A KA-BAND ORTHOGONAL HYBRID FIN-LINE MIXER

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Abstract

This paper describes a novel Ka-band mixer which utilizes a printed-circuit board. This device is mounted in an orthogonal hybrid tee. The design is scalable to higher millimeter-wave frequencies and provides a small (< 1 cubic inch) low-cost mixer with typical conversion loss of 6 dB.

Introduction

Several articles have been published on the subject of printed-circuit fin-line mixers. Araki, et.al.[1] used a branch-line hybrid to design a 20-GHz integrated balanced mixer. Bergemann[2] later designed an X-band fin-line mixer using a standard magic-T configuration. Another type of recently developed[3] fin-line mixer utilized a slot/coplanar/microstrip junction for injecting local oscillator (LO) and radio frequency (RF) signals. More recently, Meier[4] reported a printed-probe hybrid fin-line balanced mixer operating in the 94-GHz range.

The mixer described in this article employs a new technique which employs an orthogonal hybrid tee (OHT) as a mixer building block. This technique is unique in that it physically provides a common wideband impedance transformation from waveguide to fin-line for both RF and LO signals. In addition, this design is scalable to higher millimeter-wave frequencies using low-noise beam-lead Schottky barrier diodes. The OHT hybrid will be described in detail later.

Mixer Components

The Ka-band mixer schematic described below is shown in Figure 1, and the layout is depicted in Figure 2. Structurally, the mixer may be broken down into two parts, as shown in Figure 1. The part outside the dotted line is the power-dividing OHT hybrid into which LO and RF signals are fed. The part inside the dotted line is the integrated fin-line circuit which consists of impedance-matching transformers, beam-lead Schottky barrier diodes (D_1 and D_2), and intermediate-frequency (IF) low-pass filters. In this case, the diodes are Alpha DMK 4791.

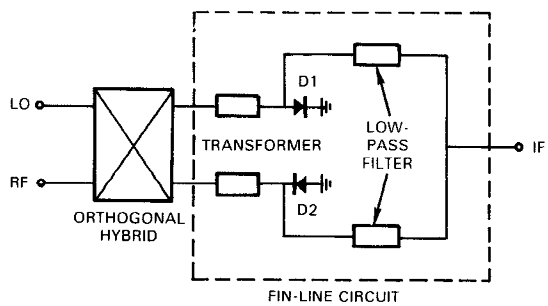

Figure 1. Schematic of Fin-Line Balanced Mixer

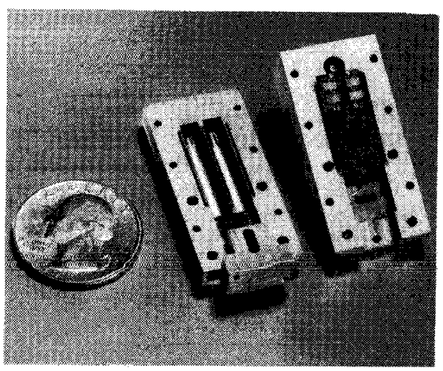

Figure 2: Layout of Fin-Line Balanced Mixer

Orthogonal Hybrid Tee

Walker et al.* originally derived the OHT hybrid from a standard magic-T. This hybrid's outputs may be constructed in two forms, Type A and Type B, as shown in Figure 3. The hybrid functions like a magic-T; yet its E and H arms are colinear in one plane, thereby forming a very compact device. In operation, one RF energy is feed into the H arm, while another is fed into the E arm. Each signal couples through its respective iris into a common cavity where the signal is split equally into two H-plane waveguide outputs. The two output signals have the same phase relationship as a magic-T.

