A NEW MIC DOUBLE-BALANCED MIXER WITH RF AND IF BAND OVERLAP

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Abstract

A new type of MIC double-balanced mixer has been developed using a combination of slot-line, microstrip, and wire near a ground-plane transmission line. A number of these mixers have been built with octave RF bandwidths in the 2 to 18 GHz region with RF and IF band overlap.

Summary

The requirement for MIC double-balanced mixers in the 2 to 18 GHz range with all three ports operating in the microwave region prompted the development of the mixer described. Two new types of 180-degree hybrids are used to realize the three orthogonal means of driving the four mixer diodes necessary for double-balanced operation. Hunton and Takeuchi[1] used a combination of slot line and coplanar line to realize a MIC single-balanced mixer. Here, slot line, microstrip, and wire near a ground-plane transmission line[2] are combined to realize a MIC double-balanced mixer. This combination of transmission lines results in IF performance unique in the higher microwave region; IF band overlap with the RF band. A typical mixer for the RF band from 2.8 to 6.2 GHz provides an IF response from dc to 3.8 GHz at the 3-dB point, with port-to-port isolation greater than 20 dB.

This configuration also permits the three dimensional structure of the double-balanced mixer to be confined to the surfaces of a single alumina substrate; the connections between the surfaces are made only at the edges of the substrate. Figure 1 shows the microstrip and wire-line side of a 5.5 to 11.5 GHz unit. The slot line on the ground-plane side runs directly beneath the tuning-fork-shaped microstrip circuit to an SMA connector. (The connection cannot be seen in the figure.) Except for the wire line, the beam-lead diodes, and some gold wire and ribbon, all the circuits are etched on the two surfaces of a single alumina substrate.

Mixers of this design have been built operating over octave bands from approximately 2 to 18 GHz. The following general description applies to all the mixers.

Each of the three ports in the mixer is simply referred to by its transmission-line type. Although each of the three ports can be used for IF, LO, or RF, the microstrip port is usually called the IF port because its response extends down to dc. The 3-dB upper-frequency limit of the microstrip port can be made to extend into the operating band of the wire-line port. The wire-line port is an octave or more wide, and the slot-line port is 5 to 50 percent wide. The frequency range of the slot-line port falls within or above that of the wire-line port and can also overlap that of the microstrip port. Figure 2 shows an example of the frequency overlap of the three ports.

Both the slot-line port and the wire-line port can operate anywhere in the 2 to 18 GHz range. Port-to-port isolation runs 20 to 30 dB; the conversion loss ranges from 5 to 8 dB through X-band. Figure 3 shows a typical plot of conversion loss. At K_u-band, conversion losses have been running several dB higher because of circuit losses; however, these losses can be reduced by using better diodes and by refining the circuits.

The slot line to microstrip hybrid is based on the configuration of the slot-line electric field.[3] Figure 4 shows the slot line to microstrip hybrid. Two microstrips running above the slot to each side couple to the electric field 180 degrees out of phase with each other; they do not couple to the magnetic field. Joining the two microstrips forms a fourth port, which is orthogonal to the slot line. It is not obvious that this is a four-port hybrid, because the two ports that are 180 degrees out of phase are used to drive the diode ring without a ground connection. The normally weak coupling between the slot line and the two microstrips results in narrow operating bandwidths. To broadband the slot line to microstrip hybrid, the connection between the two parallel microstrips and the end of the slot line must be kept an equivalent quarter-wavelength from the diodes. This minimizes loading of the diodes by these circuits over the widest possible band. However, minimizing the loading also minimizes the coupling between the slot line and the microstrips. To obtain strong coupling and wide bandwidths, capacitive stubs must be added beyond the diodes.

The primary advantage of the slot line to microstrip hybrid is that it does not limit the IF response. The wire line to microstrip hybrid, in providing the IF grounding of the diodes, determines the upper IF operating frequency.

