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PHASE AND AMPLITUDE CHARACTERISTICS OF DIELECTRIC WAVEGUIDE COUPLER AND SIX-PORT NETWORK

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An improved six-port network has been designed and fabricated using dielectric waveguide. The amplitude and phase characteristics of the 90° hybrids, as well as the amplitude characteristics of the six-port network over the range from 75 to 110 GHz, have been measured. Results of the experiments show that the six-port network is useful over a substantial portion of W band.

Introduction

Recently, Hughes Aircraft Company developed and reported[1] on a six-port network analyzer in dielectric waveguide which was fabricated via a new, low cost technique. This paper presents an extension of that design and performance data that resulted in a more cost effective and lower RF loss device. Data necessary to determine the bandwidth over which the devices can be used are presented, including phase characteristics of a dielectric coupler and the frequency response of the measurement ports of the six-port network.

Mechanical Construction

Initial interest for making six-port networks in dielectric waveguide was motivated by device compactness and the availability of low cost fabrication techniques. The original design consisted of three hybrids and one power divider in the dielectric plus two external metal waveguide couplers interfacing with input ports of the network. The present design does not use any metal couplers, but rather uses all dielectric couplers, integrating everything into a single circuit. Figure 1 shows the hardware with the top cover of the six-port network removed. Power division is accomplished by tapering two guides into a Y-junction, as shown in the figure. This method yields in-phase power division over a wide bandwidth with 0.6 dB insertion loss, a significant improvement over the 3 to 4 dB insertion loss obtained by using the previous method. Transitions from metal to dielectric waveguide are usually made using standard gain electromagnetic horns. A less expensive method in the present design uses a compound horn. With the compound horn, first one dimension of the horn is tapered outward while the other is kept constant, and then the latter dimension is tapered outward while the first is kept constant. When used as a transition, the compound horn performs equally as well as the electromagnetic horn, yet has the advantage of being much less expensive and easier to fabricate since it incorporates all of the necessary transitions in a single split block.

Dielectric Coupler

The dielectric couplers consist of two guides placed in close proximity, with the broad walls of each guide parallel to each other. Coupling occurs because the electromagnetic fields extend beyond the dielectric boundary. The length and width of the gap between the two guides determines the degree of coupling. Details of the coupler analysis are given by Marcatili,[2] Levy,[3] and Miller.[4] Amplitude characteristics are

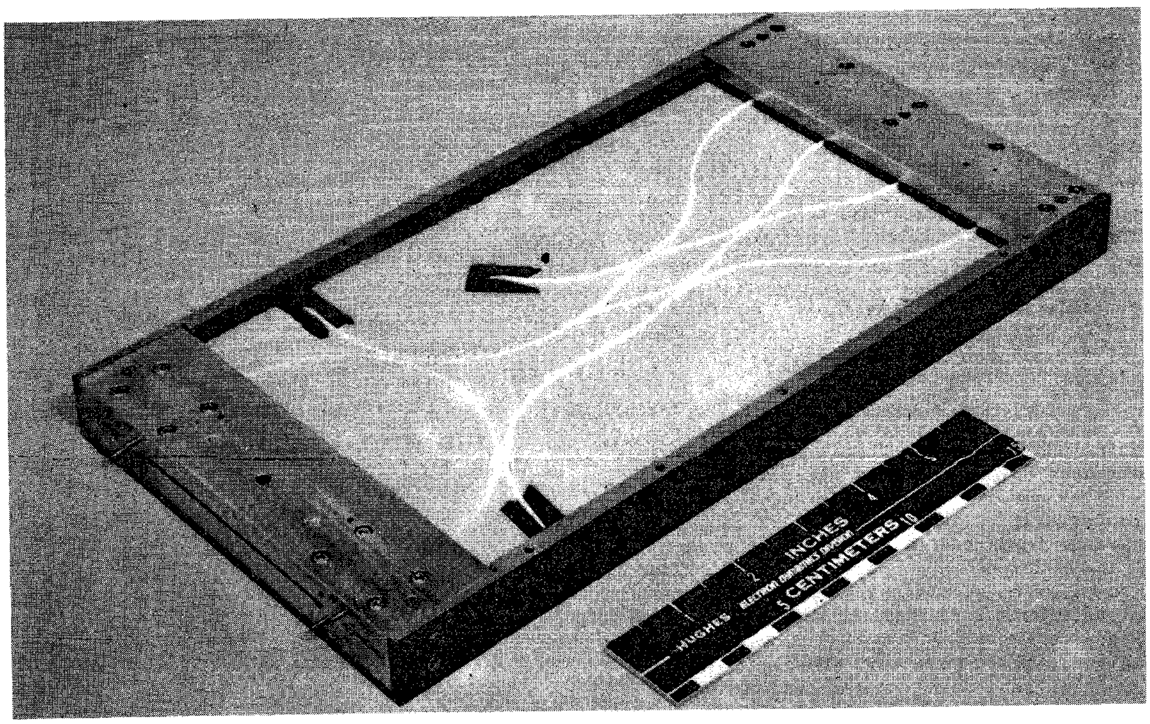

Figure 1. Six-port network.

