DESIGN AND PERFORMANCE OF A BROADBAND MIC LOW NOISE K-BAND BALANCED MIXER, POLAR DISCRIMINATOR AND RELATED COMPONENTS

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Abstract

The design and experimental performance of a broadband (18-26.5 GHz) single balanced mixer, polar discriminator and related components fabricated in microstrip on 0.010-inch thick gold plated sapphire is described. Typical conversion loss of 7.5 dB with a maximum of 8.5 dB at the top of the band was achieved in the mixer. The output polar angle of the discriminator is linear within ±15° with an input signal level of -14 dBm. Full utilization of planar techniques is made that could also be applicable for frequencies up to and above 60 GHz.

Introduction

There is an increasing need for broadband millimeter wave superhet and instantaneous frequency measuring (IFM) receivers for surveillance, electronic countermeasure (ECM), and electronic support measure (ESM) applications. This paper describes the design and performance of a 18-26.5 GHz single balanced mixer, polar discriminator and 3 dB quadrature hybrid for a future surveillance or ESM receiver front end. The components were fabricated using microstrip techniques to reduce the effects of parasitics thereby obtaining the desired broadband performance. In addition, the design in MIC leads to compact size, performance repeatability in duplicate models and the potential for low manufacturing costs.

MIC Balanced Mixer

The basic assembly of the single balanced mixer fabricated is shown in Fig. 1. It consists of a 3-dB quadrature coupler, two mixer diodes, and low pass filters to isolate the IF frequencies from the LO and RF frequencies. The IF frequency is 60 MHz but by appropriate design of the low pass filters has a pass band up to 10 GHz. The circuit was fabricated on a 0.010-inch thick gold plated sapphire substrate ($\epsilon_r \approx$ 9.6). Sapphire is used because smoother surfaces and constant dielectric with frequency can be obtained thereby reducing the circuit losses and optimum performance in 3 dB quadrature hybrids with frequency.

The substrate was mounted on a test fixture specially designed for readily testing microstrip circuits on various sized substrates. The fixture has transitions from semirigid coaxial lines to microstrip. These transitions use a two section stepped transmission line to provide a low VSWR up to 40 GHz.

Measured performance of the mixer is given in Figs. 2 and 3. Figure 2 shows the conversion loss as a function of frequency for an LO power of 1 mW and diode current of 1.0 mA. The double side-band noise figure at 26 GHz is shown in Fig. 3 as a function of diode bias current for various LO powers. The IF amplifier noise figure is assumed to be 1.5 dB. These results show that for a diode bias current of 1.3 mA the noise figure does not change appreciably with a 9 dB variation in the LO power.

The return loss for both the RF and LO ports was measured to be less than 10 dB across the frequency band. The minimum LO and RF isolation measured at the optimum noise figure current setting is 6 dB. An isolation of 10 dB can be achieved if bias currents are set to equal 2 mA.

Hewlett Packard Schottky barrier beam lead diodes (HP 5082-2769) were used with $C_{tot} \leq 0.1$ pF. These diodes were connected electrically in shunt by mounting them between the microstrip line and a grounding post through the substrate to the ground plane. A broadband RF match (return loss typically 12.5 dB) to the diodes was obtained by including the package parasitics as part of a lumped element matching network.

MIC Polar Discriminator

A polar discriminator consists of two in-phase power splitters, three quadrature 3-dB hybrids, a delay line, and four detector diodes arranged in the configuration shown in Fig. 4. The delay line is used to introduce a phase shift proportional to the frequency of the incoming signal. The rest of the configuration is used to obtain the dc voltages proportional to the sine and cosine of this phase angle.

In realizing the polar discriminator two previously designed MIC single balanced mixers were used. The bias current of each Schottky barrier diode was adjusted for optimum performance as a detector rather than as a mixer diode.

The entire polar discriminator was fabricated in microstrip using 0.01-inch thick gold plated sapphire except for the delay line. Semirigid coaxial line was used for the delay line merely as a matter of convenience and final versions of the circuit would be fabricated entirely in microstrip. Much of the circuit had been fabricated previously on a sapphire substrate for use in an image reject mixer. The experimental model of the polar discriminator was assembled by adding a microstrip in-phase power splitter and a coaxial delay line to the microstrip image-reject circuit as shown in the assembly in Fig. 5.

