BROADBAND MONOLITHIC SINGLE AND DOUBLE RING ACTIVE/PASSIVE MIXERS

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ABSTRACT

Several double balanced multi-octave bandwidth mixers, comprised of active center tapped baluns and diode rings have been fabricated using planar monolithic circuit technology. The unique approach eliminates IF extraction problems and combines the best performance characteristics of FETs and diodes.

INTRODUCTION

Traditionally, the mixer has been the most difficult element to design and analyze in modern microwave receiver systems. The vast majority of these systems employ passive diode mixers as the state-of-the-art frequency converting element. These mixers typically employ large transmission line baluns used in three dimensional structures although completely planar 2-18 GHz double balanced mixers have been demonstrated. Conventional mixer designs such as these are not feasible for monolithic implementation since their passive elements require excessive GaAs slice area. Hence, a completely new design concept must be used in the development of GaAs monolithic microwave mixers.

The design problem for any type of mixer can be divided into two main areas; the nonlinear element and the balun. If a monolithic implementation is desired, the most practical choices for nonlinear elements are planar Schottky diodes and single- and dual-gate FETs.

In the monolithic realm, the balun problem is further constrained by chip area and backside processing requirements. If passive mixer baluns were used, they would be approximately 2 cm. in length which is an order of magnitude too large for a monolithic circuit realization. Thus, active baluns or lumped element transformers are the only viable options. The problem is further complicated in that it is desirable to employ baluns that approximate low frequency equivalent center tapped transformers. A center tapped balun is a convenient way to extract the IF frequency from a conventional double-balanced diode mixer. However, a center tapped transmission line balun can not be fabricated.

DESIGN

A new balun topology, that can be readily implemented using monolithic technology, has been devised that eliminates the above problems and provides center tapped performance. Since the balun uses common gate and common source circuit techniques, an ideal 180° phase shift occurs for the signals present between the upper and lower halves of the circuit (Figure 1). Typical broadband balun performance is shown in Figure 2 As can be seen, the balun exhibits excellent balance through the design band of 2-18 GHz. The performance of a center-

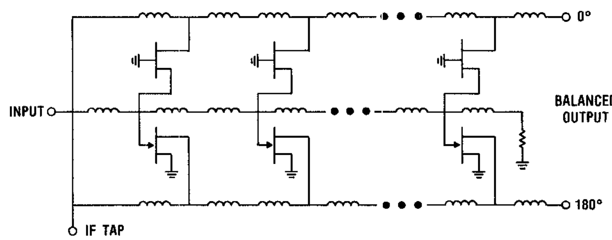

Figure 1. Lumped Element Equivalent Circuit of Center Tapped Balun.

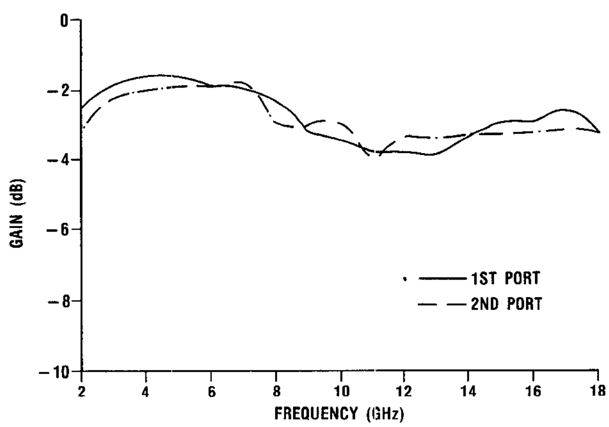

Figure 2a. Frequency Response and Amplitude Balance of Monolithic Balun.

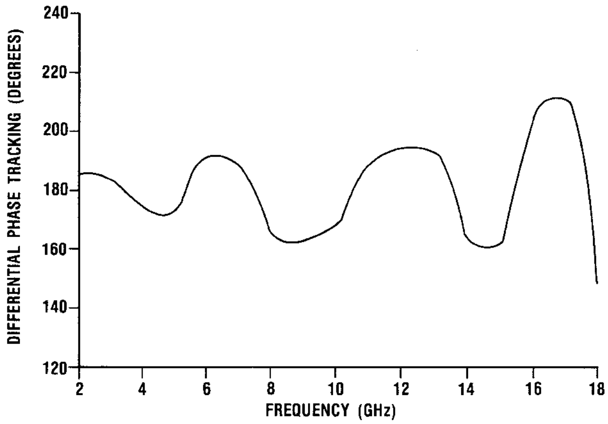

Figure 2b. Differential Phase Performance of Monolithic Balun.

tapped balun, designed to operate throughout the 2 to 18 GHz frequency band, is shown in Figure 3.

