A WIDEBAND 60 GHz 16-WAY POWER DIVIDER/COMBINER NETWORK

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ABSTRACT

A 16-way, low-loss, wideband power divider/combiner network for V-band waveguide is described. This network utilizes a section of radial waveguide operating in the TEM mode. Over a frequency band of 55-67 GHz, this 16-way divider/combiner network has an insertion loss of 1 dB maximum and better than 12 dB return loss. Matching elements which have been designed for each of the three transitions between different transmission media within this network are described in detail.

INTRODUCTION

There is an increasing demand for wideband, high power, solid state amplifiers operating in the millimeter wave frequency range, and power combining of IMPATT devices will play a major role in the development of these amplifiers. The Kurokawa combiner has been successfully used for combining many IMPATT diodes, but it is inherently narrowband because of its resonant nature. Combining by means of hybrid couplers[1] provides wideband performance , but there is a limitation to the number of modules which can be efficiently combined. Microstrip power divider/combiner[2] networks have high losses in the millimeter wave range. Therefore, the development of an N-way, wideband, and low-loss power divider/combiner network is needed.

This paper describes a wideband power divider/combiner network which utilizes a section of radial waveguide. This network has been designed for V-band waveguide. A systematic procedure has been developed for designing the complete network. This design procedure is described and performance data on the actual hardware is presented.

NETWORK CONFIGURATION

The basic configuration of the N-way divider/combiner has one standard rectangular waveguide input port and N symmetric waveguide output ports located in one plane and directed radially outward from the center. The input port must be well matched and the network should have low insertion loss over the required bandwidth. The approach to developing this network is to first make a transition from the input waveguide to a coaxial line which has circular symmetry. Next, a transition is made from the coaxial line to a circular parallel plate radial line in the TEM mode, which also has circular symmetry. Finally, a transition is made from this radial line to the N rectangular waveguide ports.

The development of the N-way divider/combiner network, therefore, consists largely of three tasks, each of which concerns the impedance matching of junctions. These are: (1) the matching of the input waveguide to the coaxial line; (2) the matching of the coaxial line to a circular parallel plate radial line[3]; and (3) the matching of the parallel plate radial line to the N waveguide ports symmetrically placed about the radial line.

NETWORK CONSTRUCTION AND MEASURED RESULTS

The network which is described has been designed for a center frequency of 60 GHz and for V-band waveguide. A V-band back-to-back coaxial-to-rectangular waveguide transition test fixture was fabricated along with a variety of pairs of matching element beads. These beads could be placed at each of the two ends of the coaxial center conductor protruding into the two waveguides. The configuration of this test fixture is shown schematically in Figure 1. A suitable matching element bead configuration was developed by evaluating matching beads of different dimensions and at different depths into the waveguide, and by varying the sliding-short adjustment while looking for wideband, low insertion loss from the test fixture. The insertion loss and return loss of this test fixture were measured by means of a V-band scalar transmission/reflection test set. Figure 2 shows the results of the insertion loss measurement of this fixture using the final matching element that was developed.

Figure 3 shows the configuration of a radial waveguide test fixture. It was not possible to measure directly on the single-pass insertion loss through the test fixture because of the lack of a practical means of actually measuring the power carried by the radial line mode. The return loss at the waveguide-to-coaxial line input can be measured directly. The parallel plate radial waveguide was terminated with tapered elements of microwave absorbing material placed around the periphery of the radial waveguide. A well-terminated condition of this radial TEM mode was confirmed. The coaxial-to-radial waveguide transition was matched by developing a suitable matchign bead by an experimental procedure similar to what was done for the development of the matching bead for the coaxial-to-rectangular waveguide transition. Again, wide bandwidth and low VSWR were obtained from this transition as measured on this second test fixture. Results are shown in Figure 4. A double-pass measurement of the overall insertion loss was made. This consisted of placing a metallic shorting ring in the radial line region, and then measuring the

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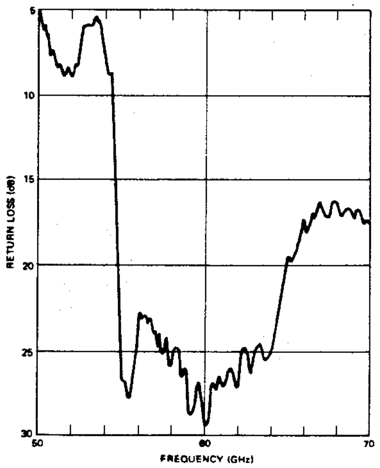

Figure 4. Return loss for an optimized V-band coaxial-to-radial waveguide transition test fixture in which tapered ECCOSORB loads are placed around the periphery of the radial line to terminate the radial line mode.

