A BROADBAND PLANAR N-WAY COMBINER/DIVIDER*

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Abstract

The experimental and predicted performance of the new broadband planar N-way combiner/divider is presented. The advantage of this combiner/divider over those previously published is that it can be realized in a planar structure. Experimental data on the planar combiner/divider for N=4 and N=7 indicates an average isolation of 20 dB between the N ports from 8 to 12 GHz, and compares favorably with analytic predictions.

Introduction

Many current applications require microwave solid-state power sources with output power levels which exceed the capability of a single semiconductor device. N-way combiners/dividers may be used in such applications to combine the output power of several devices or amplifiers.

This approach to the generation of microwave power has been limited by the absence of an N-way combiner/divider which permits combination of active two-port networks with all interconnections lying in the same plane. Such a planar structure would make it possible to realize higher power levels by combining several amplifiers in a single microstrip circuit, as shown in Figure 1.

Most of the combiners/dividers described in the literature[1, 2, 3, 4, 5, 6] are either generalizations or variations of the Wilkinson[1] N-way combiner/divider. None of them can be realized with all interconnections in the plane of circuit for values of N>2 because they require either a resistive star[1] or a star of transmission lines with multi-layer construction[2]. Consequently, planar combiners/dividers must presently be realized using corporate structures of 2-way Wilkinson, split-tee and hybrid circuits. The disadvantage of this approach is that the maximum value of N is limited by the physical size and high loss of the corporate structure.

The proposed combiner/divider is realizeable in a planar structure and exhibits low loss and nominal isolation of up to 20 dB between the N-ports over a fractional bandwidth of 40 percent.

For the sake of clarity, the single port and the N-ports will be referred to as input and output ports respectively.

Circuit Description

A schematic diagram of the planar combiner/divider is shown in Figure 2. The 50Ω input line of the combiner/divider is split into N identical transmission lines of characteristic impedance ZO, each a quarter wavelength long at the center band frequency. Adjacent output ports are interconnected with equal value resistors (RO). Values of ZO and RO are selected based upon a tradeoff between the input/output port VSWR and the uniformity in isolation between the N output ports.

It was found that the values of ZO and RO which produced the lowest input and output VSWR (less than 1.05 at the center band frequency) resulted in a relatively wide variation in isolation between the various output ports, ranging from 10 dB to 28 dB. The distribution of isolation between the output ports can be made more uniform by proper selection of ZO to RO with a corresponding increase in input and output VSWR.

Computer analysis has shown that a maximum isolation of 20 dB can be achieved with a uniformity of ±1 dB. The variation in isolation as a function of frequency is independent of the uniformity achieved between the N output ports and varies less than ±1 dB over a fractional bandwidth of 40 percent.

Two combiner/divider circuits were built for values of N=4 and N=7 to verify that the structure was capable of providing a uniform interport isolation with a nominal value of 20 dB. The circuits were realized in microstrip employing .03125 in. duroid substrate material and utilized 150Ω transmission lines. Chip resistors of 268Ω (N=4) and 350Ω (N=7) capable of 300 mW dissipation were connected between adjacent 50Ω output lines.

Photographs of the 4-way and 7-way combiners/dividers are shown in Figures 3 and 4 respectively.

Predicted and Experimental Results

The 4 and 7-way combiner/divider circuits described above, were evaluated using the HP 8542B Automatic Network Analyzer.

Measurements on the 4-way combiner/divider revealed a nominal isolation of 19.9 dB ±2.5 dB between the output ports over the frequency range of 8 to 11 GHz. From 11 to 12 GHz the nominal isolation remained approximately the same, however, the uniformity degraded to ±5.5 dB. Measurements on the 7-way combiner/divider from 8 to 11 GHz indicated a nominal isolation of 23.0 dB ±2.4 dB while the variation in isolation increased to ±6.5 dB between 11 and 12 GHz.

As indicated in Figures 5 and 6, the isolation performance as a function of frequency compares very favorably with computer predictions. The variation in isolation between the output ports was higher than the predicted value of ±1 dB. Because of availability, the values of RO used in the combiners/dividers did not correspond to the optimum values for maximum uniformity in isolation. This discrepancy in the uniformity of isolation is therefore attributable to the RO values used.