Both swept frequency and single frequency measurements of the polar discriminator were made over the 18-26.5 GHz frequency range. The cosine and sine output voltages were used to drive the horizontal and vertical axis respectively of a Textronix 502 oscilloscope and an x-y recorder. Single frequency measurements of the phase angle of the polar display were made as a function of frequency. The polar angle of the discriminator is linear within ± 15°. The amplitude variation over the band was ±2 dB after taking into consideration the variation due to the test sweeper. These results were obtained at a signal level of -14 dBm. Similar results were obtained at -23 dBm.

MIC 3-dB Quadrature Hybrid

The 3-dB quadrature hybrid was realized by connecting two 8.34-dB edge-coupled microstrip couplers in tandem. Cross overs were placed at the center of each 8.34-dB coupler in order to preserve the overall symmetry of the 3-dB hybrid and assure that the quadrature phase relationship between the outputs was maintained over the entire band. Because the coupler is physically very short, the crossovers represent a significant portion of its length and have a significant effect on the performance by introducing discontinuities that increase the ripple response. The effects of the crossovers and also of the discontinuities presented to the coupler at its ports during testing are evident in the performance characteristics of Fig. 6.

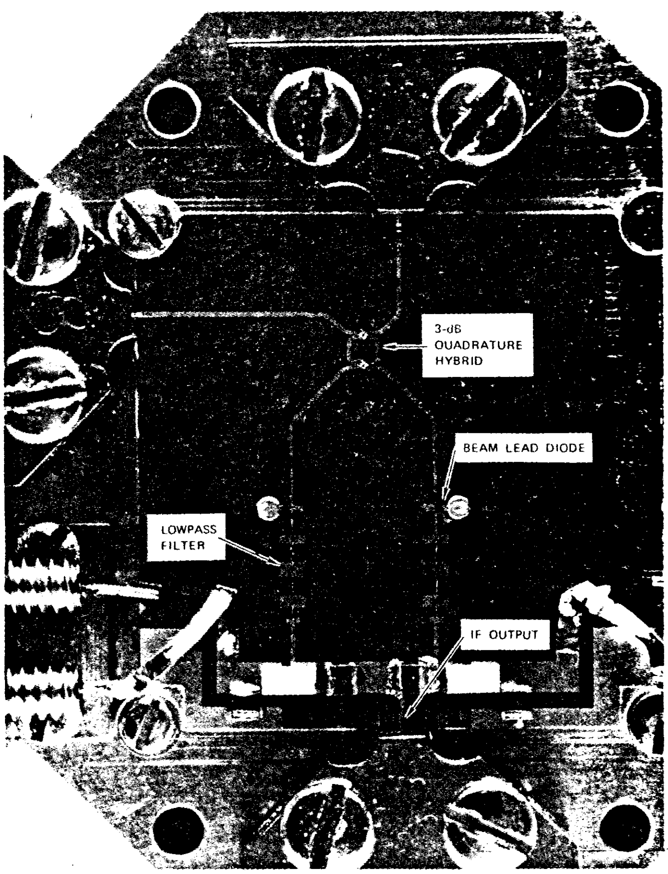

FIGURE 1 PHOTOGRAPH OF MICROSTRIP SINGLE BALANCED MIXER ASSEMBLY

Over the 18.0-26.5 GHz band, the coupling imbalance is ±0.7 dB maximum. The dissipation loss through the coupler is about 0.8 dB for each path. This loss also includes losses introduced by connectors and transitions used to test the hybrid and would be somewhat less for the hybrid imbedded in the balanced mixer or the polar discriminator circuitry.

Conclusions

The utility and advantages of planar MIC techniques applied at millimeter wavelengths have been demonstrated successfully by the above development. The above design techniques are applicable for frequencies greater than 80 GHz by proper selection of the substrate and active devices. Also the above planar techniques can be used for larger integration of components in millimeter wave subsystems.

