A MONOLITHIC BROADBAND DOUBLY BALANCED EHF HBT STAR MIXER WITH NOVEL MICROSTRIP BALUNS

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Abstract

This paper describes a planar MMIC HBT Schottky diode mixer utilizing novel baluns fabricated on a 4 mil thick GaAs substrate. The balun is based on the Marchand balun structure and is implemented in a microstrip environment. The balun structure consists of 7 closely coupled microstrip lines and backside vias. Four 10x10 μm^2 HBT Schottky diodes in a star configuration provide the mixing function. The HBT diodes have cut-off frequencies in excess of 750 GHz. The mixer achieves 8 - 10 dB conversion loss and very low spurious responses over a 26 - 40 GHz RF and LO bandwidth and DC - 11 GHz IF. This IF bandwidth is broader than a previously demonstrated CPW star mixer using InGaAs HEMT technology, and easier to integrate into an assembly due to its microstrip implementation.

Introduction

Monolithic planar star mixers with Marchand-like baluns have exhibited superior spur performance and port to port isolation over a wideband compared to conventional structures. One of the example was reported in 1993 [1] utilizing Marchand-like coplanar balun structures. The mixer exhibited very good performance and was fabricated on a 25 mil thick GaAs wafer using gate-to-channel junction of InGaAs HEMT devices for mixer diodes. But most of the supporting circuits used around the mixer are MMICs with microstrip design on 4 mil thick substrate. Consequently, microstrip to coplanar transitions are used to interface with the coplanar mixer. It is therefore highly desirable to design a mixer on a thinned wafer that is more compatible with conventional MMICs.

We have developed a microstrip star mixer with novel microstrip baluns on 4 mil thick GaAs substrate. This mixer is more compatible with existing thinned GaAs wafer process and lends itself toward higher complexity MMIC. The combination of good balun design and high performance HBT schottky diodes produced a star mixer with outstanding performance.

Design and Measurements

Star-Mixer Structure

Two key advantages of the star mixer are broad IF bandwidth and a symmetrical balun structure that enhances the mixer's spur and isolation performance [1]. A typical star mixer configuration is shown in Fig. 1. The balun which dictates the key mixer performance can be realized with different coupled transmission lines. In this work, it is realized using 7 narrow strips of coupled microstrip lines.

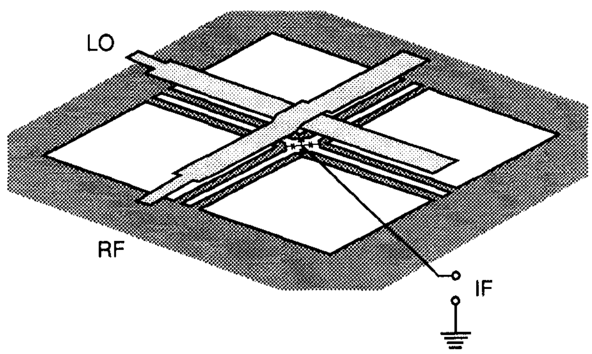

Figure 1. Conventional star mixer.

Mixer baluns

To achieve a good mixer performance, the coupled lines in the balun should have high even-mode impedance and closely matched even- and odd-mode phase velocities as discussed in [1]. To achieve this on high dielectric GaAs substrate, thick substrate is normally used. This work demonstrates that very good performance can be achieved on a thinned GaAs wafers also.

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Fig 2. shows the structure of the balun. It can be viewed as two Lange couplers without the center cross-over joined along one side. The baluns were modeled as two Lange coupler connected side by side using LIBRA. Very narrow strip widths were required to achieve the highest even-mode impedance. Our present MMIC design rule limits the minimum width of the line to 5um. Consequently, the strip width was fixed to 5um and spacing was varied to achieve the needed even- and odd-mode impedance.