Theoretically, any two hybrids can serve in a double-balanced mixer. The use of a second slot line to microstrip hybrid was rejected because of the difficulty in achieving isolation between the two slot lines. A simple method of building the second hybrid was devised. Two parallel microstrips are driven 180 degrees out of phase with each other by a third transmission line. Joining the two microstrips forms a fourth port, which is orthogonal to the third transmission line. In the mixer, the third transmission line must not couple to the slot-line fields if proper orthogonality is to be achieved. A single wire, running above one of the microstrips and using the microstrip as its ground plane, satisfies these requirements because the microstrip effectively shields the wire line from the fields of the slot line. Figure 5 shows a transmission-line model of this circuit. The two microstrips are connected approximately one quarter-wavelength from both the diode connection and the wire-line connection. The wire uses one of the microstrips as a ground plane and is connected to the other microstrip.

The model in Figure 5 adequately describes the performance of the wire line to microstrip hybrid. As is to be expected from the quarter-wavelength stub circuitry, octave bandwidth operation is achieved.

Conclusion

A MIC mixer using a combination of slot line, microstrip, and wire near a ground-plane transmission line has been developed for the 2 to 18 GHz range. It is compact, reproducible, and rugged. The mixer is useful where octave-or-less RF bandwidths are required, especially where a very broadband IF bandwidth is required. The techniques used to build this mixer will prove valuable in other applications where elements on a substrate are required to be driven in a balanced circuit.

Acknowledgments

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References

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2. Jasik, H., "Antenna Engineering Handbook," McGraw-Hill Book Co., Inc., p 30-4, 1961.
3. Cohn, S. B., "Slot Line - An Alternate Transmission Medium for Integrated Circuits," G-MTT Symposium, 1968.

