AN 18 GHz 8-WAY RADIAL COMBINER

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ABSTRACT

This paper describes a 16 to 20 GHz 8-way radial microstrip combiner with transitions to WR42 waveguide. It demonstrates greater than 20% bandwidth and insertion loss of only 0.8 dB. Excellent phase and amplitude balance has been achieved.

Introduction

A combiner is a useful tool for enhancing the power output of an amplifying system beyond the current capabilities of a single amplifier.

The radial combiner is an efficient type of combiner for achieving this. It can combine any number of amplifiers in one stage in contrast to an arrangement of planar binary symmetric hybrids such as Wilkinson combiners or Lange couplers. It also has less loss than either of the above combiners or the fork hybrid (reference 1) by virtue of its shorter interconnecting lines. Due to its symmetry it also has good amplitude and phase balance.

Fabricated combiners have been described previously. Reference 2 describes a 12-way radial combiner centered at X-band. Reference 3 describes an X-band 6-way combiner using halfwave long radial microstrip lines and also one using uniform lines with halfwave lines connecting to the isolating resistors.

This paper describes for the first time an 18 GHz 8-way radial microstrip combiner with transitions to WR42 waveguide. It demonstrates greater than 20% bandwidth and insertion loss of only 0.8 dB. Excellent phase and amplitude balance has been achieved.

Design Background

The schematic of the combiner is shown in Figure 1. It comprises eight exponentially tapered transmission lines that connect together at the center to form the common port and are bridged at the radial end by resistors. Identical matching networks on the radial ports match to 50Ω and the common port is also matched to 50Ω.

Figure 2 shows computed curves of the combiner radial port input impedance $Z_R = (R_R + jX_R)$ and common port input impedance $Z_C = (R_C + jX_C)$ when the radial ports are matched. The parameters are plotted as a function of the taper fractional wavelength (ℓ/λ_T), taper characteristic impedance (Z_2) at the radial end and isolating resistor (R_I). The taper characteristic impedance at the common end is set at 100Ω. The taper wavelength λ_T is related to the uniform line wavelength λ by:

$$\lambda_T = \frac{\lambda}{\sqrt{1-p^2}}$$

where p, the taper rate is given by:

$$p = \frac{\log_e (Z_1/Z_2)}{4\pi\ell/\lambda}$$

Note that:

1.) The common port input resistance R_C is largest at a ℓ/λ_T value of approximately 1/4.

2.) R_C is largest for a lower value of isolating resistor R_I and higher value of Z_2.

3.) Radial port resistance (R_R) varies more slowly with frequency for a lower value of R_I.

4.) Radial port reactance is lower for a lower value of R_I.

The optimum choice of line length is therefore quarter-wave, with a high value of Z_2 and low value of R_I.

Choice of Dielectric

Beryllia was chosen as the dielectric over Alumina for two reasons.

1.) By virtue of its lower dielectric constant, the input impedances at the common and radial ports are higher and thereby simplifying matching.

2.) The thermal conductivity of Beryllia is approximately ten times that of Alumina, and consequently, heat dissipated in the resistors is conducted better to the ground plane.

Theoretical Design

A computer program was written for the combiner, in which the matching circuit, tapered line and resistor details were inputted. The program calculated return loss of all ports, transmission loss and isolation between radial ports. The program took into account in addition, the coupling between the tapered lines and parasitics of the resistors. The tapered line length was chosen at a quarter wave and resistance value at 70Ω. Since the tapered lines must bridge to the resistors, their widths at the low impedance end was set. The even mode characteristic impedances at the narrow and wide ends of the taper were at 96Ω and 27Ω, respectively. Because of the coupling between the tapered lines, their odd mode impedances were lower than these values.

The common and radial port matching circuits were varied on the computer until a reasonable match was obtained on all ports between 16.0 and 20.0 GHz. No effort was made to adjust the parameters for improvement of radial to radial port isolation. The predicted response of the combiner is shown in Figure 3. Predicted return loss is greater than 11 dB. Radial to radial port isolation varies between 15 dB and 26 dB. The transmission calculations did not take into account the dissipative loss of the microstrip conductors.