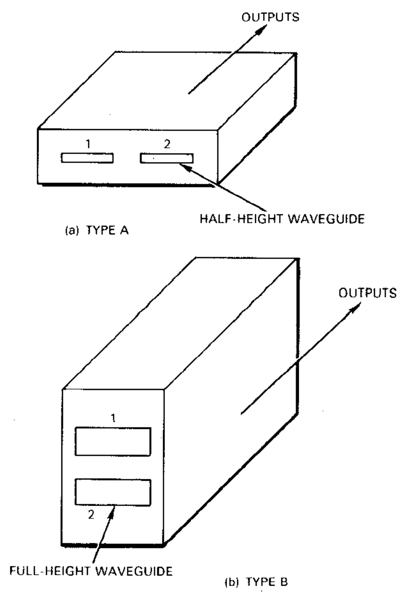

Figure 3: Two Forms of Orthogonal Hybrid Tee Outputs

To these authors' knowledge, Type A OHT is the only hybrid that has been put into application. Type B has never appeared in any published literature. In this article, the OHT hybrid refers only to Type B since the Type A half-height waveguide hybrid cannot utilize the advantages of low-cost fin-line media. The Type A hybrid cannot use fin-line media because of its very small E-plane dimensions. On the other hand, the Type B OHT hybrid lends itself to the unique fin-line mixer design because of the way the output waveguides are arranged. This arrangement is shown in Figure 3(b). The Type B OHT layout is shown in Figure 4.

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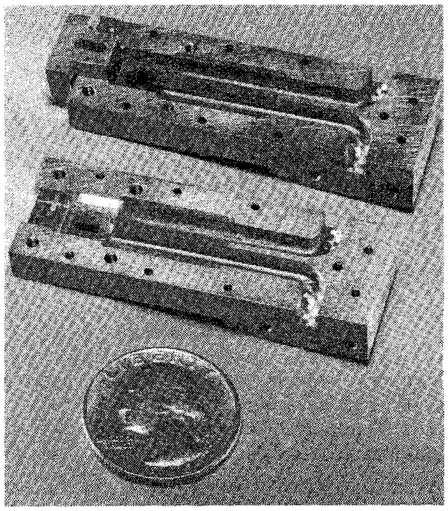

Figure 4: Layout of OHT Hybrid

Fin-Line Structure

As shown in Figure 2, the Ka-band fin-line circuit is printed on a 0.0197-mm thick substrate using Type 5880 RT/DUROID. This fin-line has a two-sided printed circuit: on one side, a slot taper transformer[5,6] to match the waveguide impedance to the diode impedance; and on the other, an IF microstrip low-pass filter[7] with a cutoff frequency of 10 GHz. The microstrip filter ground plane is obtained from the surrounding tapered slot copper. The two beam-lead diodes are thermal bonded across the slot to the ground pads. These ground pads are located $\lambda/4$ away from the slot transformer's short-circuited ends. Grounding for beam-lead diodes is realized through two plated through holes. The fin-line circuit pattern is illustrated in Figure 5.

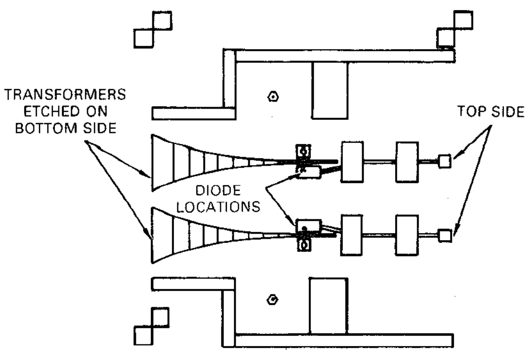

Figure 5: Fin-Line Circuit Pattern

In the mixer, the fin-line substrate is located symmetrically at the center of the E plane. It sits flush with the two output waveguide openings, with the transformer at the entrance of the cavity. This configuration is shown in Figure 6. One half of the substrate is inserted inside the top waveguide, and the other half is inserted inside the bottom waveguide. The ground-plane side of the substrate is grounded to the waveguide walls. Two wires are soldered to the outputs of the low-pass filters at one end, and to the center IF connector conductor at the other end.