Hence, if two such baluns are used in conjunction with a diode ring to form a double balanced mixer, the IF signal appearing at the diode terminals propagates (in phase) down both arms of the balun and can be summed at a common node, thus forming a virtual center tap. This center tap can be used for IF extraction or grounded to complete the IF return path (Figure 4). Since active baluns are not reciprocal, a combining or dividing structure will be needed on the RF port depending on whether the mixer is used as a up- or down-converter (Figure 5).

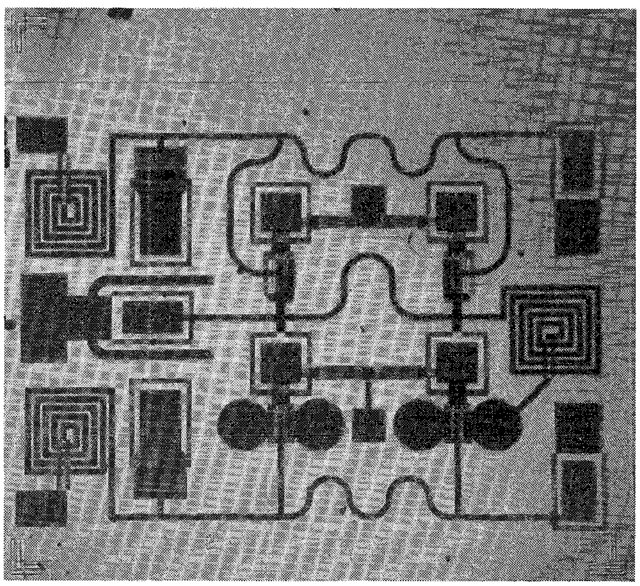

Figure 2c. Monolithic 2-18 GHz Distributed (Splitting) Balun.

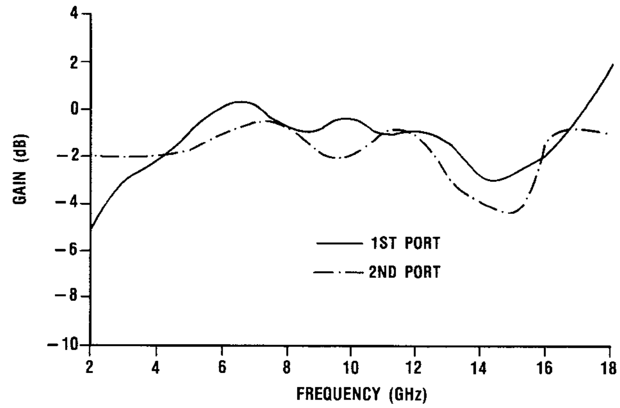

Figure 3. Center-Tapped Balun Performance.

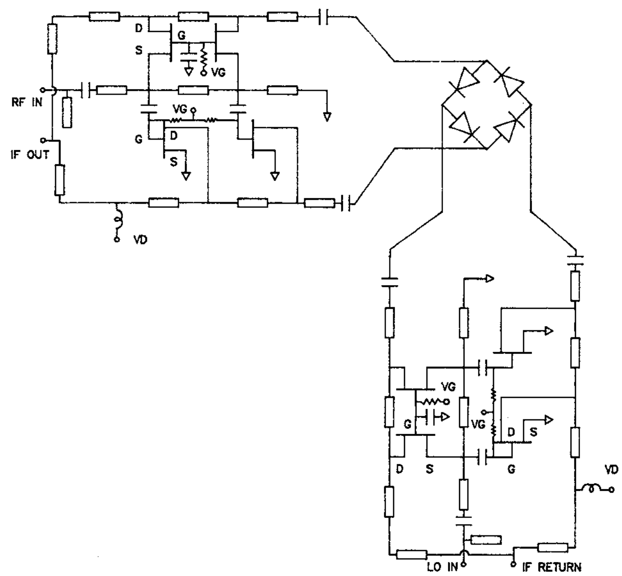

Figure 4a. Down-Converter Mixer Circuit Diagram.

