LOW NOISE OCTAVE BANDWIDTH WAVEGUIDE MIXER

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Abstract

A new broadband mixer capable of operating over two full adjacent waveguide bands (18 to 26.5 GHz and 26.5 to 40 GHz) is described. The maximum conversion loss is 6.5 dB from 20 to 40 GHz with a corresponding average DSB noise figure of 5.7 dB.

Introduction

In a conventional waveguide mixer, the ultimate usable bandwidth is limited by the operating frequency range of the waveguide used. Generally, mixer performance degrades considerably when operating with a bandwidth exceeding 10 to 15%, and becoming totally unusable when operating near the waveguide cutoff frequency because of unacceptably high losses. This paper describes a new mixer design which utilizes a crossbar mixer configuration together with a double-ridge waveguide mount. The mixer is capable of operation from 18 to 40 GHz with excellent performance. Over most of the operating frequency range, typical conversion loss of 5 to 5.6 dB was measured, with a minimum of 4.2 dB. A minimum double sideband (DSB) noise figure of 4.8 was measured at 31 GHz, using an IF amplifier with a 1.5 dB noise figure. Typical noise figure is 5 to 5.7 dB from 22 to 40 GHz. In all cases, the mixer is fixed tuned at 35 GHz.

Design Considerations

The basic requirements for designing a mixer with an operating frequency range exceeding an octave bandwidth are as follows:

1. The waveguide used for the fabrication of the mixer must have an effective usable bandwidth well exceeding an octave bandwidth.

2. The circuit elements, such as the mixer diode and its embedding network, must be properly matched to the waveguide impedance.

The operating frequency range selected for the present design, i.e., 18 to 40 GHz, covers two adjacent waveguide bands, i.e., K-band (18 to 26.5 GHz) and Ka-band (26.5 to 40 GHz). It is not possible to use the standard Ka-band waveguide (WR28) for the mixer design since the theoretical cutoff of the WR28 waveguide is at 21.08 GHz. In order to achieve octave bandwidth operation, a new mixer configuration* utilizing a single crossbar mixer [1,2] together with a double-ridge waveguide mount is employed. The use of a double-ridge waveguide mount extends the cutoff frequency for the TE_{10} mode to below 18 GHz. Specifically, for the standard double-ridge waveguide used (WRD108C24), the cutoff frequency is lowered to 15.25 GHz. The single crossbar mixer reported previously[1,3] has shown excellent RF performance over a wide range of frequencies. A conversion loss as low as 4 dB and an instantaneous RF bandwidth of greater than 13 GHz have been achieved over the Ka-band frequencies at TRW. The novel design described here combines the advantages of the crossbar mixer and that of a double-ridge waveguide mount, providing both low loss and extremely broadband characteristics.

*patent pending

Mixer Description

The octave bandwidth mixer consists of a double-ridge waveguide mount, a ridged waveguide-to-coaxial line transition, two Schottky barrier diodes and a low pass filter as shown schematically in Figure 1. The double-ridge waveguide mount also serves as the back-short housing of the mixer mount. The mechanical configuration of the octave bandwidth mixer is shown in Figure 2. The heart of the mixer is a pair of low noise Schottky barrier diodes connected in series across the broadwalls of the ridged waveguide. As shown in Figures 1 and 2, one of the electrodes of each diode connects to a metal crossbar which serves as a mechanical support for the diodes and also as a transmission line for the incoming LO power and the IF output signals. In actual operation, the RF signal is fed directly to the ridged waveguide port. On one end of the crossbar, LO power is fed via a ridged waveguide-to-coaxial transition and capacitively coupled to the diodes. The IF output is extracted from the opposite end of the crossbar via a microwave integrated circuit lowpass filter (LPF). The LPF is used to prevent LO power leaking to the IF output. Electrically, the two mixer diodes are connected in series with respect to the RF signal and in parallel with the IF output. This provides a higher impedance level to the RF signal and a lower impedance level to the IF signal than a single diode mixer. Therefore, an inherent impedance match condition for both the RF and IF signals is achieved for broadband performance. In addition, the relatively low impedance of the ridged waveguide further improves impedance matching of the mixer diodes. This results in an extremely broadband mixer design with uniformly low losses over an operating frequency range exceeding an octave bandwidth.

A prototype octave bandwidth mixer utilizing a double-ridge waveguide mount, as shown in Figure 2, was designed, fabricated and tested. In the mixer design, performance optimization was achieved by proper selection and implementation of the following critical bandwidth limiting elements, namely,

- Schottky barrier diodes
- Contact whiskers
- Adjustable backshort section
- Crossbar geometry

The Schottky barrier diodes must have small junction capacitance and low series resistance. It was found that mixer diodes with zero bias junction capacitance of 0.02 pF and series resistance of less than 10 ohms are adequate for the present application. A whisker length of approximately 0.020 inch using a 0.001 inch diameter wire was used for tuning out the parasitic capacitances of the mixer. A second tuning element, a contacting adjustable short of the plunger type, provides external tuning for the mixer. Ideally, the metal crossbar embedded in the waveguide should be transparent to the microwave signal and be lossless. In fact, for a properly designed crossbar, it can be considered as a microwave circuit with reactive elements only. It is, therefore, essential that the geometry and dimensions of the crossbar be properly designed such that its resonances do not occur within the operating frequency band of interest. In the present design, a 0.025 inch diameter cylindrical crossbar of full waveguide width is used.