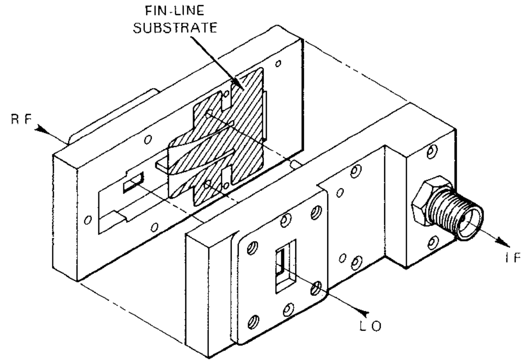

Figure 6: E-Plane Fin-Line Substrate Location

Analysis and Results

A Ka-band fin-line balanced mixer prototype was fabricated and tested using the design approach described in the foregoing paragraphs. An adjustable short was incorporated into the prototype design so that the center frequency could be set at any part of the 26.5- to 40-GHz band. The sliding short can be seen in Figure 2. Its setting determines the mixer's operating center frequency.

The following measurements are taken for one particular setting for both the OHT hybrid (Figure 4) and the mixer (Figure 2). The irises are both theoretically[8] and experimentally determined for best coupling at the operating frequency. Figure 7 shows the coupling and isolation of the OHT hybrid. Across a 4-GHz band, the coupling to either output port is 4.5 $\pm$ 0.5 dB, which can be improved. The isolation across the full 26.5- to 40-GHz band is a 26-dB minimum.

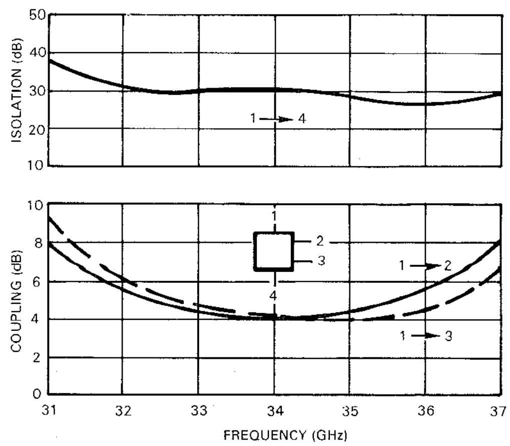

Figure 7: Performance of Orthogonal Hybrid

Figure 8 shows the mixer's conversion loss performance. As the curve shows, an optimum conversion loss of 5.5 dB falls at a LO power of +13 dBm.

The drive can probably be lowered after the irises are optimized. It was also found that the IF can be operated up to 1 GHz with only slightly higher conversion loss.

Conclusion

A novel technique to design a Ka-band fin-line balanced mixer using an orthogonal hybrid tee has been

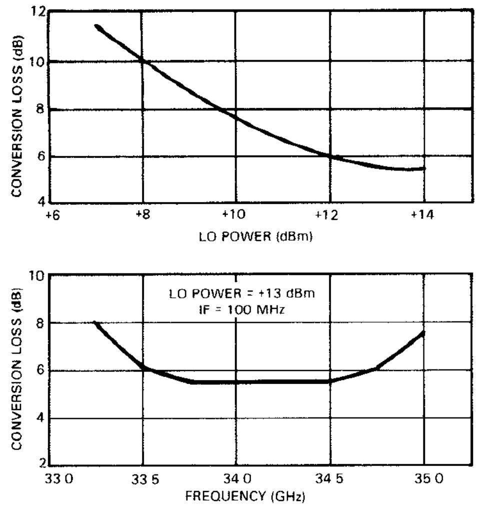

Figure 8: Conversion Loss Performance

demonstrated. The excellent conversion loss which the mixer achieved has proven the usefulness of this new technique in constructing a high-performance compact mixer. Besides being able to take advantage of low-cost printed-circuit construction techniques, use of low-parasitic low-noise beam-lead Schottky barrier diodes also becomes possible. Finally, if scaling is used, the technique described here is applicable to frequencies well into the millimeter-wave region.

Acknowledgements

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