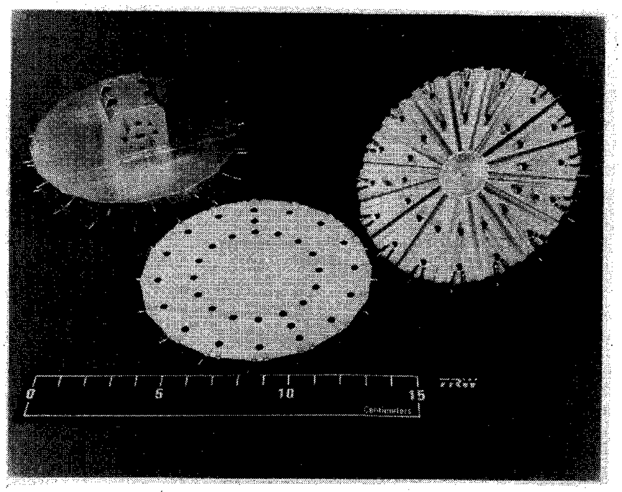

Figure 5. 16-Way V-band radial line divider/combiner network.

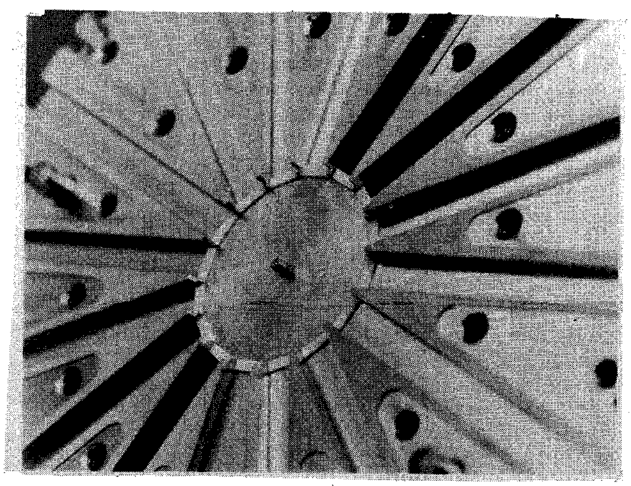

Figure 6. A close-up view of dielectric chip matching elements.

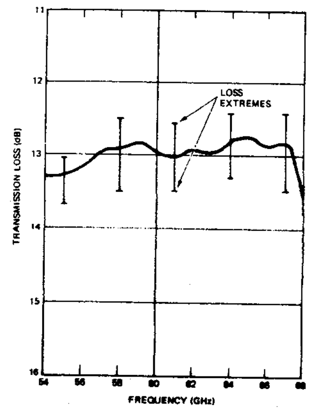

Figure 7. Measured transmission loss from the input (common) port to one of the output (radial) ports of the 16-way radial waveguide power divider/combiner. The ideal transmission loss is 12 dB.

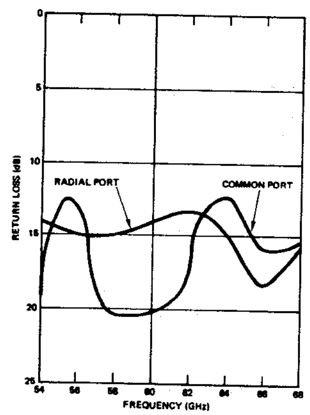

Figure 8. Return loss of both input (common) port and a typical output (radial) port on the 16-way radial waveguide power divider/combiner.

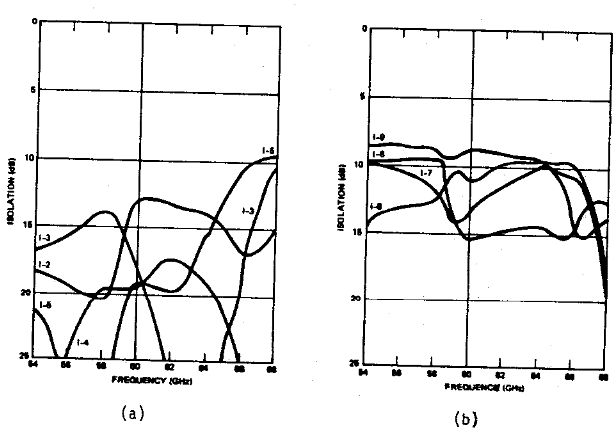

Figure 9. Isolation between output ports on the 16-way radial waveguide power divider/combiner (a) ports 1-2, 1-3, 1-4, and 1-5, (b) ports 1-6, 1-7, 1-8 and 1-9.

return loss at the input waveguide.

