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140 GHZ QUASI-OPTICAL PLANAR MIXERS

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A planar quasi-optical mixer operating around 140 GHz has been developed using beam lead diodes. Utilizing a spherical lens for the RF input, a conversion loss as low as 7 dB has been measured at 127 GHz with an LO frequency of 141 GHz.

Introduction

For millimeter-wave applications in the 100 to 300 GHz range, a new quasi-optical crossbar mixer has been developed. The concept is an extension of the work previously reported on planar slot antennas at millimeter frequencies.[1] Using a planar approach, the mixer is considerably more compact than quasi-optical mixers using transitions from metal waveguide and other optical components such as mirrors, prisms, and grids.[2] The major advantage of the planar design lies in its reproducibility and low cost due to the use of conventional photolithographic processing and high cutoff frequency beam lead diodes.

Mixer Design

Figure 1 shows the design of the quasi-optical crossbar mixer. The circuit patterns are fabricated on a dielectric substrate using photolithographic processing techniques. The crossbar mixer consists of a pair of high-cutoff frequency GaAs beam lead Schottky barrier diodes, a coplanar waveguide section, a pair of slot antennas and an IF low pass filter. The RF signal to the slot is optically coupled to the slot antennas by a spherical dielectric lens placed in front of the mixer circuit substrate. The spherical lens provides not only a gain for the RF signal, but also a focusing mechanism to direct the incident RF power onto the slot antenna area. The RF signal received by the slot antenna is then coupled to the diodes via a slot line to coplanar waveguide transition. In order to maintain the proper phase relationship between the two RF signals coming from the two slot antennas, the diode pair is positioned off-center so that the electrical path lengths between the two RF signals differ by approximately one half wavelength. The LO power to the diodes is fed via a waveguide section placed directly behind the diodes on the opposite side of the substrate, as shown in Figure 1. One end of the coplanar waveguide section is isolated and the other end is connected to a microstrip low pass filter for the IF output port. In actual operation, the mixer circuit substrate is mounted in a metal block. The IF is taken off coaxially via an SMA connector. The mixer assembly is shown in Figure 2. A spherical dielectric lens is mounted on a movable platform for focusing the beam onto the slot antennas to optimize performance. Figure 3 shows the detail of the D-band substrate. The major advantage of the quasi-optical mixer design is that the physical size limitation for the fabrication of the conventional waveguide components at millimeter-wave is totally removed. All of the circuits and devices are fabricated on a planar surface, which facilitates low cost batch processing. In addition, the design is applicable to monolithic fabrication using GaAs substrates.

Two quasi-optical crossbar mixers, one V band and one D band, were fabricated and tested. The V-band mixer was fabricated on a 0.030 inch thick Duroid substrate for modeling purposes, while the D-band mixer was fabricated on a 0.007 inch thick quartz substrate. Duroid material was found to be sufficiently low loss for the fabrication of the V-band mixer. No appreciable degradation was observed when compared to a V-band mixer fabricated on quartz substrate. The measured conversion loss of the V- and D-band quasi-optical mixers over their respective frequency bands is shown in Figure 4. The

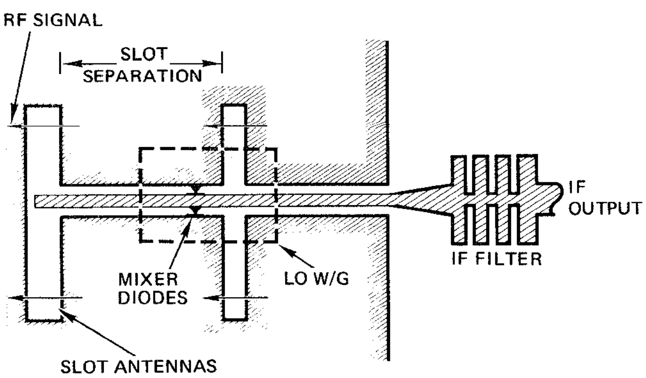

Figure 1. Quasi-optical crossbar mixer circuit layout.

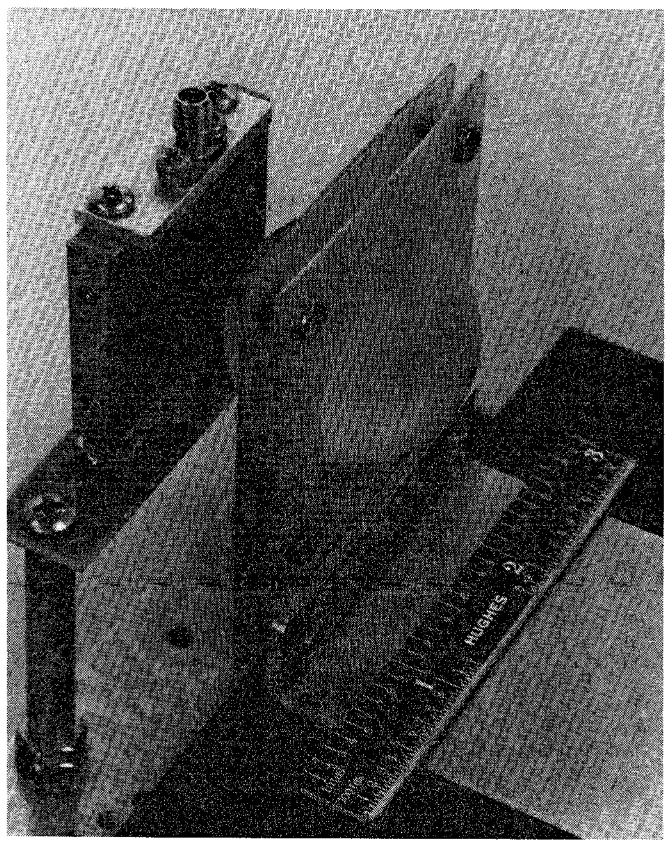

Figure 2. Quasi-optical crossbar mixer assembly.

