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AN E-PLANE COUPLED MATCHED WAVEGUIDE 5-PORT FOR MAKING 6-PORT MEASUREMENTS OVER A FULL WAVEGUIDE BAND

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Abstract

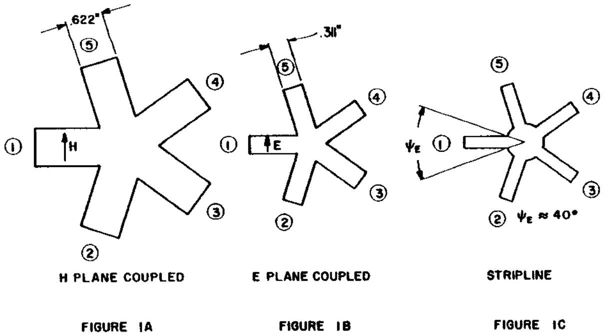
Recently, it has been shown that an ideal 6-port network consists of a perfect directional coupler and a matched reciprocal five port. In this paper an E-plane coupled waveguide five port which is well matched over an entire waveguide band will be described and its use for making 6-port measurements demonstrated over the Ku band 12.5 - 18.0 GHZ.

Introduction

It has been found that a 6-port with ideal q point distribution can be constructed from a matched reciprocal five port and a perfect directional coupler, and working models have been built in stripline.[1] One of the important potential applications of 6-port technology is in the millimeter region where waveguide is the natural medium for measurement equipment. With this in mind, we have developed a WR62 E plane coupled junction five port which is well matched over the waveguide band 12.5 - 18.0 GHZ. WR 62 waveguide has the 2/1 aspect ratio characteristic of millimeter bands making this device well suited for scaling up to millimeter bands.

Theoretical Considerations

Since a theoretical analysis is much more difficult in the waveguide case than in the stripline case, the design proceeded in a largely empirical fashion. H plane coupling would lead to a large diameter cavity for which the frequency dependence of the equivalent admittance could be expected to be rapid making for a difficult matching problem (figure 1a). E plane coupling gives the possibility of a much smaller diameter central cavity (figure 1b). Furthermore, it is known from recent theoretical and experimental work that for an equivalent coupling angle of about 40° a quite broad band junction five port can be built in stripline without the need for external matching (figure 1c). Based on the known similarity between many E plane coupled waveguide components and stripline components (such as branch guide couplers), it was hoped that a broad band E plane coupled 5 port junction could be obtained and indeed this has turned out to be the case.



Figures 1a,b,c Geometries for H-plane coupled and stripline five ports.

Experimental Devices

In figure 2 the return loss and coupling from port 1 to ports 2 and 3 are plotted from 12.4 - 18.0 GHZ for the geometry of figure 1b. Although the coupling unbalance is small, the return loss is as poor as 5.5 dB improving toward the high end of the band. Increasing the cavity diameter from .529" to .883" so that the geometry is similar to that of figure 1c results in a marked improvement in the return loss over the band as can be seen from figure 3a. The coupling angle is 43° which is close to the coupling angle of 40° which was found to be optimum for the stripline case. The similarity between the stripline and E plane coupled cases is apparent. The return loss is best at the high end of the band. It can be balanced up by including narrow wall irises at the junction. The VSWR is now <1.5 from 12.5 - 18.0 GHZ and the unbalance between ports 2 and 3 is less than about .5 dB (figure 3b). Experience with the stripline five port has shown that this performance is more than enough to allow good 6-port measurement to be made with a properly calibrated unit.[1]

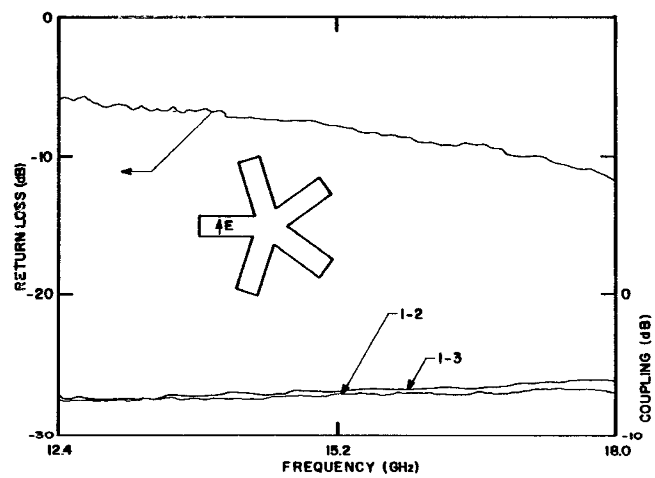


Figure 2 Plots of return loss and coupling vs frequency for a WR62 5 port with the geometry of figure 1b.

