QUASI-OPTICAL SLOT RING MIXER NOISE FIGURE MEASUREMENTS

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ABSTRACT

Noise-figure measurements of an X-band slot-ring mixer using quasi-optical coupling of LO and RF energy are described. The mixer noise figure varies from 5.5 to 9 dB over the IF band, and extension of this design to millimeter wavelengths should be straight-forward.

INTRODUCTION

The quasi-optical slot ring mixer (1) combines the functions of receiving antenna and mixer into one planar device. Its simple construction makes it suitable for large-scale integration into a receiving system using many such mixers simultaneously, for imaging or other applications. Since local oscillator energy is coupled quasi-optically, the LO feed system can be a simple lens illuminating the mixers from a common source. In this paper we report for the first time measurements of noise figure for this type of mixer. Hot and cold quasi-optical loads were used to determine that the average SSB noise figure over the 1-1.9 GHz IF bandwidth was 6.8 ± 1.1 dB. First, the mixer itself will be described.

MIXER OPERATION

Referring to Fig. 1, we note that the mixer is fabricated by etching a pattern on one-sided copper-clad 0.005-in. Kapton, a plastic having a relative dielectric constant of about 3. A circular slot having an inner radius of 0.125 in. and an outer radius of 0.175 in. forms a slot-ring antenna capable of receiving incoming radiation arriving perpendicular to the mixer plane on either side. Two mixer diodes (Alpha DMF5600A) at right angles to each other bridge the gap. In operation vertically polarized LO energy drives the diodes so that a horizontally-polarized incoming signal is down-converted at each diode in the proper phase to combine at the IF coplanar-waveguide low pass filter, which passes the 1-2 GHz IF band while keeping the RF fields within the slot ring structure.

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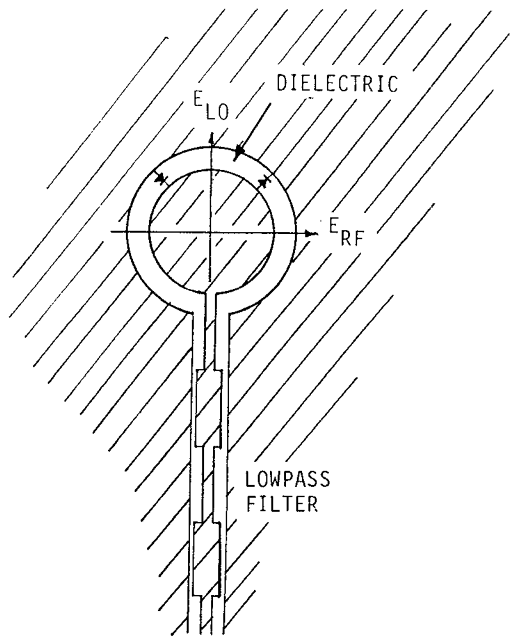

Fig. 1. Quasi-optical slot-ring mixer.

NOISE FIGURE MEASUREMENT

Since this quasi-optical mixer has no well-defined input port suitable for network-type noise measurements, a pair of temperature-controlled quasi-optical loads were fabricated. These loads were styrofoam boxes lined with foil to reflect incoming energy down to absorber material covering the bottom. An X-band horn was aimed into each box and showed a return loss exceeding 20 dB, even when the absorber in the cold load was submerged in liquid nitrogen at 77^{o}K.

The slot-ring antenna used in this mixer has a broad, two-sided pattern much like that of a one-wavelength loop antenna. The two main lobes, one on each side of the antenna, are perpendicular to the plane of the substrate. This causes the mixer to be equally sensitive to energy arriving on either side of the substrate. In these experiments, the mixer was mounted horizontally and the lower side was exposed to one of the two identical

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loads (see Fig. 2). The loads were mounted on a cart on tracks so that the mixer saw the same physical environment except for a temperature change when one load was substituted for the other.