The predicted input VSWR for both combiners is shown in Figures 2 and 3 and corresponds to a mismatch loss of 0.1 dB to 0.87 dB which is not unreasonable for combining amplifiers. The input VSWR initially observed was unacceptable and was attributed to discontinuities at the substrate/housing interface in the area of the input connector. The input VSWR data presented in Figures 2 and 3 was achieved by placing a piece of high dielectric material on the 50Ω input line, over the point of the discontinuity. This improvement of the VSWR to well below predicted levels implies that significant improvement in input VSWR can be obtained by the addition of a suitable matching structure.

* Patent Pending

The predicted output VSWR was 2.14 to 2.17 for N=4 and 2.77 to 2.88 for N=7. Measurements on the 4-way combiner/divider indicated an output VSWR between 1.2 and 2.7. The experimental output VSWR for N=7 was 1.7 to 3.7. The discrepancy between predicted and experimental results was also attributed to discontinuities at the substrate/housing interface in the area of all output connectors.

Conclusions

Results have been presented for a new N-way combiner/divider which is well suited for the generation of microwave power through the combination of several amplifiers. Since the combiner/divider offers the unique advantage of planar construction, the combination of amplifiers can be realized in microstrip or stripline. Theoretical results have shown that values of ZO and RO which are optimized for the lowest input and output VSWR result in the highest variation of isolation between the N output ports. The minimum isolation exceeds 10 dB which in the circuit of Figure 1 would provide graceful degradation in the case of a device failure.

ZO and RO can also be optimized for maximum uniformity of isolation between the output ports with a corresponding increase in input and output VSWR.

The performance of the combiner/divider is acceptable over 40 percent bandwidth and was verified at X-band. The bandwidth can be increased by the addition of transmission line/resistor sections to each of the N output ports.[7]

Acknowledgements

The authors express their sincere appreciation to Mr. S. Fumia for his valuable contributions in the area of artwork generation.

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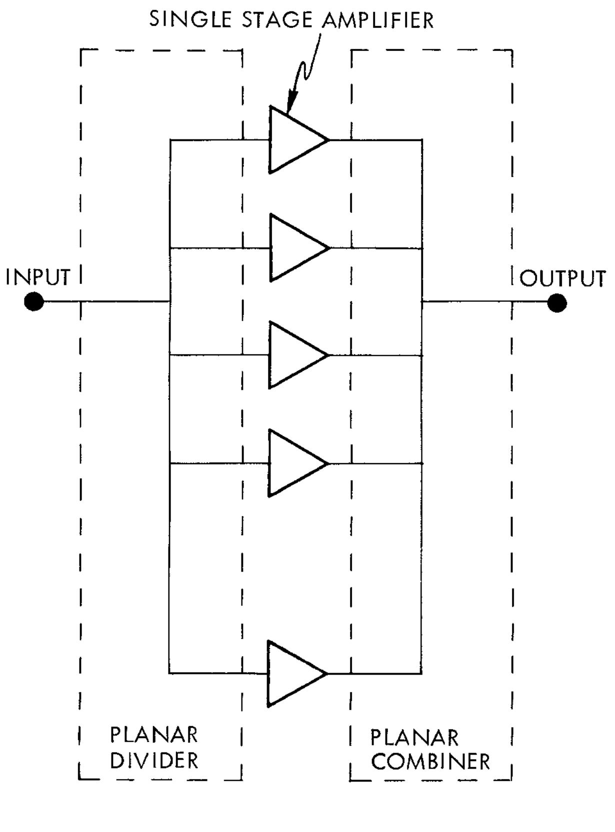