well known for this type of coupler, but the phase is equally important for six-port applications. The phase change as a function of coupling strength was measured by keeping the physical gap length constant and varying the width. In our experiments, phase measurements were taken at the single frequency of 94.0 GHz.

Initially, the gap width of the coupler was set to give equal power splitting between the direct and coupling arms. By placing a short in each of the arms an equal distance from the coupling region and monitoring the power at the isolation port, we verified that the phase of the coupled port lagged 90° behind that of the direct port. If the phase difference is 90°, then the power of the two arms should, upon reflection from the shorts, recombine into the isolation port, which was found to be the case. A phase bridge was used to measure the relative phase of the two arms as a function of coupling coefficient. It was found that the relative phase remained constant at 90° throughout most of the coupling range. Significant deviation occurred when the imbalance between the two arms became greater than 15 dB. In this range, however, the measurement error became too great for reliable data to be taken. The phase change of the direct port as a function of the coupling coefficient was also measured and found to be virtually constant since it is within the measurement error of the experiment. Figure 2 shows the results of the phase measurements for both direct and coupled ports.

The coupling coefficient of a coupler is a function of the gap between the two dielectric guides in units of wavelength. Thus, for a given physical gap size, the coupling coefficient is a function of frequency. Therefore, since our experiment showed little or no phase change as a function of coupling coefficient, we may conclude that the phase characteristics of a dielectric coupler are virtually independent of frequency.

The frequency response of the dielectric coupler and the six-port network was measured across the full waveguide band using the recently developed Hughes Automatic Reflectometer. The Reflectometer is a computer controlled instrumentation system that allows automated scalar transmission and reflection measurements to be made over a full waveguide band. Figure 3 shows the response of the two ports as a function of frequency. This particular coupler is centered at 96.0 GHz, where the insertion loss is 2.0 dB. The insertion loss includes propagation loss through the dielectric, launching loss due to transitions from metal to dielectric guides, and radiation loss due to the curvature of the dielectric guides. Figure 4 shows the response of the coupled port normalized to the direct port.

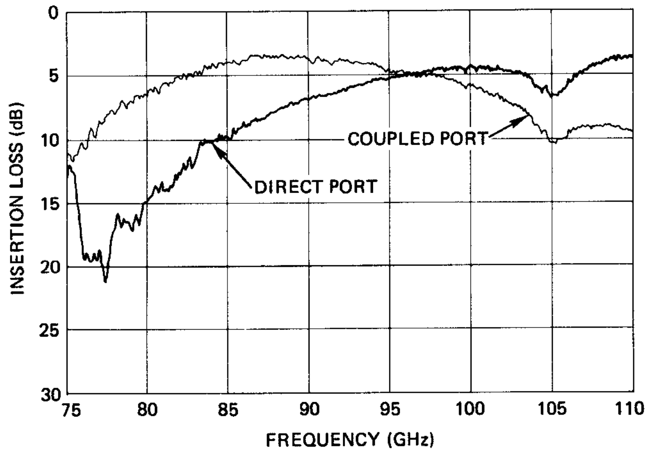

Figure 3. Frequency response of a dielectric coupler.

Six-Port Network

The frequency response of the six-port network was measured across the full waveguide band. The power was incident into port 1, while all other ports were terminated into matched loads. The response of each port was taken in turn by terminating it through a 20 dB coupler and sampling its power at the coupled arm to minimize error. Figure 5 shows the six-port circuit, where the input power port is Port 1, the test port is Port 2, and the four measurement ports are labeled P_3 through P_6. Figure 6 shows the frequency response of Ports 2 through 6. As expected from the symmetry of the circuit, Ports 3 and 4 have similar response and Ports 5 and 6 have similar response.

Conclusion

The phase and amplitude characteristics of a 3 dB dielectric waveguide hybrid and the amplitude characteristics of a complete dielectric waveguide six-port network have been measured from 75 to 110 GHz. Results of the experiments show that the dielectric waveguide six-port network is useful over a substantial portion of W band. The dielectric design provides a low cost fabrication technique and a compact mechanical configuration compared to its metal waveguide counterparts.

