MULTILAYER HYBRID IN CIRCULAR WAVEGUIDE

Earl T. Harkless and Douglas N. Zuckerman
Bell Laboratories, Holmdel, New Jersey 07733

ABSTRACT

A circular-waveguide multilayer dielectric sheet hybrid junction having nearly constant power division over 40-110 GHz and minimal spurious mode generation is designed using ray optics. Experimental results are given and broadband filter applications are examined.

Introduction

The formation of a hybrid junction via a dielectric sheet (or a perforated metal plate) placed at 45 degrees across the right angle intersection of two waveguides has been the subject of considerable investigation.[1] Use of multiple dielectric layers to reduce distortion of the scattered waves has been described by Saleh.[2] This paper will show how a 3-layer dielectric can be applied to the circular-electric mode hybrid junction to yield considerably improved performance over previous designs in both unwanted mode conversion levels and broadband equality of power division. Application to a band-splitting filter is discussed.

Circular-Electric Mode Hybrid Junction Analysis

Figure 1 shows a hybrid junction or directional coupler in oversize circular waveguide, for use with the TE°_{01} mode. The electric field can always be decomposed into H or E-polarized components. Far from cutoff, the two components may be treated as plane waves. The reflection and transmission magnitudes of any portion of the circular electric field pattern can then be computed from these components using a transmission-line analogy and standard formulas.

The TE°_{01} content of the reflected or transmitted field is the average circumferential transverse electric field magnitude, i.e., the average of the two reflection or transmission coefficients. The distorted component (mode conversion; mostly TE°_{21} or TM°_{21}) is one-half the difference of the reflection or transmission coefficients. Use of a 3-layer dielectric sheet to reduce variations between the H and E polarized components has been proposed by Saleh.[2] By choosing a center sheet with a large permittivity the E and H component reflections both become much larger than wanted. By adding a lower permittivity quarter-wave matching section on both sides of the center sheet, the reflection can be lowered to a desired value. As shown by Saleh,[2] both E and H polarization scattering values can be made equal to some desired value. Examination of the frequency response of this design also reveals that the additional degrees of freedom provided by using three sheets can yield much more constant reflection and transmission performance than is possible with a single sheet. This is demonstrated by the calculated response of Figure 2 where the center sheet has a permittivity of 12.0 and the outer sheets have 1.45. Both single-sheet and 3-sheet hybrids have been designed to obtain reflection and transmission near 3 dB across the 40 to 110 GHz band, but the 3-sheet design is much flatter. Spurious mode excitation of the single-layer design is about -17 dB across the band, while the 3-layer design calculates to -31 dB at band center and -19 dB at the band edges. In a practical hybrid, performance will be constrained by the availability of materials having proper dielectric properties.

Return Loss of a Band-Splitting Filter

An array of band-splitting filters (Figure 3) is used to split the 40-110 GHz WT4 system waveguide band into seven subbands.[3] Reflections between filters cause echoes and degradation of system performance. The 3-layer hybrid, because its power division is much flatter than that achievable with a single-layer hybrid, gives sufficient return loss improvement to reduce the worst echoes by at least 9 dB.

Experimental Results

The permittivity and thickness of each sheet was determined by measuring its TE°_{01} insertion and return loss when mounted transversely across a 2-inch diameter waveguide over 40-110 GHz.

Three-layer hybrid results are given in Figure 4. The middle layer had a dielectric constant of 13.5 and a thickness of 0.1275 inch. The two outer layers had dielectric constants of 1.6 and a nominal thickness of 0.0426 inch. The calculated performance curve displays the power division and mode conversion loss as computed from ray optics plus (1) elbow loss at the intersection of two waveguide;[4] (2) offset loss due to misalignment between the propagating fields and waveguide axes; and (3) dissipation of energy in the dielectric sheets (outer layers mainly). Offset and dissipation loss have been determined experimentally.

Insertion and return losses for a simulated band diplexer (hybrid with two ports short circuited) are shown in Figures 5 and 6. The frequencies of the minimums and maximums agree to within about 5 percent. Some of the measured maximums are smaller than predicted. This in in part due to limitations of the test set in measuring very high return losses. The measured insertion loss varies from 1 dB at 40 GHz to 2.1 dB at 110 GHz. Improved materials are required to reduce this loss. Another more narrowband hybrid, designed for operation from 75-110 GHz, was built using commercially available foamed quartz for the outer sheets. Extrapolating the performance of this hybrid to the band diplexer gives a predicted 1.6 dB loss at 110 GHz instead of the 2.1 dB reported above. This indicates that with the quartz material a lower loss broadband hybrid can be realized.