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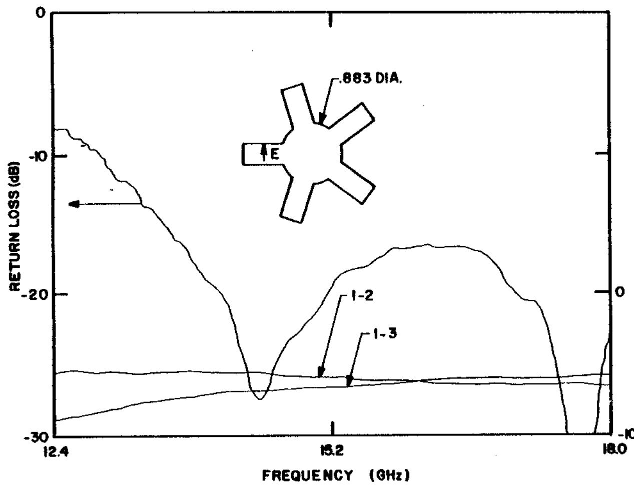
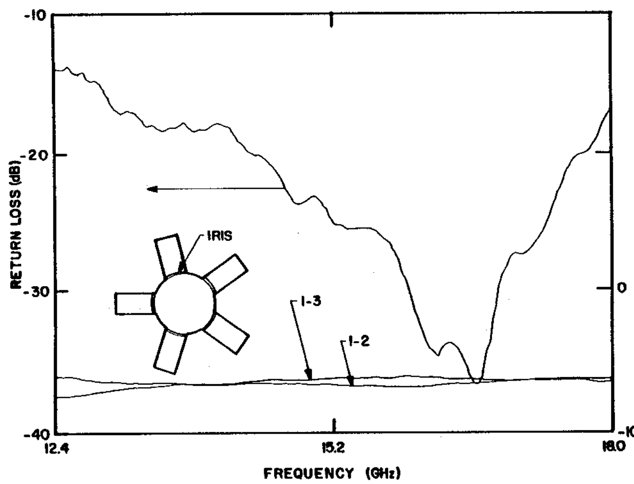




Figures 3a,b Plots of return loss and coupling vs frequency for WR62 5 ports with geometries similar to figure 1c.

Q Point Distribution

The WR62 5 port whose performance is given in figure 3b has been calibrated in a 6 port configuration using a calibration procedure based on a very good load and four offset short circuits.[2] The 6 port measurement system includes a plug-in switch box for the PMI-1038 D14 mainframe. The switch box is controlled by an HP-85 personal computer which switches the three detectors attached to the five port in turn to the channel A plug-in. A picture of the measurement system including the WR62 5 port is given in figure 4. The calibration program written for the HP-85 allows Z, ϕ_Z and the magnitude and phase of the inverses of the Q points i.e. 1/Q1, 1/Q2, 1/Q3 to be plotted as a function of frequency. These plots are given in figures 5a, b, c, d, e, f, g, h, respectively. The phase of Q1 has been set to zero. Since a high directivity coupler was used for the reference detector, the magnitude of Z should reflect the magnitude of the input reflection coefficient.[2] This is indeed the case as Z varies from somewhat less than .2 at the band edges (VSWR=1.50) to close to zero in the middle of the band where the device is best matched. Furthermore, the angle of 1/Q2 is close to -120° and the angle of 1/Q3 is close to 120° in the middle of the band, which corresponds to the ideal distribution for a 6 port. Furthermore, the variation of the Q points with frequency is quite smooth which means that very precise frequency control is not required in order to make accurate measurements.

References

1. E.R.Bertil Hansson, and Gordon P. Riblet "An Ideal 6-Port Network Consisting of a Matched Reciprocal Lossless Five-Port and a Perfect Directional Coupler",IEEE Trans.on Microwave Theory and Techniques, Vol. MTT-31, 1983.

2. G.P.Riblet and E.R.B.Hansson,"Aspects of the Calibration of a Single Six-Port Using a Load and Offset Reflection Standards", IEEE Trans.on Microwave Theory and Techniques, Vol. MTT-30, pp.2120-2125, Dec.1982.

