A NOVEL BROADBAND DOUBLE BALANCED MIXER FOR THE 18-40 GHZ RANGE*

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ABSTRACT

Double balanced mixers have been constructed in the 18-40 GHz range, utilizing unique planar transmission line techniques** which permit easy integration of the mixers with other components to provide a compact, low-cost receiver assembly for band extension of EW systems. The design concepts are discussed and the performance results are presented for three mixer circuits mounted in waveguide structures for operation from 18-26.5 GHz, 26.5-40 GHz and 18-40 GHz.

Introduction

Much work has been published concerning broadband downconverters in the 18-40 GHz frequency range to extend EW capabilities to these high frequencies. The primary thrust behind the development of the mixers discussed in this presentation was to evolve a design which would be low-cost, small in size, readily integratable with other components in an MIC format and which would also provide the sensitivity, intermodulation product suppression and reliability required in a practical EW system.

Circuit Description

The design approach adopted utilizes a balanced slot line and a bifurcated, balanced microstrip line to couple the signal and L.O. to four beam lead Schottky diodes. The diodes are mounted in a star configuration as suggested by R. Mouw.[1] For ease in interfacing with test equipment, the development models were constructed on a substrate mounted in the E-plane of split block waveguide housings. Figure 1 illustrates the conceptual design. The RF signal is coupled to the diodes via a waveguide to bilateral fin-line which is then transformed to a balanced microstrip configuration which, in turn, is bifurcated to form a symmetrical four-wire slot line. The four beam lead mixer diodes are mounted centrally at the junction of the two four-wire lines. The IF is coupled orthogonally from the center of the junction area by means of a plated through hole which connects annular pads on either side of the substrate.

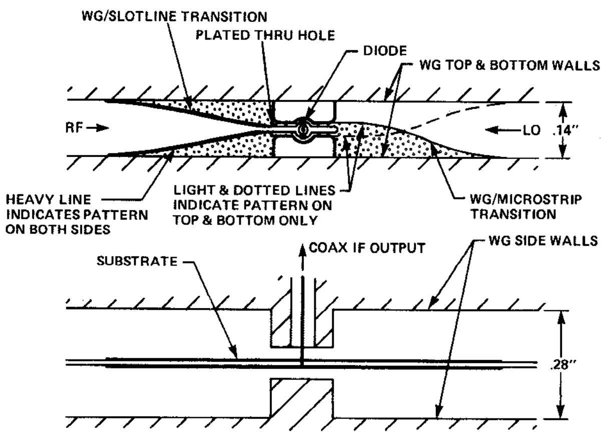

FIGURE 1. CONCEPTUAL DESIGN OF PLANAR BALANCED LINE DOUBLY BALANCED MIXER

Figure 2 illustrates the electric fields associated with the two four-wire lines. The top view depicts the electric field configuration of the four-wire slot line and the bottom view that of the bifurcated microstrip line. These modes are referred to as the parallel and transverse even modes based on the orientation of the fields relative to the original waveguide field. The odd modes are not intentionally excited but they can be by circuit or diode asymmetries. Figure 3 gives a clearer picture of the diode mounting detail. Two diodes are mounted on each side of the board as shown in Figure 4 which also clarifies the IF output connection to the circuit board.