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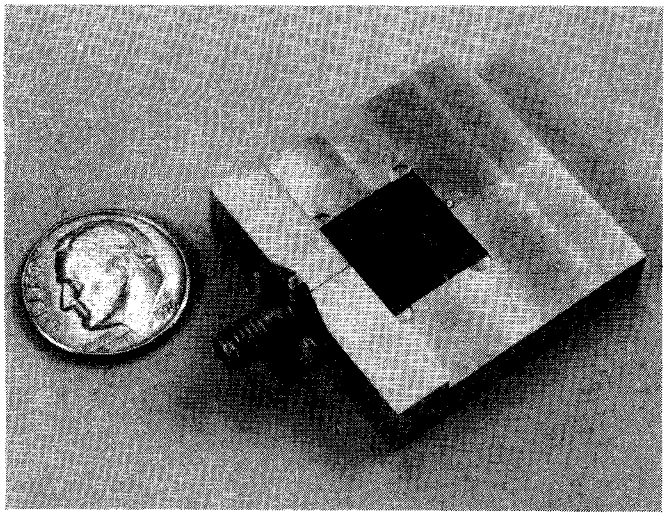

Figure 3. D-band planar mixer mount.

typical conversion loss for the V-band mixer was 9 dB measured over an RF range from 60 to 68.9 GHz. For the D-band mixer, a minimum conversion loss of 7 dB was measured at 126 GHz. It was found that the performance of the mixer is extremely sensitive to the geometry of the circuit patterns, particularly, the dimensions of the slot antennas and slot separations (i.e., 0.047 and 0.065 inch). The smaller slot separation showed somewhat narrower band performance but lower conversion loss. The optimum length of the slot antenna was found to be approximately one-half wavelength at the center frequency.

Both of these mixers were fabricated with high-cutoff frequency GaAs beam lead diodes fabricated at Hughes Electron Dynamics Division. The diodes have a typical zero-bias junction capacitance of 30 fF and a typical series resistance of 4.5 ohms, which corresponds to a cutoff frequency of 1178 GHz.

Conclusion

The feasibility of a high frequency quasi-optical planar mixer has been demonstrated. Its design is suitable for both hybrid and monolithic fabrication at frequencies beyond 100 GHz. The design provides inherent wide bandwidth for both the RF and IF and interfaces easily with lens antennas for a very compact overall structure.

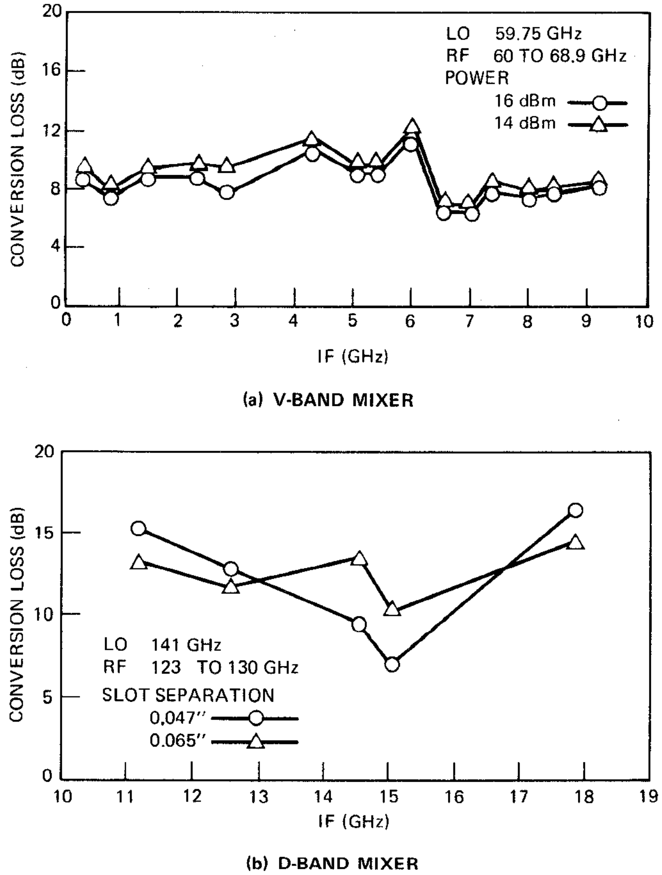

Figure 4. Conversion loss of quasi-optical crossbar mixer.

References

1. P. Yen, J. A. Paul and T. Itoh, "Millimeter-Wave Planar Slot Antennas with Dielectric Feeds," 1981 IEEE MTT-S International Microwave Symposium Digest, pp. 114-116, 1981.

2. J. A. Paul and N. E. Swanberg, "Quasi-Optical Mixer Offers Alternatives," Microwave System News, Vol. 9, No. 5, May 1979.