Results

Evaluation of the mixer performance was carried out using K- and Ka-band test equipment with appropriate ridged waveguide-to-standard waveguide transitions. Figure 3 shows the mixer conversion loss characteristic over the 18 to 40 GHz range, measured with the mixer fixed tuned at 35 GHz. The DSB noise figure shown in Figure 4 is measured with a 750 MHz IF amplifier (1.5 dB noise figure). Over an octave bandwidth from 20 to 40 GHz, the measured minimum and maximum noise figures were 4.8 and 7 dB respectively. However, it should be noted that from 22 to 40 GHz the minimum and maximum noise figures are 4.8 and 5.7 dB respectively. A differential of only 0.9 dB over a bandwidth of 18 GHz clearly indicates the broadband performance of the mixer design.

The RF performance of the octave bandwidth mixer is extremely encouraging, particularly its broadband performance which exceeds an octave bandwidth. The design principle of the octave bandwidth can be extended to other frequency ranges, such as from 40 to 80 GHz and 80 to 160 GHz. This offers the technical feasibility of covering the 20 to 160 GHz frequency band with just three mixers.

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References

1. L. E. Dickens, et al, "A Mixer and Solid State LO for a 60 GHz Receiver", IEEE-GMTT International Microwave Symposium, May 19, 1971, pp. 188-190.

2. L. T. Yuan, "A Low Noise Broadband Ka-Band Waveguide Mixer", IEEE-GMTT International Microwave Smyposium, May 12, 1975.

3. Final Report, "Millimeter Wave Technology and Ka-Band Terminal Development", 1974, Microwave Technology Department, TRW Systems Group, Redondo Beach, California.

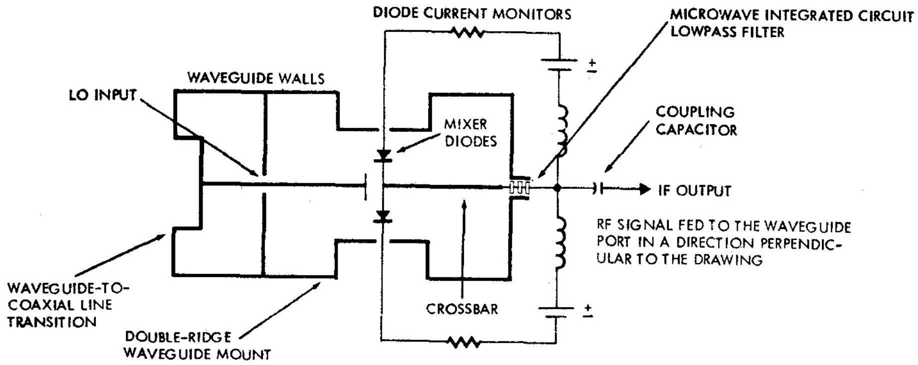

Figure 1. Octave Bandwidth Crossbar Mixer Schematic Diagram

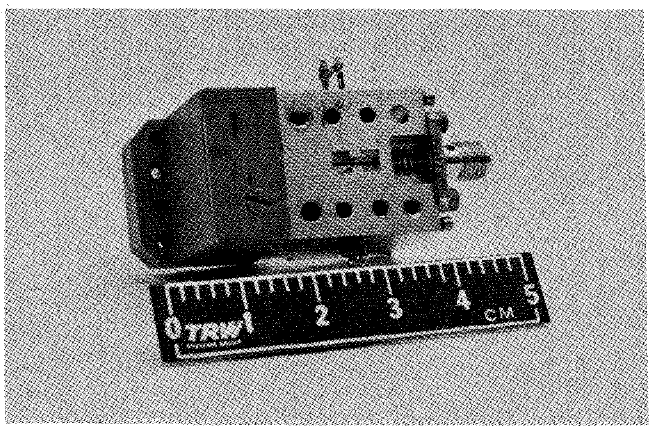

Figure 2. Octave Bandwidth Crossbar Mixer

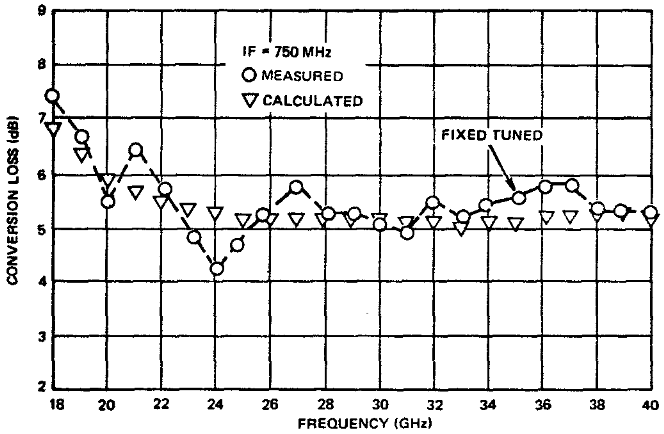

Figure 3. Octave Bandwidth Mixer Conversion Loss vs Frequency

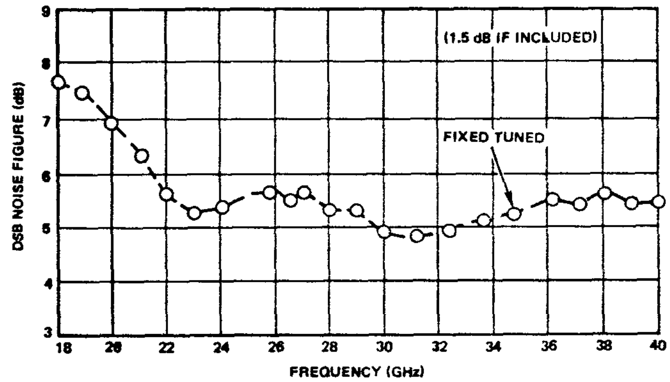

Figure 4. Octave Bandwidth Mixer Noise Figure vs Frequency