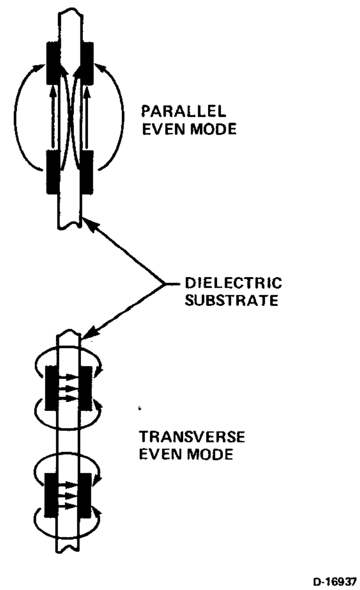

FIGURE 2. EVEN MODE PATTERNS ON BALANCED 4-WIRE LINE

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Referring again to Figure 1, note that the parallel mode launches in the slot is terminated in a short circuit formed by the bifurcation of the balanced microstrip line. Locating the bifurcation approximately one quarter wavelength from the plane of the diodes results in an open circuit at the diodes for the parallel mode. The placement of a pair of plated-through holes through the slot line conductors, as shown in Figure 1, terminates the transverse mode in a short circuit. Locating these plated-through holes a quarter wavelength from the diodes transforms the short circuit to an open circuit at the plane of the diodes for the transverse mode. These quarter wavelength stubs are, in fact, the only structures which limit the L.O. and RF operating bandwidths other than the diodes themselves, so that this design approach should perform well over an instantaneous bandwidth of at least an octave for both the L.O. and the RF. Note that, although the slot line port and the microstrip port in Figure 1 have been arbitrarily labeled as the "RF" and "L.O." ports respectively, they are interchangeable.

The principal factor limiting the IF bandwidth is the length of the ground return from the diodes to the outer conductor of the coaxial IF output line. This path is along the four-wire lines to the waveguide walls and along the waveguide walls to the outer conductor of the IF line. As indicated in Figure 1 this path length can be made quite short by narrowing the waveguide "A" dimension in region occupied by the four-wire lines.

RF to L.O. isolation is inherent in this mixer design, since there is no cross-coupling between the transverse and parallel modes are also isolated from the IF output unless circuit or diode asymmetry is introduced.

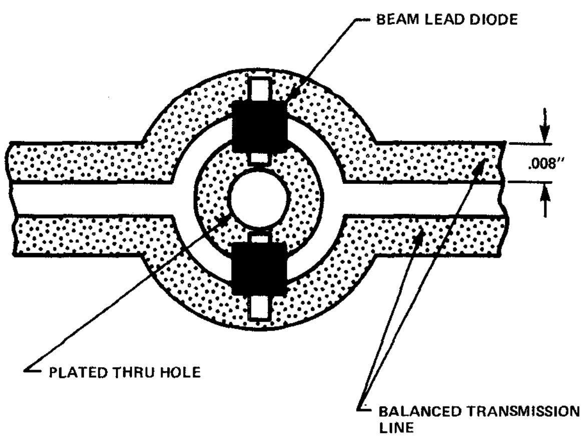

FIGURE 3. DIODE MOUNTING DETAIL

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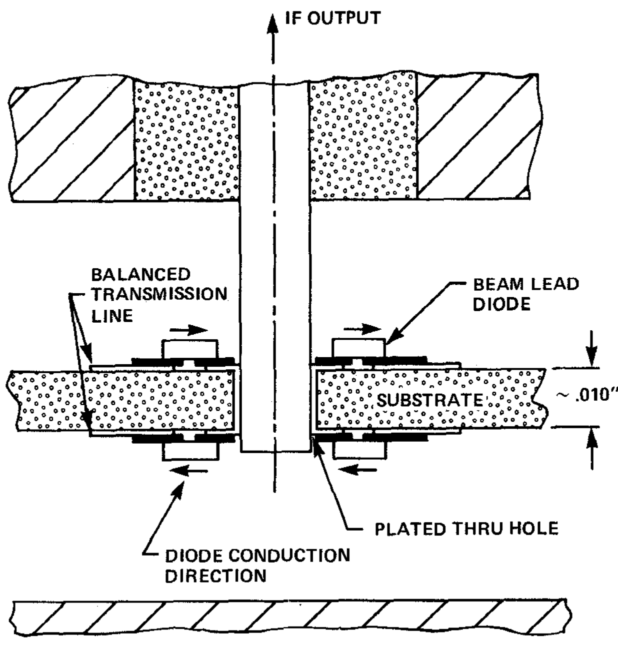

FIGURE 4. CROSS-SECTION THRU CENTRAL PLANE THRU DIODES

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Prototype Results

A mixer using these design concepts was constructed for operation from 26.5 to 40 GHz with transitions to WR-28 for the L.O. and RF signal ports and SMA connector at the IF output. RT Duroid type 5880 with copper clad on both sides and a dielectric thickness of 8 mils was used for the substrate material for low cost considerations. MA-40185 silicon Schottky beam lead diodes were selected for their intrinsic mechanical strength and reliability. A split-block aluminum housing was used to mount the substrate centrally in the waveguide. The transitions from waveguide to both the parallel and the transverse four-wire transmission line modes were designed for a typical return loss in excess of 20 dB.