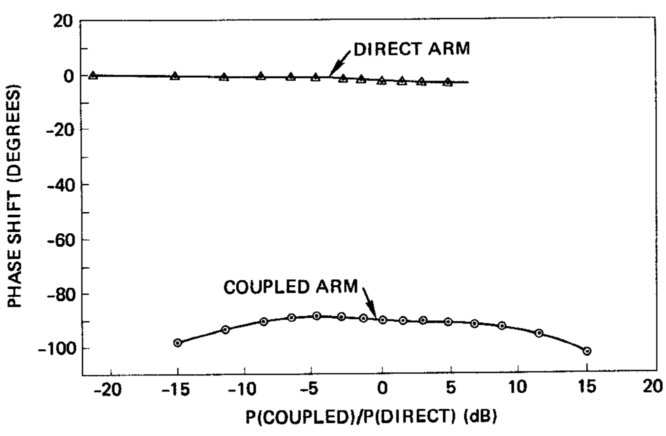

Figure 2. Phase characteristics of a dielectric coupler.

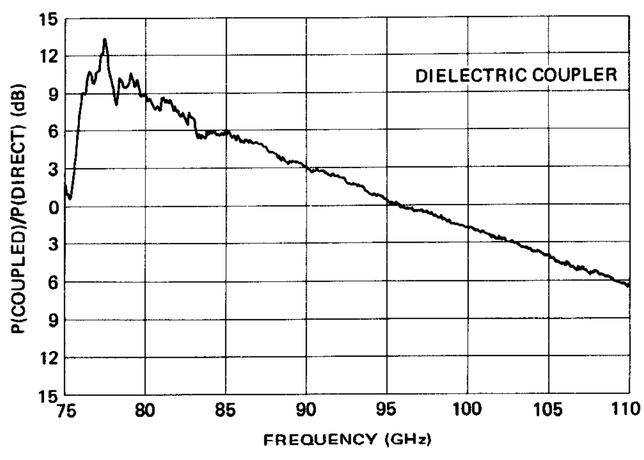

Figure 4. Coupling coefficient vs frequency for a dielectric coupler.

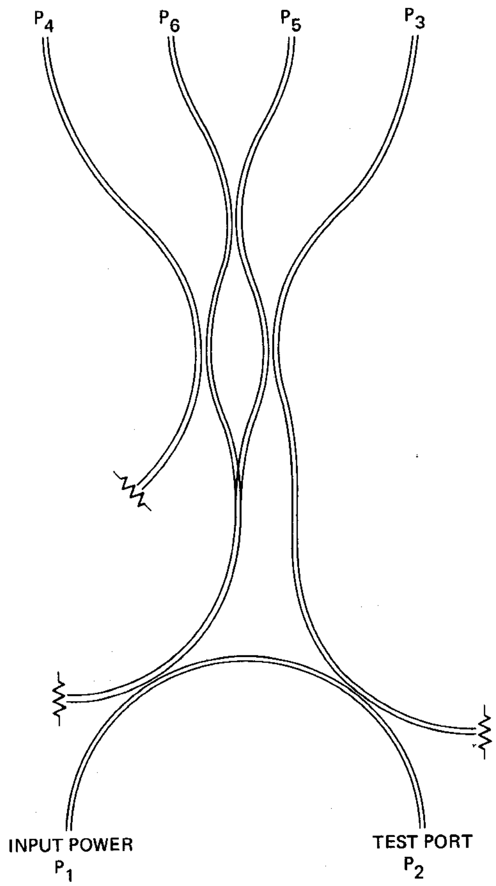

Figure 5. Six-port circuit.

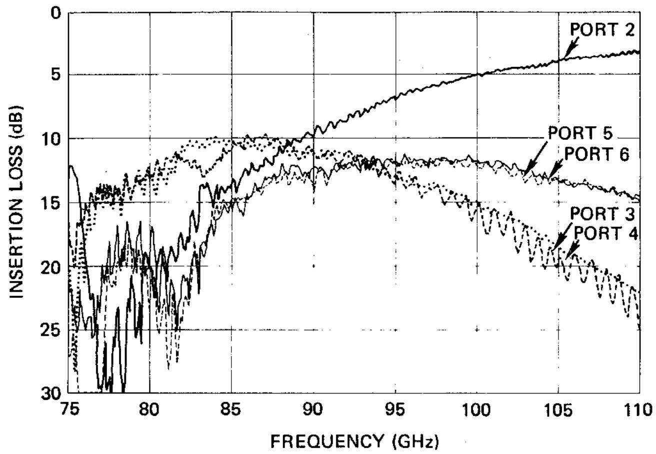

Figure 6. Frequency response of the six-port network.

References

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