Acknowledgments

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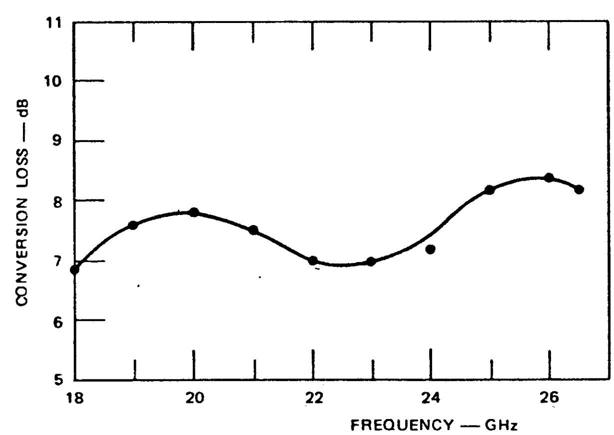

FIGURE 2 CONVERSION LOSS AS A FUNCTION OF FREQUENCY FOR THE SINGLE BALANCED MIXER. LO Input power = 0 dBm, diode bias currents = 1 mA.

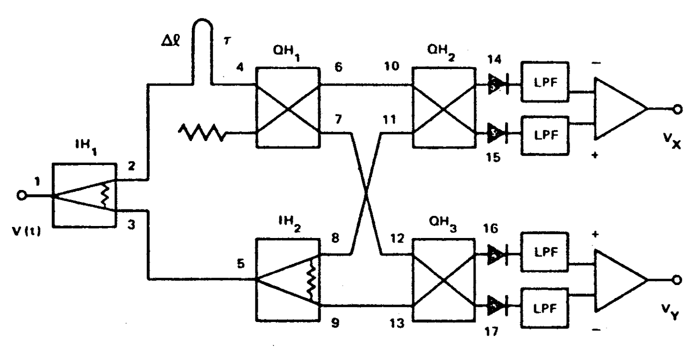

Figure 4 BLOCK DIAGRAM OF POLAR DISCRIMINATOR

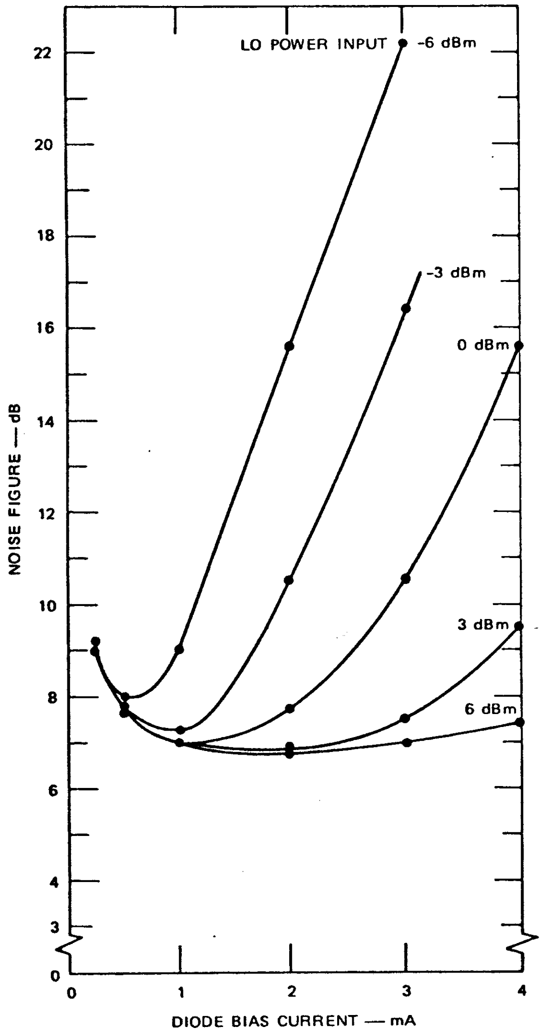

FIGURE 3 DOUBLE SIDEBAND NOISE FIGURE OF THE SINGLE BALANCED MIXER AS A FUNCTION OF DIODE BIAS CURRENT FOR VARIOUS LO DRIVE POWERS