Conversion loss was measured using fixed frequency L.O.'s at several frequencies throughout the 26.5 to 40 GHz band, without retuning. To preclude the possibility of measurement error due to L.O. or RF leakage a filter was used in the IF output port to provide a minimum of 40 dB attenuation in 26.5 to 40 GHz band. The match and loss of the filter was calibrated on a computer controlled network analyzer throughout the IF frequency range.

The actual conversion loss data were obtained at the different L.O. frequencies without retuning by measuring the signal input level and the corresponding IF output level for IF's from 0.5 to 8 GHz. The average value of the measured conversion loss at each signal frequency were then recorded. The variation about the average value was typically ±0.25 dB or less.

Scaled designs of the K_A Band mixer were also built in WR-42 and in standard double ridged waveguide and the conversion loss was measured over the 18-26.5 GHz and the 18-40 GHz bands respectively, using the measurement technique described above. Figure 5 is a plot of the measured conversion loss for all three mixers at an L.O. input level of 10 mW. The third order intermodulation product intercept point is 16 dBm or greater at the same L.O. drive level. The worst case VSWR for the L.O. and RF ports was 2.0: 1.0 for the waveguide bandwidth units and 2.4:1.0 for the octave bandwidth unit. Figure 6 is a photograph of the mixer assemblies.

Conclusion

A unique planar, integratable, doubly-balanced mixer has been developed for use in wide band EW, 18-40 GHz band extension applications. Measured data demonstrates that the performance levels are comparable to doubly balanced mixers in common use at lower frequencies, so that the mixers should be useful for Radar and Communications Applications as well. The planar feature permits low cost integration of the mixer design into complex fin line and microstrip subassemblies without the need for waveguide transitions.

Acknowledgement

*This work was sponsored by AFAL, Wright-Patterson AFB, Ohio 45438, Contract No. F333615-80-C-1013. **Patented, US Patent No. 4,291,415. (Inventor, Dr. Charles D. Buntschuh).

Reference

1. R. Mouw, "A Broadband Hybrid Junction and Application to the Sideband Modulator," MTT-16, pp 911 ff., November 1968.

Typical Performance Curve

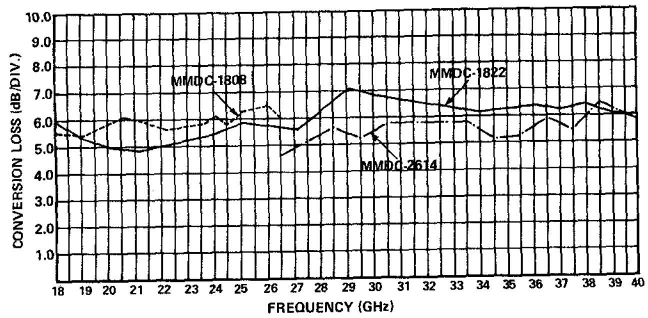

FIGURE 5. AVERAGE CONVERSION LOSS vs. FREQUENCY FOR VARIOUS IF'S AND LO FREQUENCIES

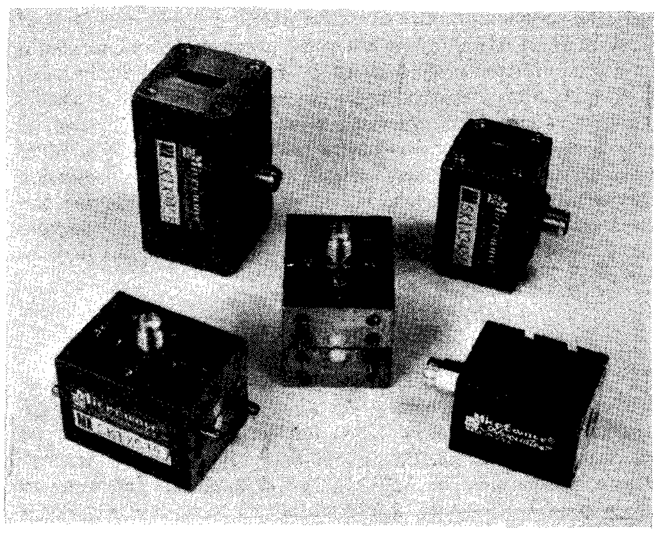

FIGURE 6. MIXER ASSEMBLIES