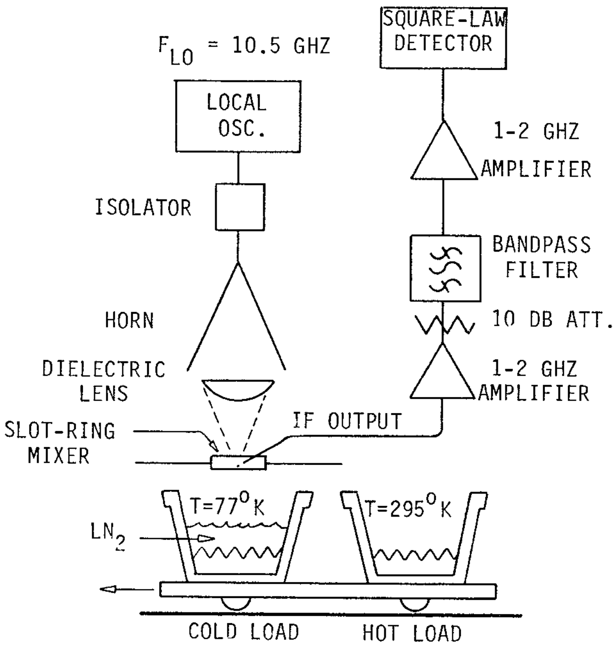

Fig. 2. Quasi-optical mixer hot/cold load measurement setup.

The local oscillator power was fed from above the mixer through a high-gain horn whose radiation was focused on the mixer with a dielectric lens. A 40-mW Gunn oscillator at 10.5 GHz provided more than adequate power through this quasi-optical feed arrangement. One drawback of this approach at present is that the upper side of the mixer is exposed to room-temperature radiation of both polarizations. This means that even though the lower side was exposed to a 77°K environment when the cold load was in place, the upper side saw 295°K. For this reason, the calculations of mixer noise figure assumed that the effective mixer input temperature with the cold load was the average of the two temperatures, or 186°K. In finding the system noise figure, this added noise was lumped in with IF noise and leads to a system noise figure that is considerably higher than that of the mixer alone.

DISCUSSION OF RESULTS

The single-side band (SSB) mixer noise figure F_m and temperature T_m in Fig. 3 were corrected for an upper sideband image response that varied from 7 to 15 dB lower than the desired lower sideband RF input at 8.5-9.5 GHz. The data are an average of three trials, and have a probable uncertainty averaging +0.9,-1.1 dB. The mixer's noise figure of 5.5 dB at the low end of the IF range is quite acceptable, especially considering the simplicity of the circuit. The conversion loss varied from 5.5 to 9.0 dB over the IF range; this data basically agrees with conversion loss figures reported earlier (1).

Fig. 3 also shows system noise figure, which is degraded by the effects of the room-temperature energy entering the mixer from the upper (LO) side, as well as the IF noise figure of about 2.5 dB. It may be possible to improve the system noise figure significantly by interposing a polarization grid between the LO lens and the mixer. Since the LO and RF polarizations are orthogonal, the LO power passes but the RF power is blocked.

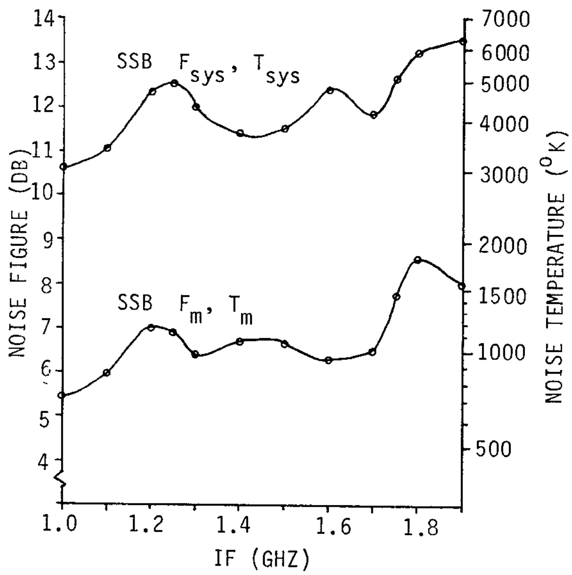

Fig. 3. Mixer noise figure and temperature Fm, Tm, and system noise figure and temperature Fsys, Tsys.

CONCLUSIONS

A quasi-optical slot-ring mixer has performed quite well in hot/cold load noise figure tests. SSB mixer noise figures in the 5.5-9 dB range were measured with a probable error of +0.9, -1.1 dB. Plans for future work include extending the present work to the millimeter-wave regime where the simplicity and efficiency of this quasi-optical design can be used to maximum advantage.

REFERENCES

(1) K. Stephan, N. Camilleri, and T. Itoh, "A Quasi-Optical Polarization-Duplexed Balanced Mixer for Millimeter-wave Applications," IEEE Transactions on Microwave Theory and Techniques, vol. MTT-31, pp. 164-170, Feb. 1983.