A 100-Element Schottky Diode Grid Mixer

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INTRODUCTION

Power-combining schemes involving solid-state devices quasi-optically coupled in free-space have recently been employed to develop high-power microwave oscillators with directive beams [1-3]. These grid oscillators pave the way for high-power solid-state millimeter-wave sources. However, oscillators are only one of several electronic components that are amenable to packaging in the grid configuration. A grid loaded with diodes produces a nonlinear device suitable for mixing or detecting quasi-optical signals with improved dynamic range compared with conventional single diode mixers. This is particularly important for superconducting tunnel-junction (SIS) receivers where dynamic range is quite limited. Millimeter-wave high dynamic range front-ends are also the subject of a U.S. Navy initiative addressing current needs in its microwave electronics operational capability [4]. In this paper, we present a 100-element planar grid mixer consisting of Schottky beam-lead diodes placed in bow-tie shaped unit cells. Preliminary results show that the reflection coefficient of this grid agrees well with theory. A grid conversion loss of 9.3 dB at 10 GHz has been measured.

MIXER GRID THEORY

A diagram of the Schottky diode mixer grid is shown in Figure 1. To predict the behavior of a device when placed in the grid, we need to determine the impedance presented to the diode terminals at the apex of each bow-tie shaped unit cell. Assuming the grid to be infinite with a uniform plane wave normally incident upon the grid surface, we can impose boundary conditions along the grid symmetry lines. In effect, this reduces the problem of analyzing the grid to that of analyzing an equivalent waveguide as shown in Figure 1. A transmission-line model for the grid is derived by performing an EMF analysis in this equivalent waveguide.

The circuit that represents a Schottky diode placed in the grid is shown in Figure 2. The transmission lines represent the propagating TEM mode in the substrate and the cell bow-tie pattern. The tunable mirror is represented by a shunt reactance jB.

Simulation of the grid is carried out by calculating the reflection coefficient the grid presents to a normally incident plane wave. The diode is added to the model by using its measured RF s-parameters.

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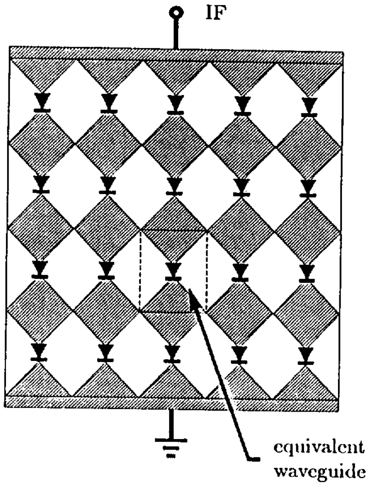

Figure 1. Schematic of the Schottky Diode Grid Mixer. Boundary conditions on the symmetry lines reduce the grid to an equivalent waveguide as shown. The unbalanced IF signal is taken off the top of the grid. The IF impedance of the square grid is equal to the IF impedance of a single diode.

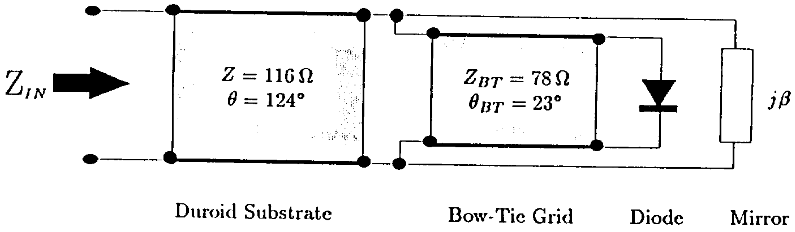

Figure 2. Transmission-line model for the grid mixer. The diode is modelled using its measured RF small signal s-parameters.

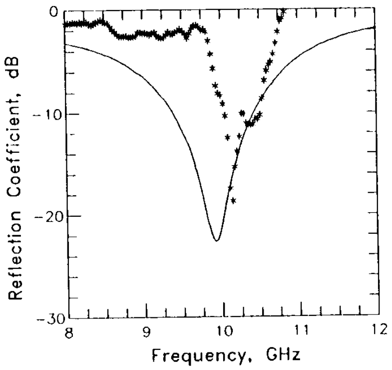

Figure 3. (—) Theoretical and (∗) measured grid mixer reflection coefficient. The theoretical curve was obtained using the transmission-line model and Schottky diode RF s-parameters.

An important property of the grid mixer is its ability to increase dynamic range without compromising sensitivity. Since the RF power is spread among all the devices, the saturation power of the grid is increased by a factor of the number of devices. However, the noise of the grid is the same as the noise of a single device because the individual noise powers from each device are uncorrelated. Consequently, the dynamic range is also increased by a factor of the number of devices.

EXPERIMENTAL RESULTS

The devices used in the grid are Hewlett-Packard low-barrier Schottky beam-lead diodes (HSCH-5332) mounted on a 3.2 mm thick Duroid substrate with $\epsilon_r = 10.2$. The grid is 30 mm (1.00λ) across and the grid period is 3 mm (0.100λ). The mixer grid reflection coefficient was optimized for RF and LO signals near 10 GHz by adjusting the dimensions of the unit cell bow-tie pattern and the substrate thickness. A mirror behind the grid acted as a reactive tuning element. Measurement of the grid reflection coefficient using an error-corrected quasi-optical reflectometer was compared with theory and found to be in reasonable agreement (Figure 3). A small DC bias of 4.5 mA was required to match the IF impedance to 50 Ω (Figure 4).

The mixer grid conversion loss was measured for a combined 10.225 GHz LO signal and a 10.439 GHz RF signal incident upon the grid. For an absorbed LO power at the grid of 2.2 dBm, a double side-band conversion loss of 9.3 dB was measured for the 214 MHz IF frequency.

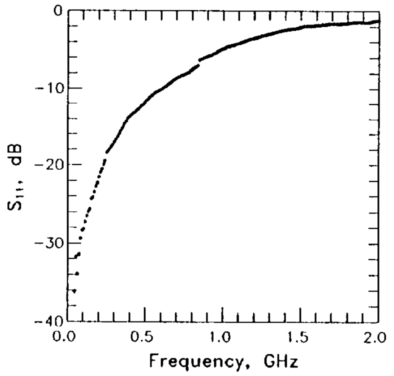

Figure 4. Measured grid mixer IF return loss for a DC bias of 4.5 mA .

CONCLUSIONS

In this paper we have presented a planar grid of 100 Schottky diodes suitable for use as a quasi-optically coupled mixer. The mixer grid is attractive for millimeter-wave applications because of its low-loss quasi-optical coupling, and because its dynamic range can be increased by a factor of the number of devices in the grid. This is important for SIS receivers where dynamic range is fundamentally limited.

ACKNOWLEDGMENTS

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