Figure 1 - Application of Planar N-Way Combiner/Divider

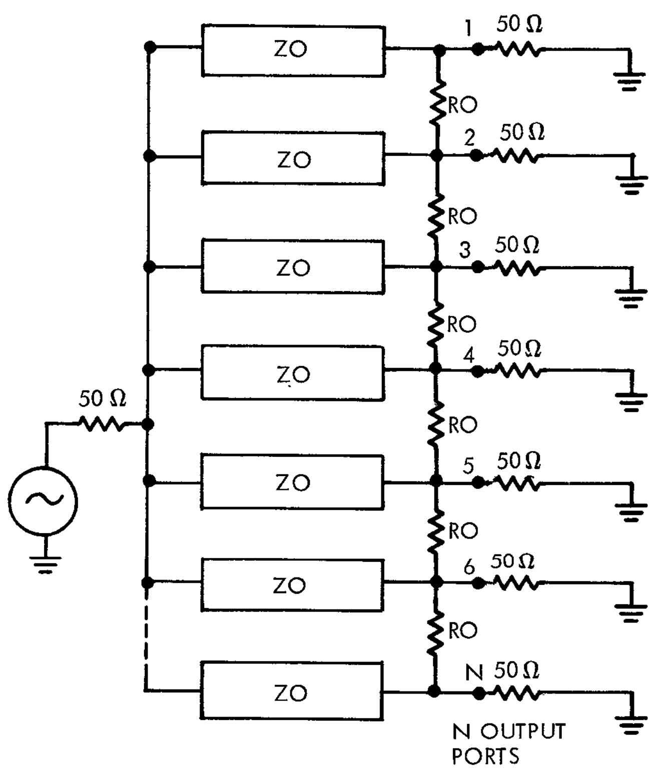

Figure 2 - Broadband Planar N-Way Combiner/Divider

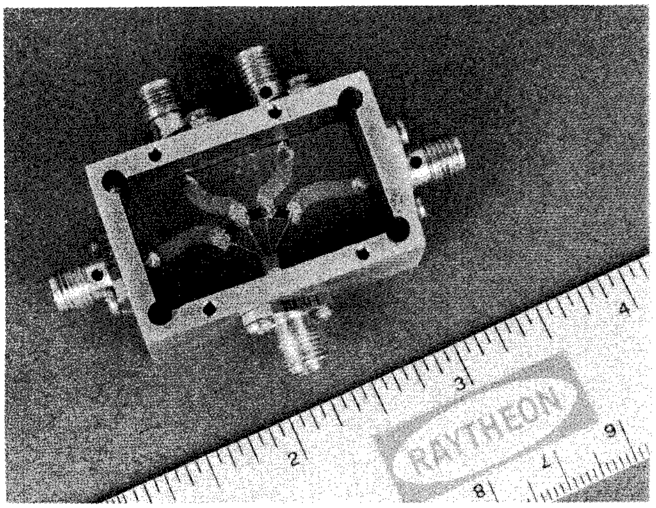

Figure 3 - 4-Way Broadband (8-12 GHz) Planar Power Combiner/Divider

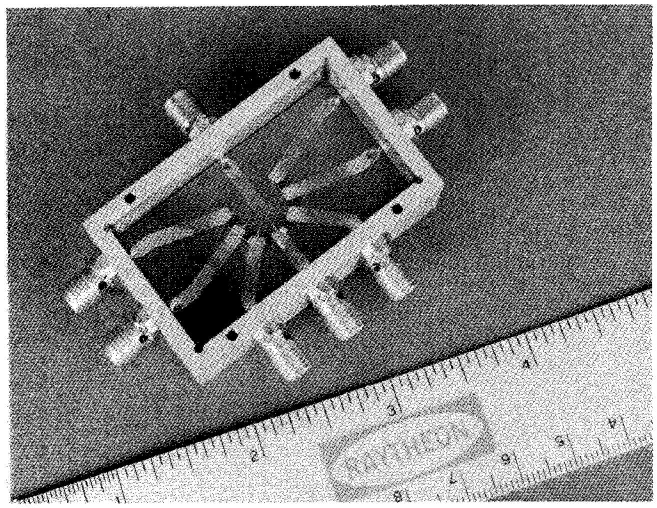

Figure 4 - 7-Way Broadband (8-12 GHz) Planar Power Combiner/Divider

