the first mismatch larger than the reflected signal.

In order for the circuit to function, it is necessary for the signals reflected and transmitted at the second mismatch to be 90° out of phase. For a lossless mismatch, this condition is automatically satisfied. The delayed and nondelayed signals reaching each detector add on a vector basis to produce the amplitude response shown in Figure 5a. The detector currents, made opposite in sign by opposite polarization of the diodes, combine to produce the discriminator function shown in Figure 5b.

The meandering delay line has a delay of 8 ns. A larger value would provide greater sensitivity but would not permit meeting the linearity requirements. In addition it would mean increased group delay for the complete discriminator. The delay line is a 50 ohm line in a channel fully loaded with dielectric. The full loading is used to decrease the velocity of propagation and, therefore, minimize the physical length. The line is approximately 30 inches long and has a loss of about 3 dB. A computer analysis of the delay line has shown that if each of the bends has a 30 dB return loss, proper spacing of the bends permits achieving a return loss for the complete delay line of better than 35 dB across the 500 MHz band when it is terminated in a 50 ohm load. This high return loss is necessary since multiple reflections of the delay line adding in phase would significantly degrade the linearity of the discriminator.

The two detectors shown in Figure 3 are identical except for the opposite polarity of the diodes. The detectors are floating at a relatively high DC potential. Blocking capacitors are used to isolate the detectors from the remainder of the stripline structure. Filters provide the necessary RF short circuits behind the diodes and prevent leakage on the baseband outputs.

Models of the discriminator have been built and tested. The discriminator is operated with an input power of +13 dBm and the diode detectors operate in the linear region. The output current from each diode, at the carrier frequency, is 6 mA. The sensitivity is approximately

0.25 mA/MHz of frequency deviation, when operating into a low impedance amplifier. Nonlinearity of less than 1 percent has been achieved with the required frequency deviation.

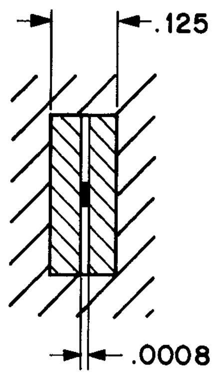

Figure 1B Stripline medium for delay line.

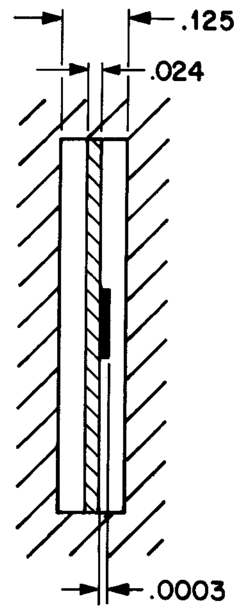

Figure 1A Stripline medium for power splitting, combining, and detector circuits.

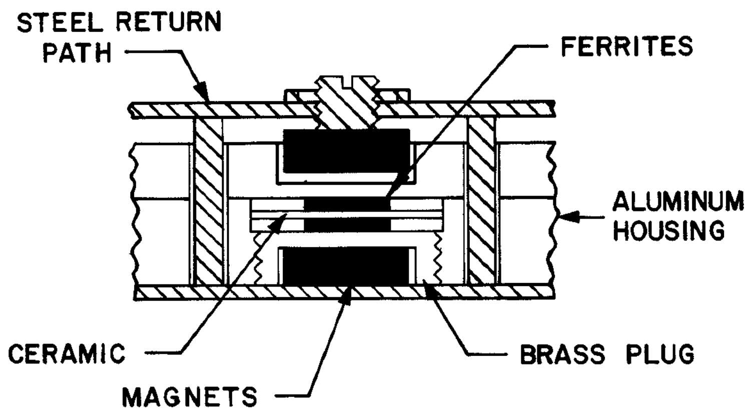

Figure 2 Cross-sectional view of stripline circulator.