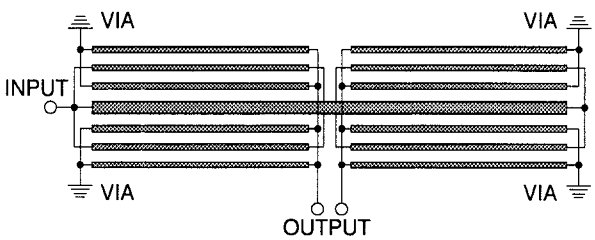

Figure 2. Planar coupled-line Marchand balun with 7 coupled microstrip lines.

Diodes

A 10umx10um Schottky junction is used as a diode. The diode has 0.0257 pF zero-voltage junction capacitance and 8.1 ohm series resistance resulting in a cutoff frequency of 750 GHz. Additional experiments are being done to achieve lower series resistance and lower parasitic capacitance.

Mixer Structure

Figure 3 shows the picture of the star mixer. The balun has 10um wide center line and 3 coupled lines on each side to form Lange coupler like structures without a center cross-over. A spacing of 15um between coupled lines was chosen to achieve correct odd-mode impedance. During simulation, length of the baluns were adjusted to achieve the desired center frequency.

All 4 diodes are connected together by a ring to form a star mixer. The inductance of these connecting lines will limit the IF bandwidth. But due to the small size of the HBT diodes, the connecting inductance was minimized.

The IF port is connected to the center ring by a 50 ohm microstrip lines and a tapered section. Even though the IF connection upsets the geometric balance of the baluns, the mixer still exhibited very good isolation between LO and RF ports.

Performance

Figure 4 shows the conversion loss of the mixer. The mixer is configured as an upconverter with output frequency of 28 GHz. The IF bandwidth is at least 11 GHz. To identify what limits the IF bandwidth, the mixer was also measured as an upconverter with an output frequency of 26.5GHz. The mixer exhibited the same IF bandwidth of 11 GHz. This proves that the parasitics of the IF port limits the bandwidth, not the baluns. The bandwidth should be easily extended either by simple matching and by optimizing the diode connections to each other and to the IF port.

Figure 5 shows the LO to RF port isolation. It shows more than 35 dB of isolation across the whole bandwidth between LO port and RF port.

Figure 6 shows the (-2,1) spurious response of the mixer used as an upconverter with the same output frequency of 28 GHz. It achieves more than 50 dB rejection.

Conclusion

We have described an EHF band monolithic star mixer with a broad bandwidth. It achieves excellent performance by utilizing a novel balun design on a 4 mil thick substrate and high performance Schottky diodes. The performance compares favorably with the one reported in Ref. [1], and has the advantage of higher level of integration with other MMICs in the system.

Acknowledgments

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References

[1] S. A. Maas and K. W. Chang, "A Broadband, Planar, Doubly Balanced Monolithic Ka-Band Diode Mixer," IEEE Microwave and Millimeter-Wave Monolithic Circuits Symposium Digest for papers, 1993.