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Construction

Figure 4 shows the microstrip outline. The substrate is 0.025 inch thick Beryllia. The radial port matching consists of 29.5Ω lines of length 0.397λ at the center frequency. Microstrip lines in 0.42 inch wide troughs connect from the radial ports of the combiner to the microstrip-to-waveguide transitions, which are stepped ridge waveguide types. This design was chosen in order that the waveguide resonance of the combiner cavity was above the working frequency.

The common port coaxial line transition to waveguide is a capacitive probe, the design of which is described in Reference 4.

Measured Performance

The measured results of the final combiner are shown in Figure 5. The common and radial port return losses are tuned to peak around 18.5 GHz. The maximum VSWR over a 20% bandwidth is better than 2:1. The transmission loss is 0.8 dB at band center of which 0.5 dB can be attributed to the actual combiner substrate dissipation, and the remaining 0.3 dB is due to different transitions. The amplitude unbalance of the eight transmission paths is between 0.25 and 0.8 dB over the range 16 to 20 GHz. The phase unbalance is ± 11° at 18 GHz.

Conclusions

This paper has described a radial combiner designed for 18 GHz. It has low transmission loss, low amplitude and phase unbalance and reasonably good radial to radial port isolation.

Acknowledgments

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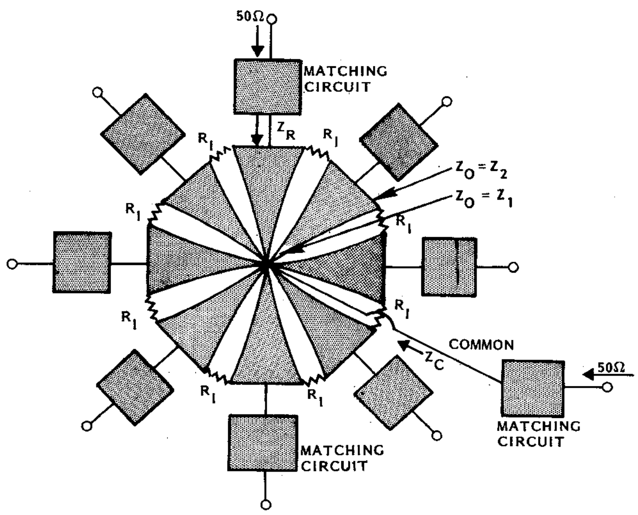