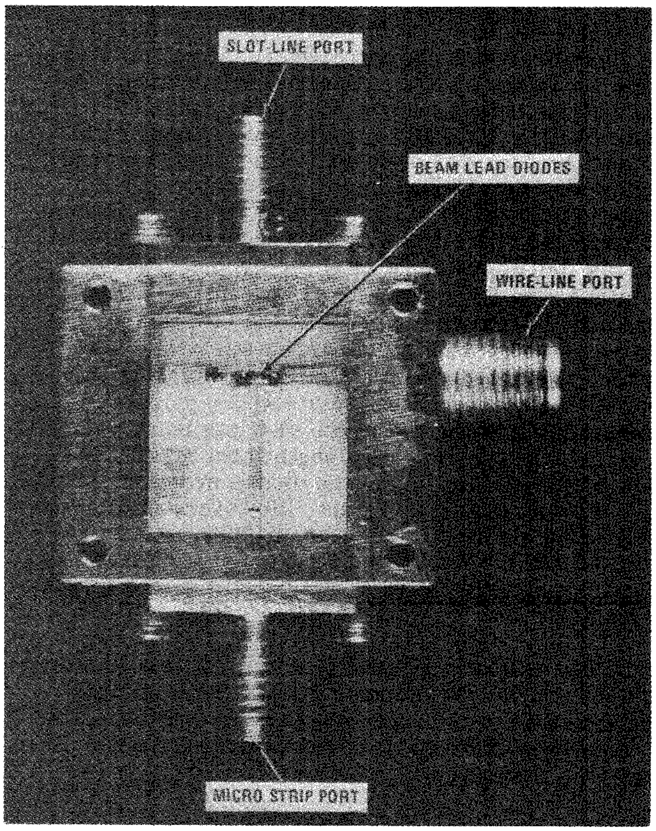


FIG. 1. X-BAND MIC DOUBLE BALANCED MIXER

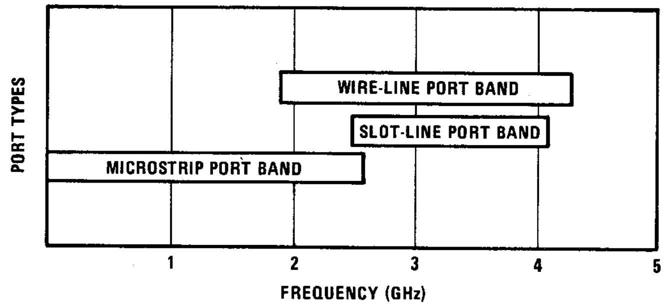


FIG. 2. OPERATING FREQUENCY BANDS OF S-BAND MIXER

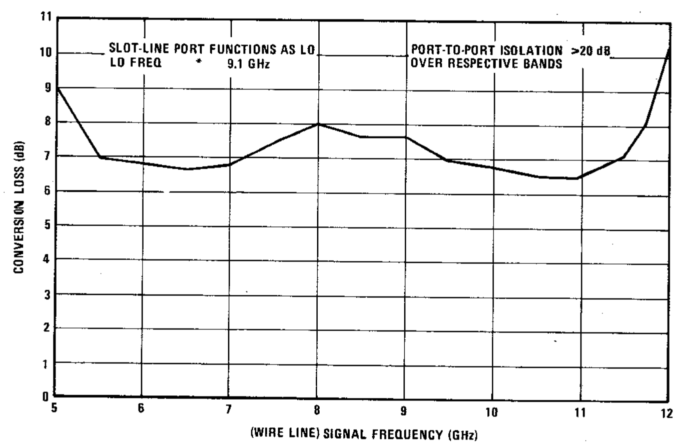
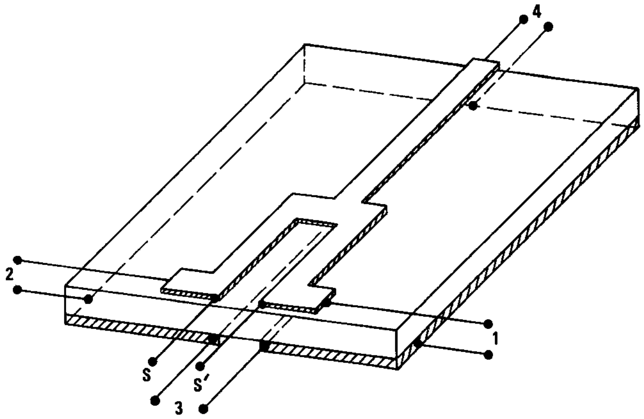
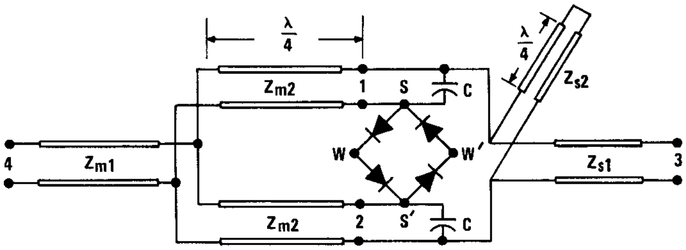


FIG. 3. X-BAND MIC DOUBLE BALANCED MIXER CONVERSION LOSS



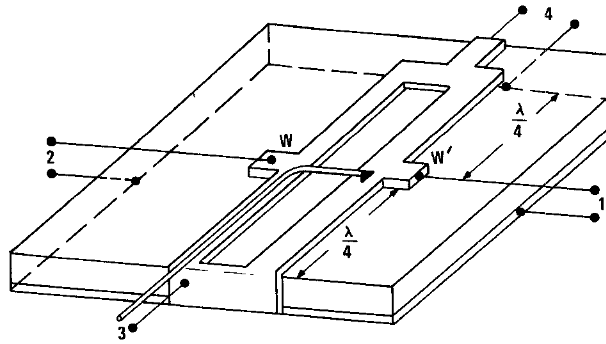
A. SLOT LINE TO MICROSTRIP HYBRID

NOTE: Z_m AND Z_s REFER TO MICROSTRIP AND SLOT-LINE IMPEDANCES, RESPECTIVELY.

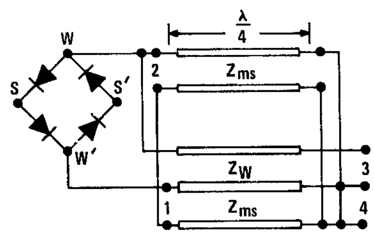


B. TRANSMISSION-LINE MODEL OF HYBRID AS USED TO DRIVE DIODES.

FIG. 4. SLOT LINE TO MICROSTRIP HYBRID



A. WIRE LINE TO MICROSTRIP HYBRID



NOTE. Z_{ms} IS THE MICROSTRIP IMPEDANCE, & ZW IS THE WIRE LINE IMPEDANCE. PORT 4 IS SHORTED TO GROUND.

B. TRANSMISSION-LINE MODEL OF HYBRID AS USED TO DRIVE DIODES.

FIG. 5. WIRE LINE TO MICROSTRIP HYBRID