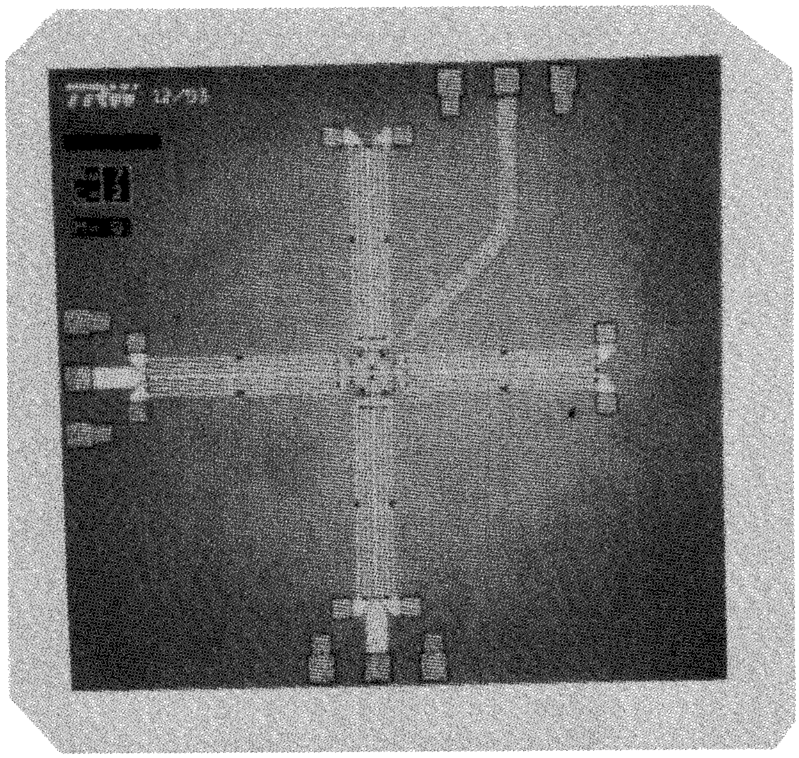

Figure 3. Photo of the star mixer

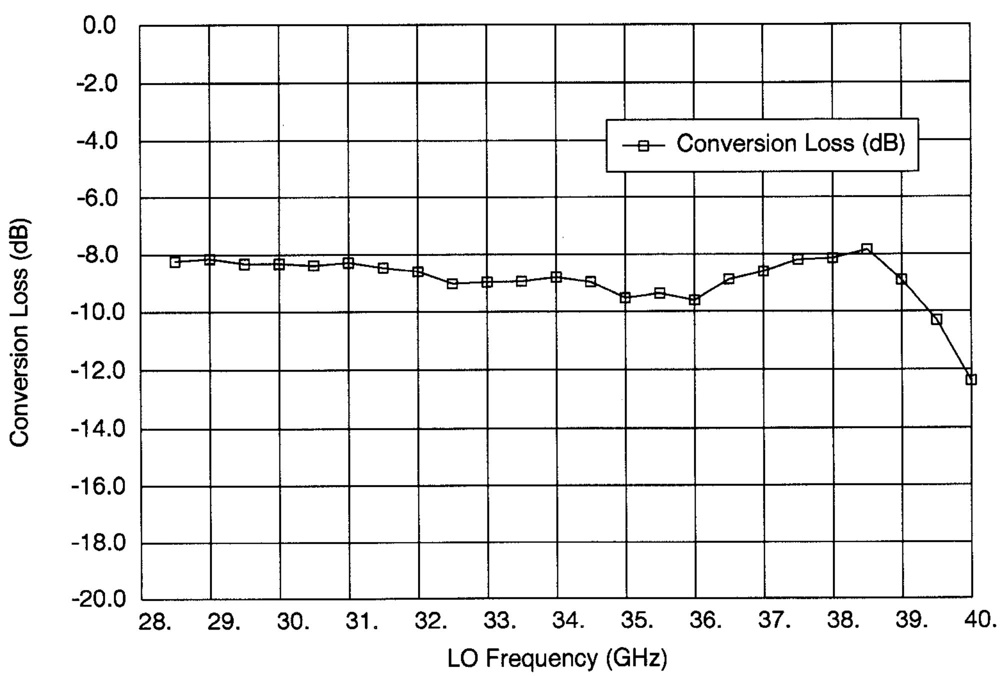

Figure 4. Conversion Loss as an upconverter with Output Frequency of 28 GHz. IF Power = -10 dBm