The complete 16-way V-band radial waveguide power divider/combiner network is constructed by utilizing the previous two matched transition elements. The impedance matching of the radial waveguide to the 16 symmetrically-placed rectangular waveguides on the final hardware was done by means of the symmetric placement of a set of uniform dielectric chips near the interface of the radial waveguide and the array of rectangular waveguide. A photograph of the final hardware is shown in Figure 5. A close-up view of these dielectric chip matching elements is shown in Figure 6.

Excellent results have been achieved from the final unit. An insertion loss of 1±0.3 dB for the 16 power division coefficients and a return loss at the input port better than 12 dB over the 55-67 GHz frequency range was measured. The average power division coefficient of the 16 output ports is plotted vs frequency in Figure 7. The power imbalance over the output ports is ±0.6 dB. This power imbalance is probably a result of imperfections in the machining of the unit and/or of the matching elements. Figure 8 shows the return loss of input port and a typical output port of this network. Isolation coefficients between output ports have also been measured. Lowest isolation is observed between directly opposing output ports. Results of the measurements of the isolation coefficients of this power divider/combiner are presented in Figure 9.

CONCLUSIONS

A 16-way radial waveguide power divider/combiner for a 60 GHz center frequency shows a good input match and low insertion loss over wide bandwidth. This power divider/combiner network is suitable for applications such as the power combining of solid state amplifier modules, and also for phased array antennas. For the power combining of IMPATT amplifier modules, the use of external ferrite components will be necessary to obtain sufficiently high module-to-module isolation.

ACKNOWLEDGMENT

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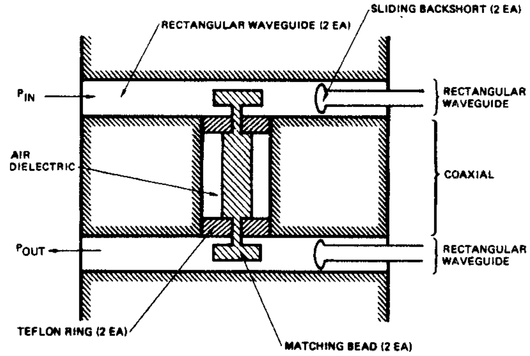

Figure 1. Back-to-back waveguide to coax test fixture for developing a low insertion loss, low VSWR V-band waveguide to coax transition.

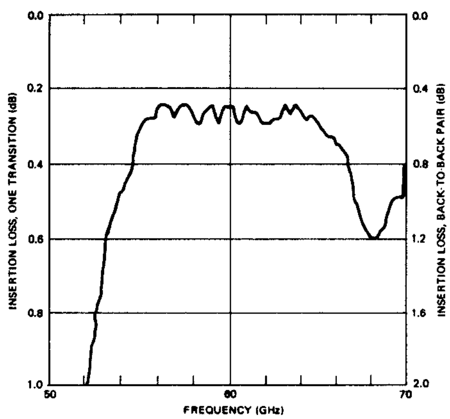

Figure 2. Insertion loss of the V-band symmetric back-to-back waveguide-to-coax test fixture after a suitable matching bead was developed.

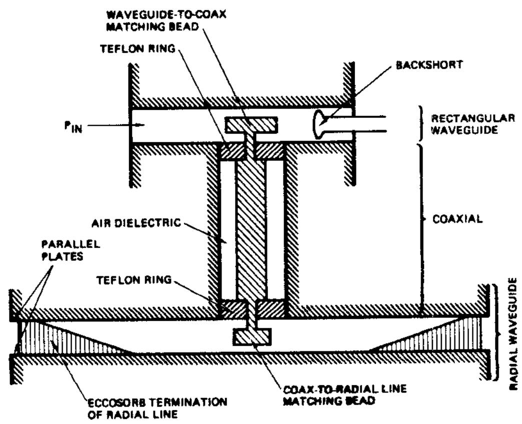

Figure 3. Test fixture for developing a matched V-band coax-to-radial line transition. Upper section is the matched waveguide-to-coax transition previously developed.