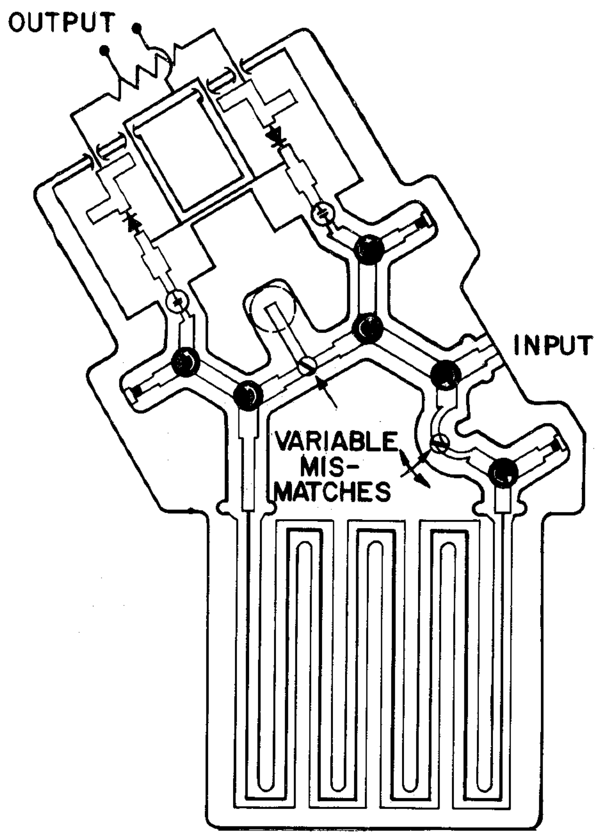

Figure 3 Circuit layout of the integrated discriminator.

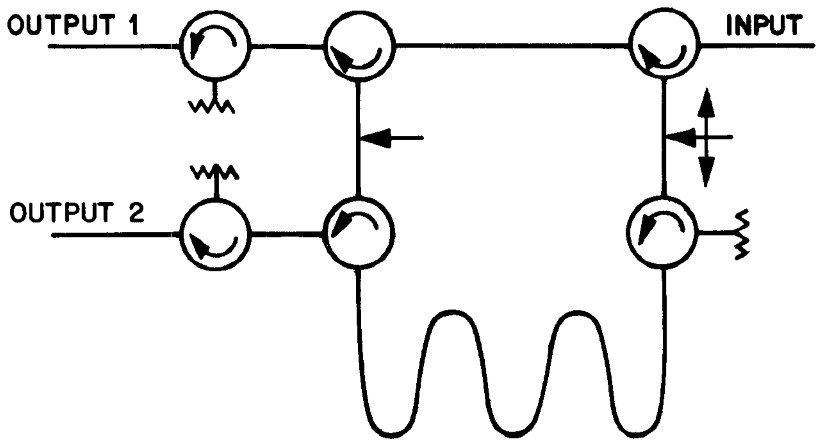

Figure 4 Simplified diagram of the circuitry used to convert frequency deviation to amplitude variation.

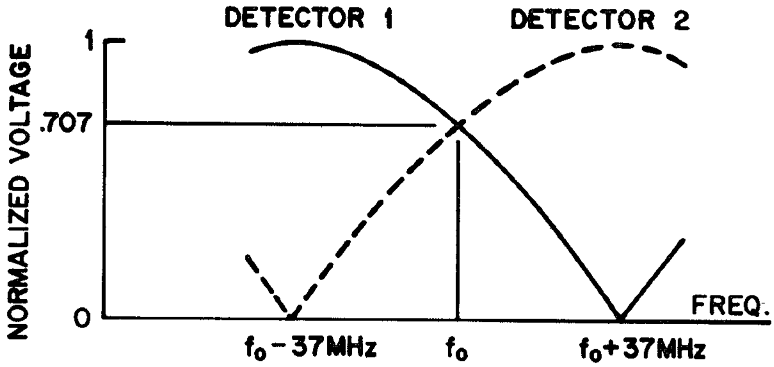

Figure 5A Normalized detector input voltages as a function of instantaneous frequency.

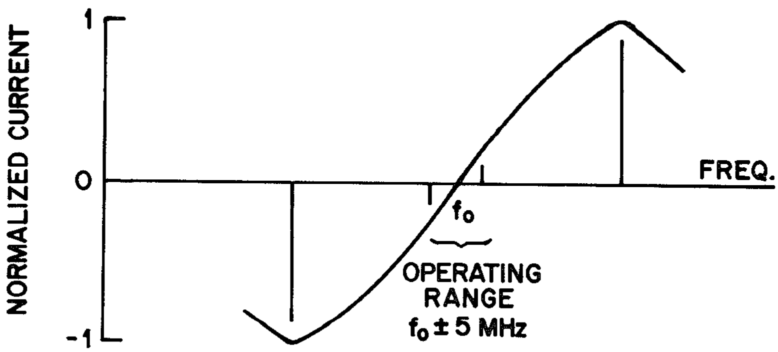

Figure 5B Normalized current of combined detectors as a function of instantaneous frequency.