GaAs PROCESSING

Fabrication of the above balun and mixer structures was accomplished by using Texas Instruments (TI) baseline ion implanted GaAs process for three inch diameter 0.15 mm thick semiconductor wafers. The FET channel doping profile was optimized for high transconductance and low noise performance yielding the best mixer performance. The TiPtAu 0.5 µm gates were defined with E-beam lithography, the ohmic metal employed was AuGeNIAu, and the MIM (metal-insulator-metal) capacitors were constructed with a 2000 Å thick layer of Si_3N_4. The same baseline low noise FET process was also used to fabricate the diode structures.

Figure 4b. Monolithic Double Balanced Mixer.

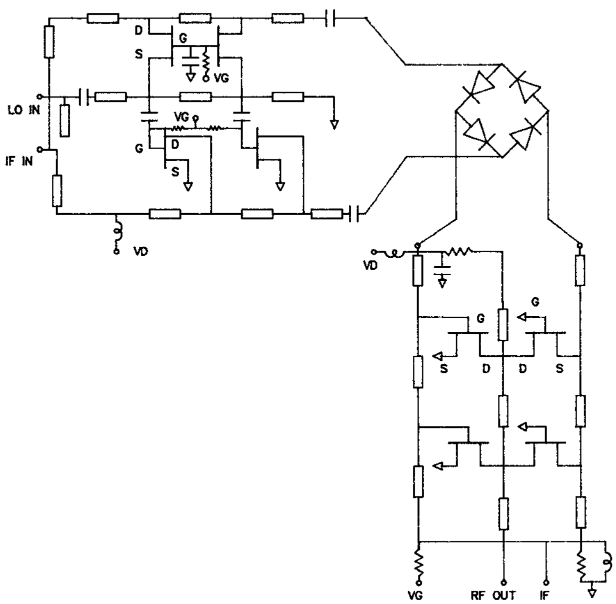

Figure 5. Up-Converter Mixer Circuit Diagram.

PERFORMANCE

The conversion loss characteristics, at an IF frequency of 4 GHz, of a typical single-ring down-converter is shown in Figure 6. As can be seen in the above illustration, the performance is comparable to conventional diode designs requiring similar amounts of pump power (12 dBm). With the LO drive shown, the mixer exhibited a 1 dB compression point (referred to the input) of 6 dBm, LO-to-RF isolation greater than 25 dB, and RF-to-IF isolation greater than 20 dB.

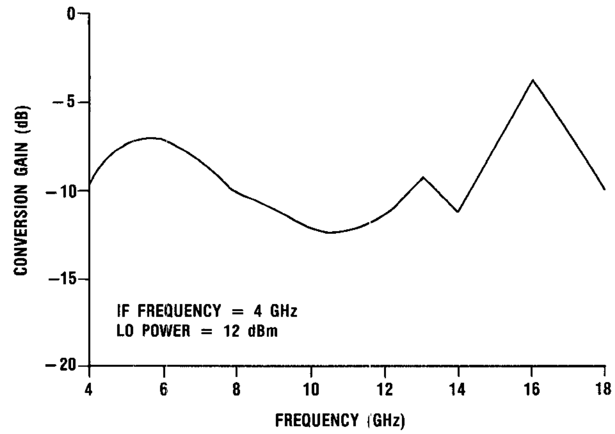

Figure 6. Conversion Loss Performance of Down-Converter Mixer.

The frequency limitations of the RF and LO ports are determined by the distributed amplifier-like sections which can be designed to operate over extremely large bandwidths. The IF frequency response can also be designed to exhibit broadband performance. This mixer concept can also be extended to include double ring mixer topologies Double ring approaches have the added advantage of allowing the IF frequency response to overlap the RF and LO frequency bands, thus making IF extraction even easier. By employing the same balun and diode technology, a double ring mixer was also fabricated (Figure 7). The conversion performance as a function of frequency and the LO drive requirements, which were measured at an IF frequency of 500 mHz, are shown in Figure 8. Although the mixer employs diodes as the nonlinear element, the conversion gain is somewhat greater than a conventional design because of the gain associated with the balun The isolation and compression point characteristics, which are comparable to hybrid designs, are shown in Figure 9