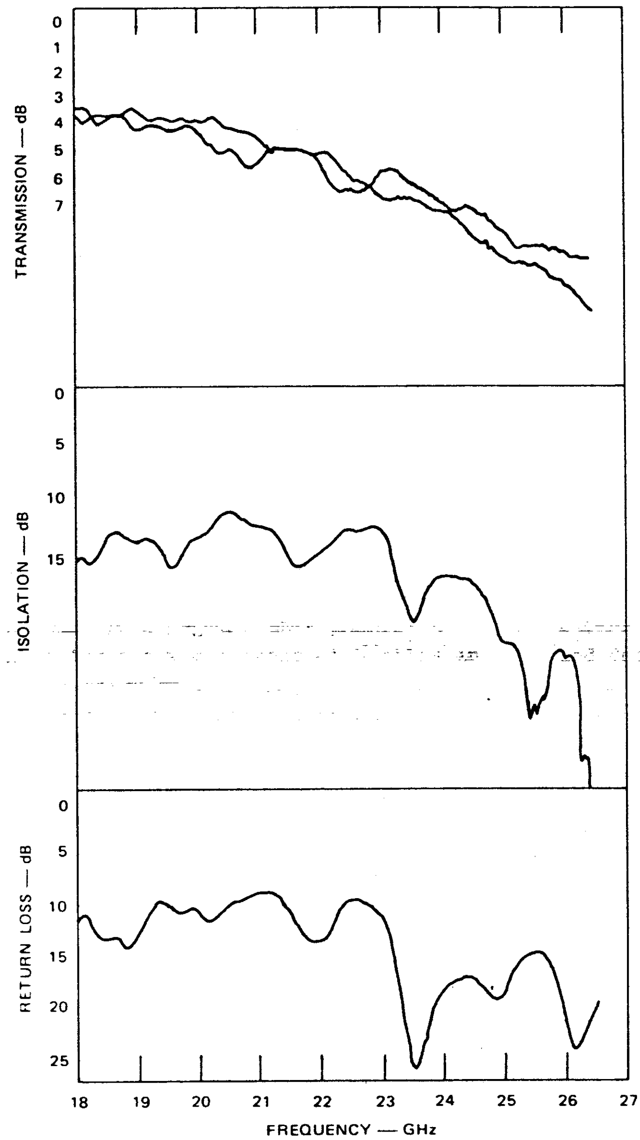

FIGURE 6
PERFORMANCE CHARACTERISTICS FOR THE K-BAND, MIC, 3-dB, QUADRATURE HYBRID

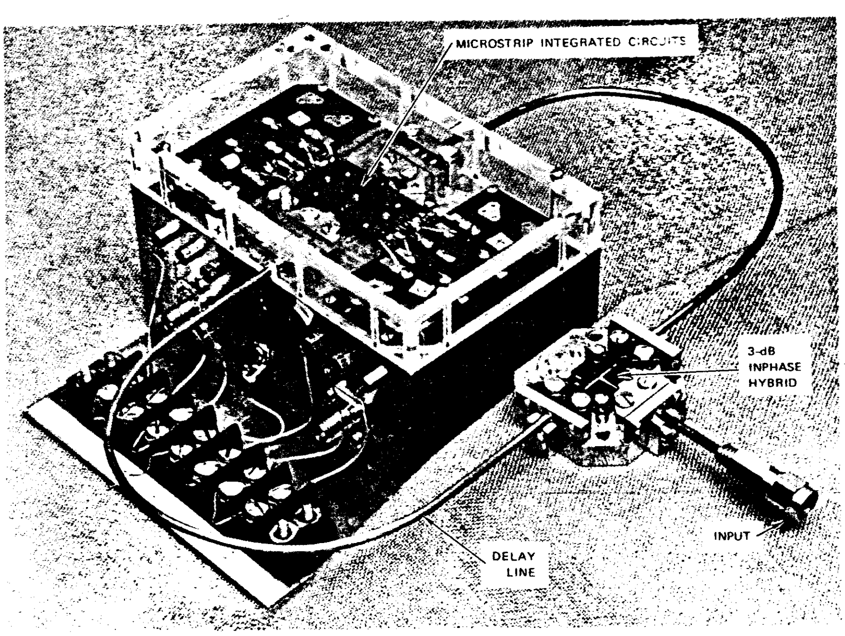

FIGURE 5
PHOTOGRAPH OF THE EXPLORATORY MODEL OF MIC K-BAND POLAR DISCRIMINATOR