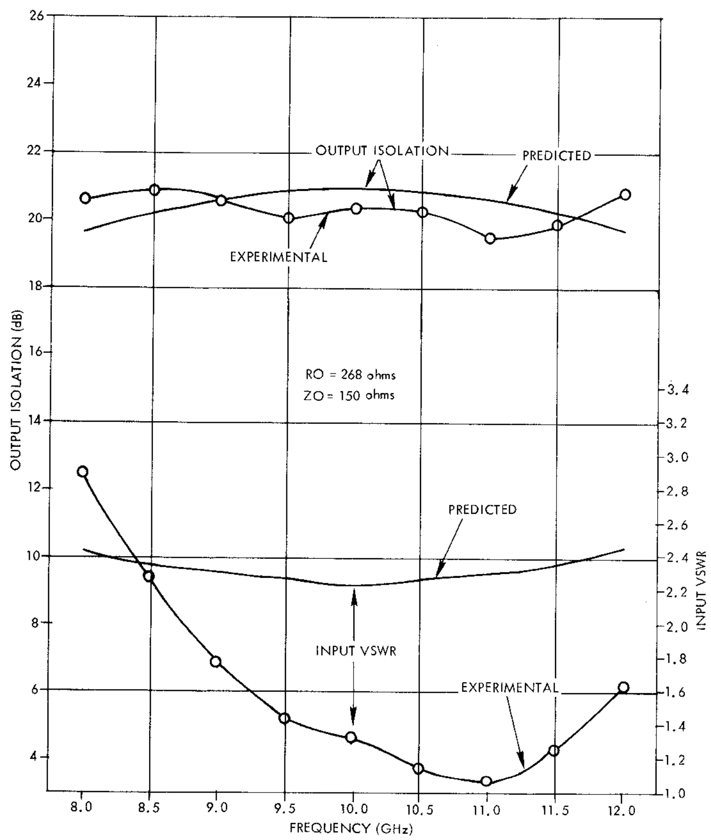

Figure 5 - 4-Way Planar Combiner/Divider
Experimental and Predicted Data for Input VSWR and Average Output Isolation* versus Frequency

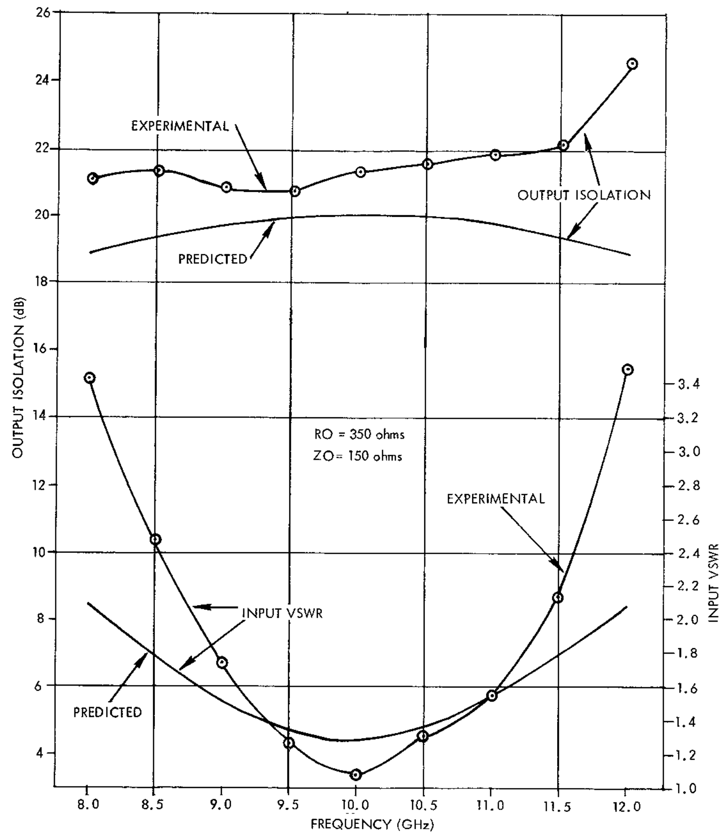

Figure 6 - 7-Way Planar Combiner/Divider
Experimental and Predicted Data for Input VSWR and Average Output Isolation* versus Frequency

* Isolation Data Corrected for Mismatch Loss