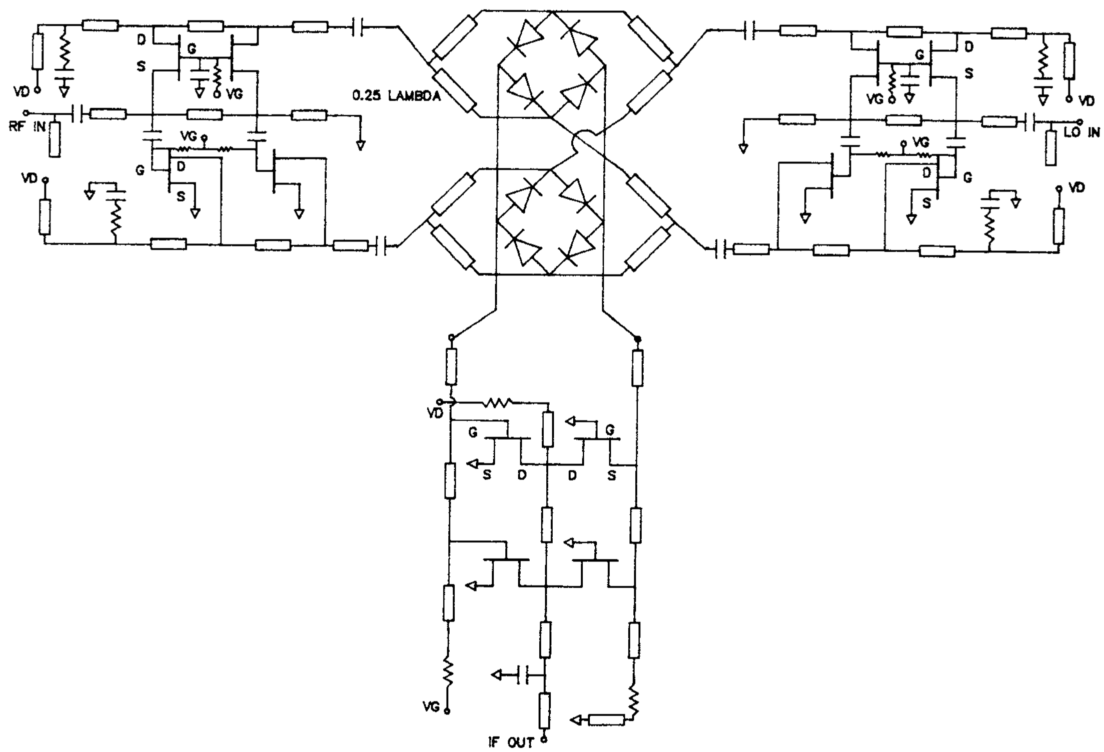

Figure 7. Circuit Diagram of Double Ring Mixer.

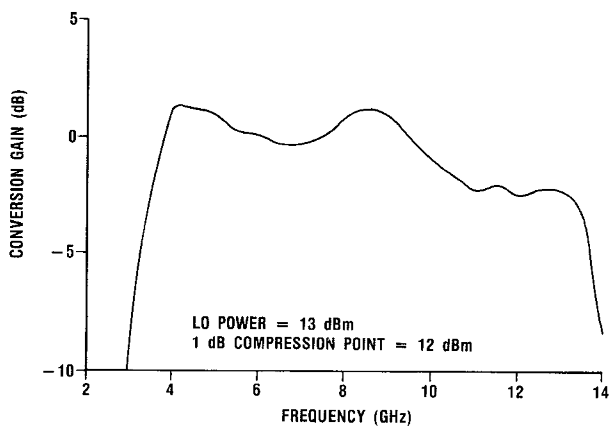

Figure 8. Conversion Loss Performance of Monolithic Double Ring Mixer.

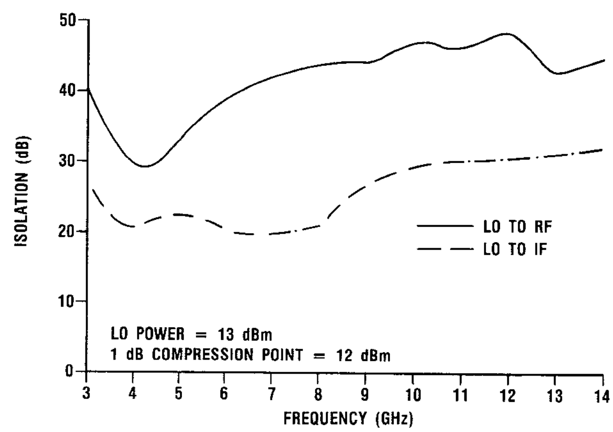

Figure 9. Isolation Performance of Monolithic Double Ring Mixer.

CONCLUSION

By using this dual-mode characteristic of distributed broadband baluns in diode mixer topologies, a very compact monolithic circuit can be designed to operate over a frequency range several octaves wide with performance comparable with conventional passive diode mixers. This approach also combines the best performance features of FETs and diodes.