Figure 1. Radial Combiner Schematic

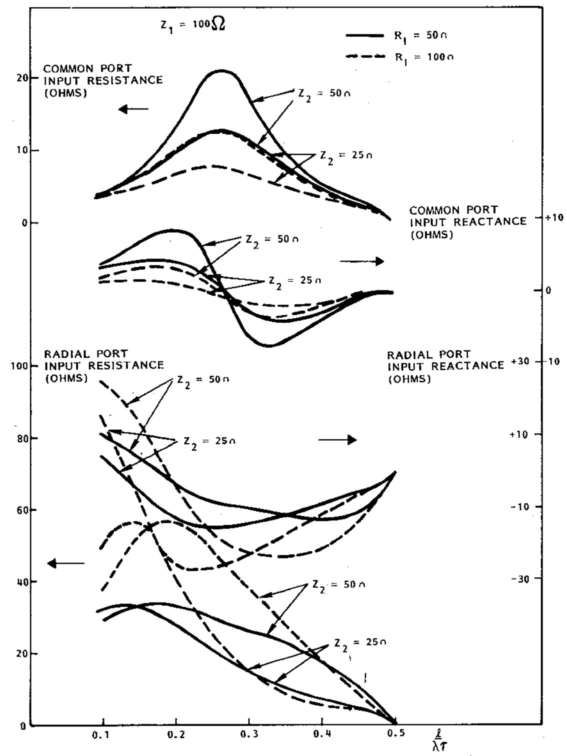

Figure 2. Combiner Computed Impedance Data

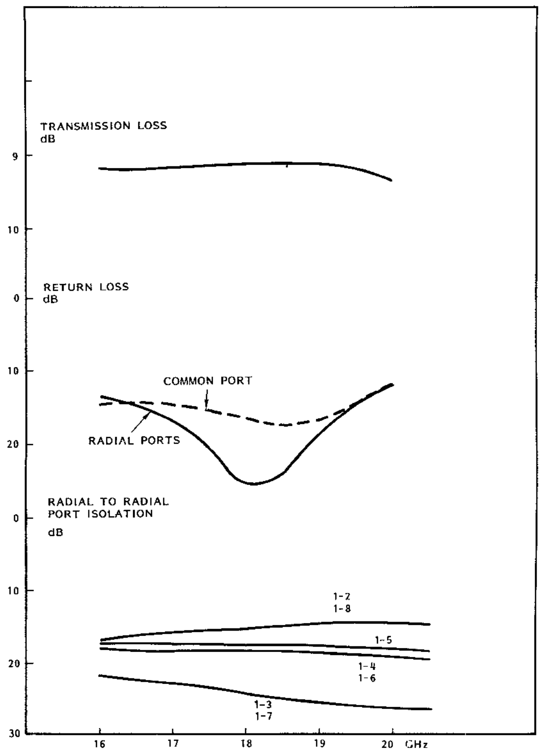

Figure 3. Combiner Predicted Performance

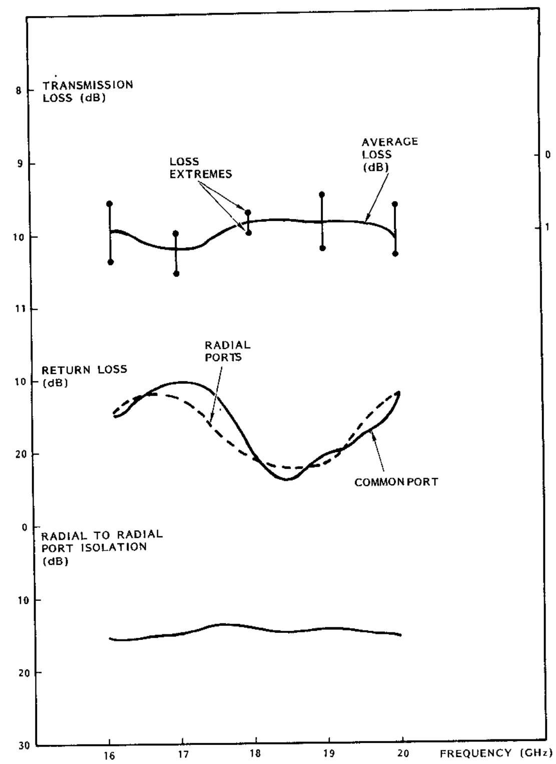

Figure 5. Combiner Measured Performance

Substrate: Beryllia 0.025 thick

Dimensions in Inches

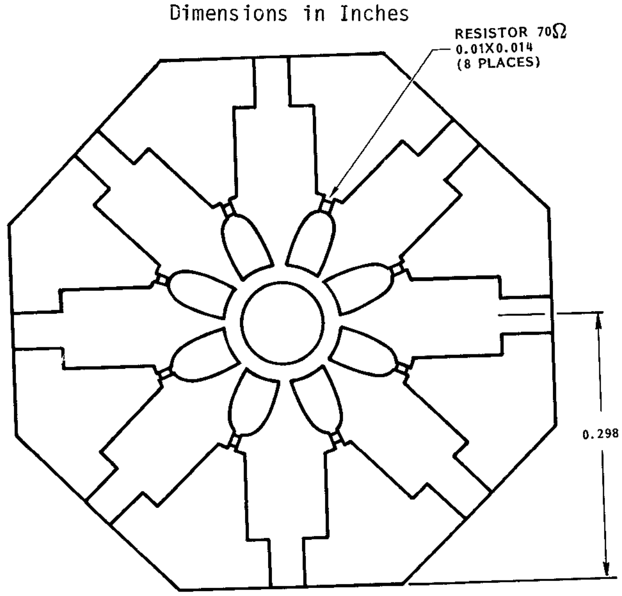

Figure 4. Combiner Microstrip Outline