Conclusion

By using techniques presented here it was possible to construct a 3-layer circular waveguide hybrid having considerably flatter power division and lower mode conversion than heretofore possible. Extraneous loss mechanisms were identified. The use of a 3-layer hybrid rather than a single layer in a band-splitting filter can result in lower insertion loss and improved return loss.

References

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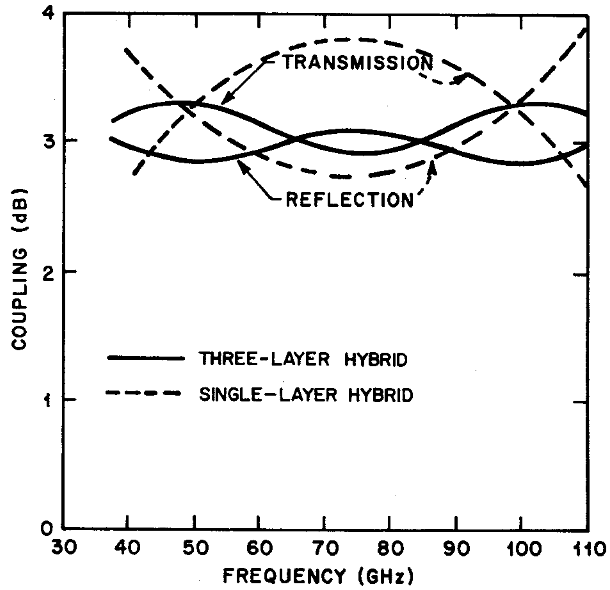
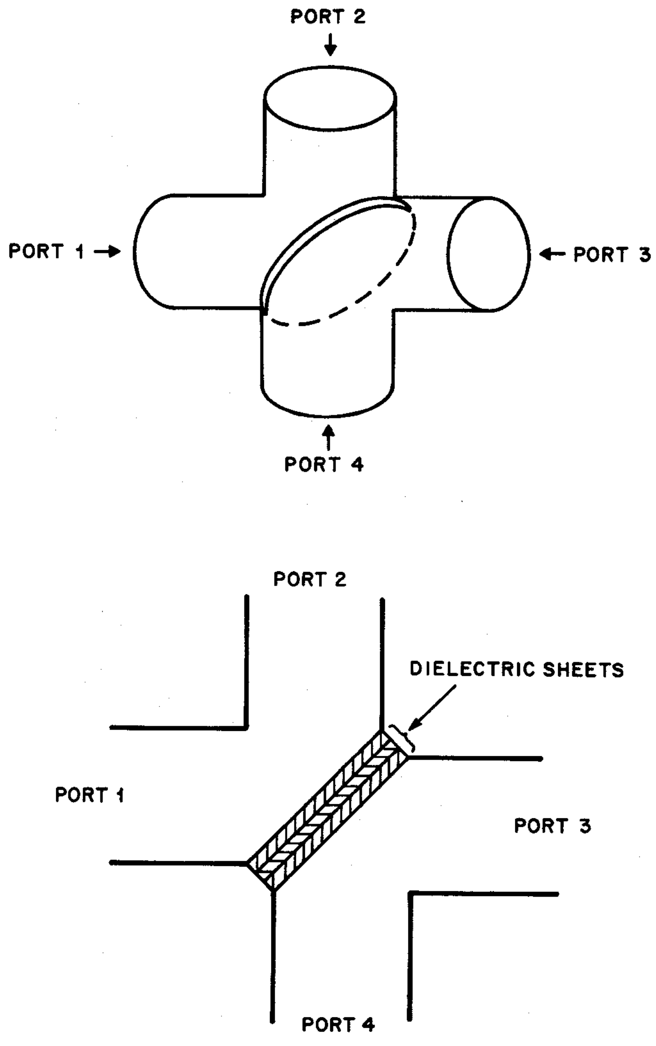


FIGURE 2 POWER DIVISION IN THREE-LAYER DIELECTRIC BROADBAND HYBRID (SINGLE-LAYER ALSO SHOWN FOR COMPARISON)