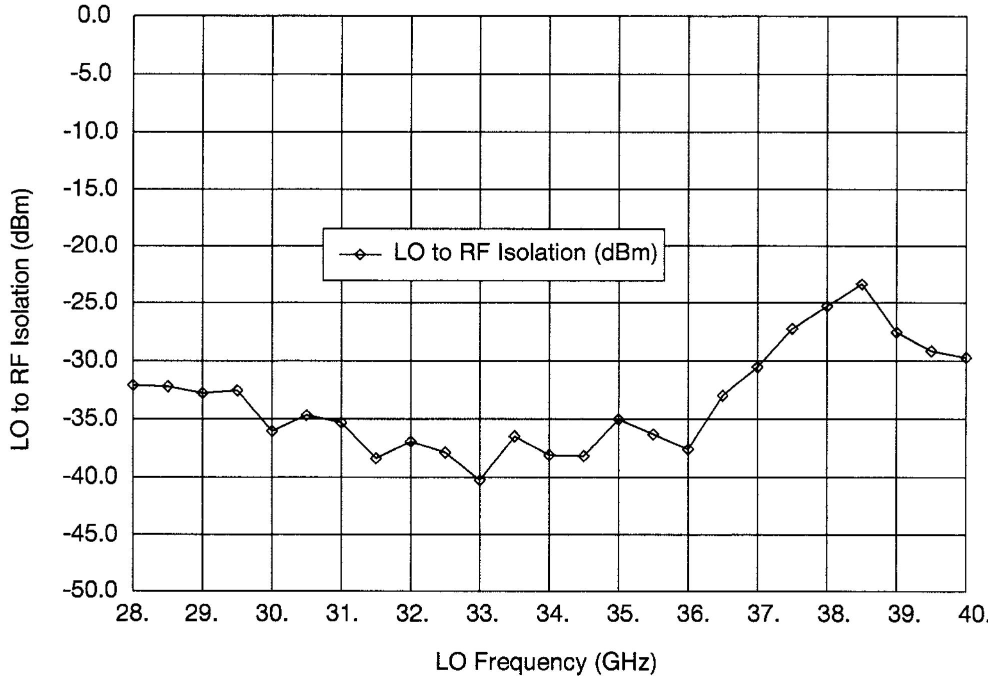

Figure 5. LO to RF port Isolation with LO drive level of +16dBm

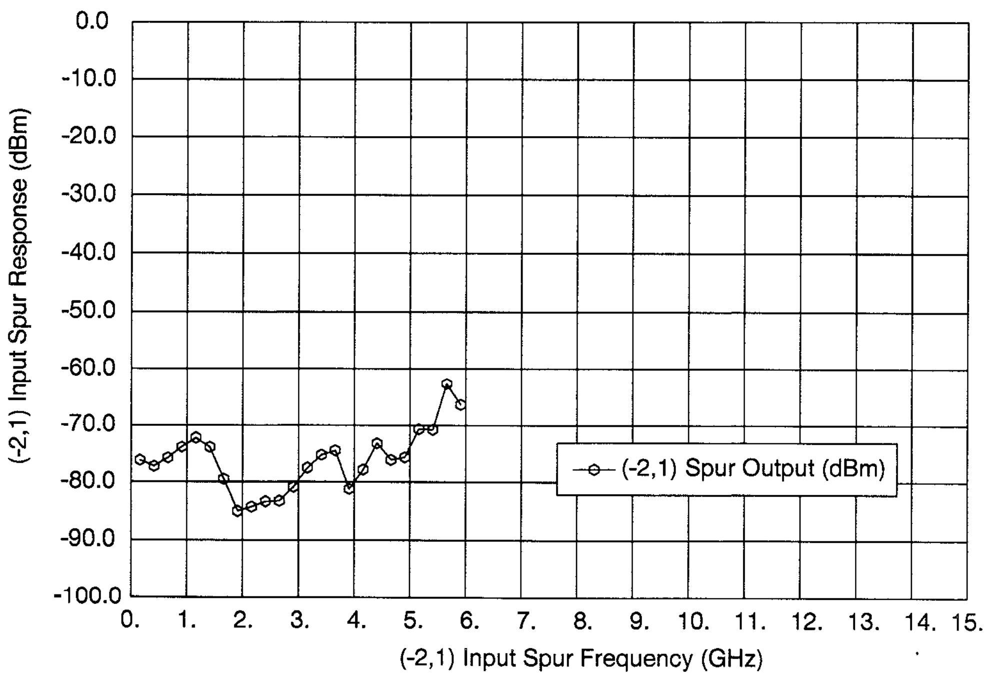

Figure 6. (-2,1) Spurious Response as an upconverter with Output Frequency of 28 GHz. IF Power = -10 dBm