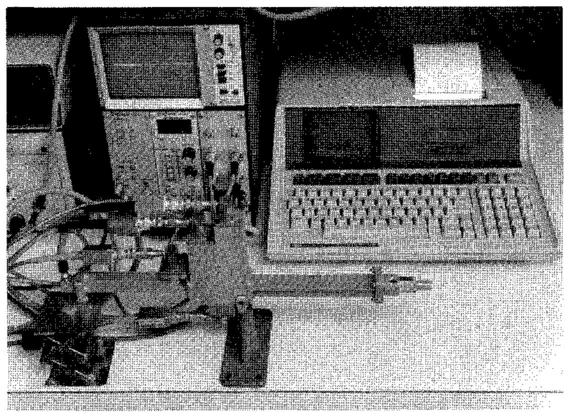
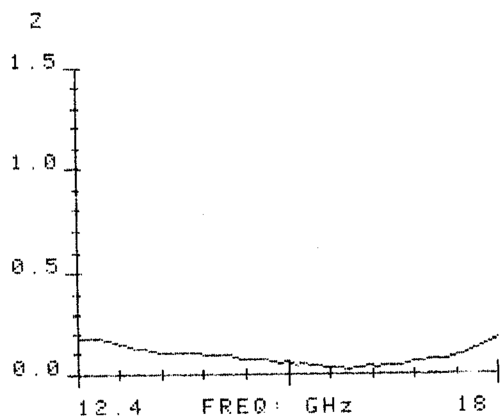
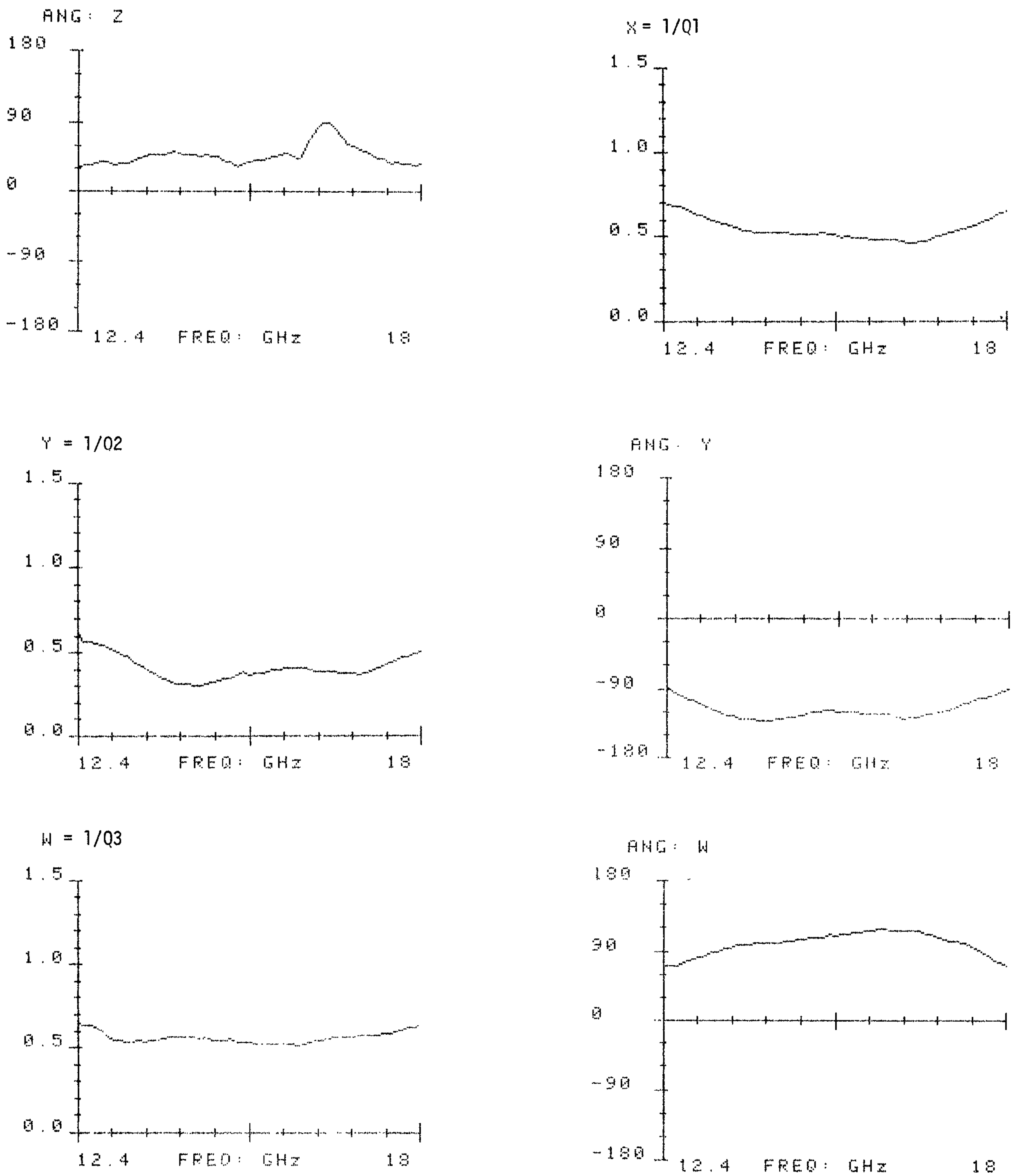


Figure 4 A picture of a six-port measurement system which uses the WR62 5 port in conjunction with an HP85 personal computer.





Figures 5a,b,c,d,e,f,g,h Plots of the calibration qualities Z, Θ_z, and magnitude and phase of 1/Q1, 1/Q2, 1/Q3 vs frequency for the WR62 6-port system pictured in Figure 4.