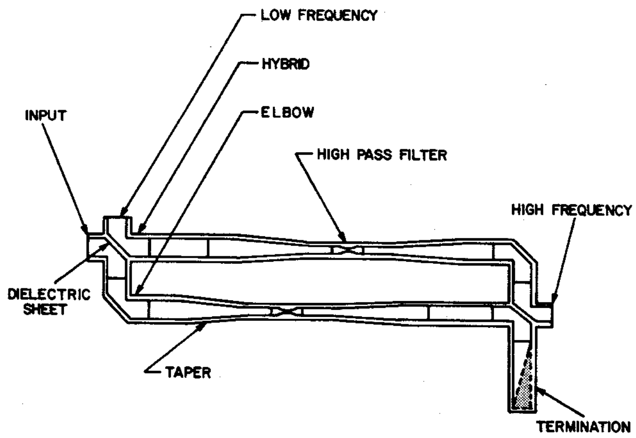


FIGURE 3 BAND DIPLEXER

FIGURE 1 MULTI-LAYER HYBRID IN CIRCULAR WAVEGUIDE

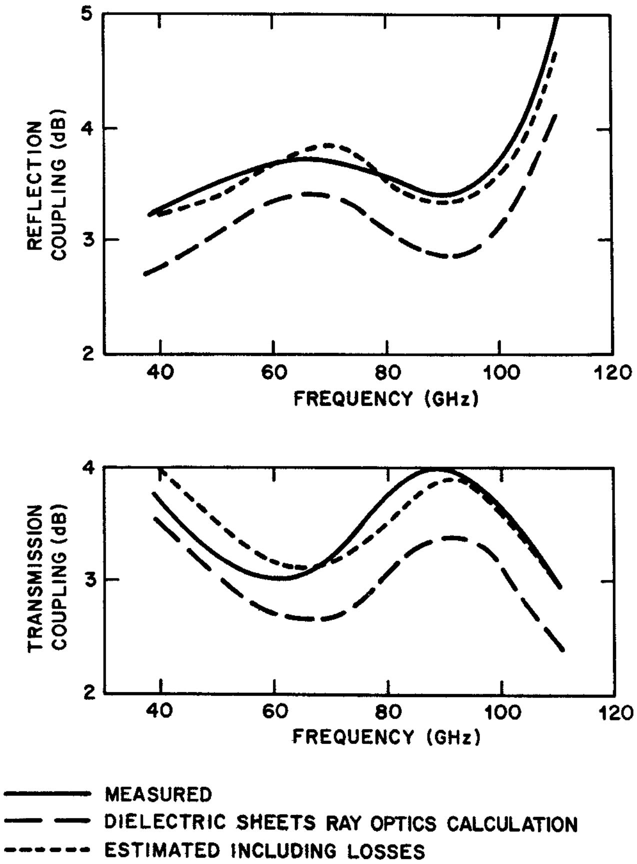


FIGURE 4 COMPARISON OF MEASURED AND CALCULATED PERFORMANCE OF THREE-LAYER DIELECTRIC SHEET HYBRID JUNCTION

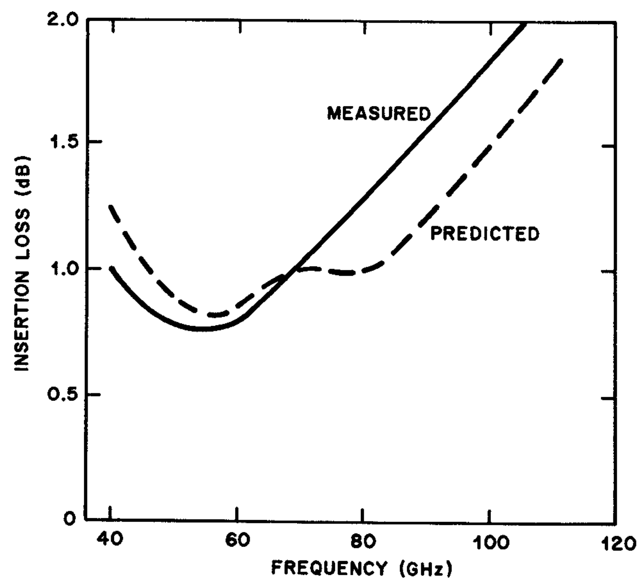


FIGURE 5 INSERTION LOSS OF SIMULATED BAND DIPLEXER

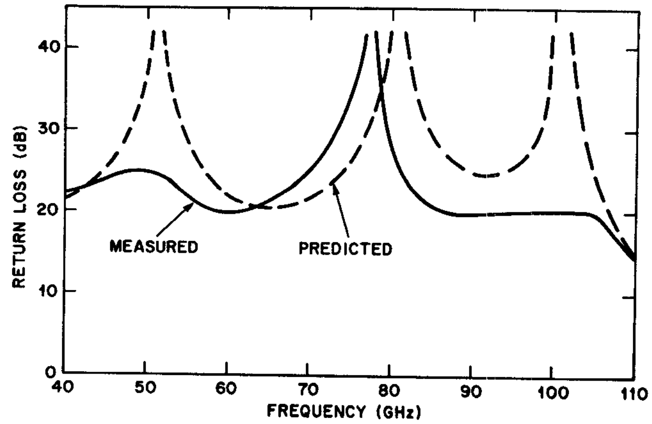


FIGURE 6 SIMULATED BAND DIPLEXER RETURN LOSS