A COMPACT SEVEN-WAY POWER DIVIDER FOR SATELLITE BEAM FORMING NETWORKS

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ABSTRACT

A new seven-way power divider/combiner is described. This divider meets the physical and performance requirements needed to implement a novel beam forming network for a communication satellite. Theory, fabrication, and experimental results on two different realizations are presented.

Introduction

An important configuration of a multibeam antenna requires that the radiating elements be excited in clusters of seven, with most of the power being radiated from a center element and the remainder of the power being divided equally among six surrounding elements(1)-(3). The implementation of this approach makes challenging demands on the design of the beam forming network, particularly in the case of a satellite application where size and weight are prime considerations.

This paper describes a new type of seven-way power divider/combiner which is the key to a novel beam forming network for a communication satellite.

A portion of the proposed beam forming network for a satellite for mobile communications is shown in Figure 1. In this case some ninety -six seven-way power dividers/combiners would be involved in creating forty-six simultaneous receive and transmit beams from the total feed array which is about 2.1x3.6 meters in extent.

In order to conserve size and weight for the beam forming network which services this antenna, a novel idea was conceived for combining two sets of seven-way divider/combiners on a single transmission line circuit layer(1). The key to the successful implementation of this scheme is the ability to form the basic seven-way divider in the very compact form shown in Figure 2. Approximately half of the input power must be delivered to an output port whose axis is parallel to that of the input port, with the remaining power divided equally among six radial ports. Some key requirements for this divider are shown in Table I.

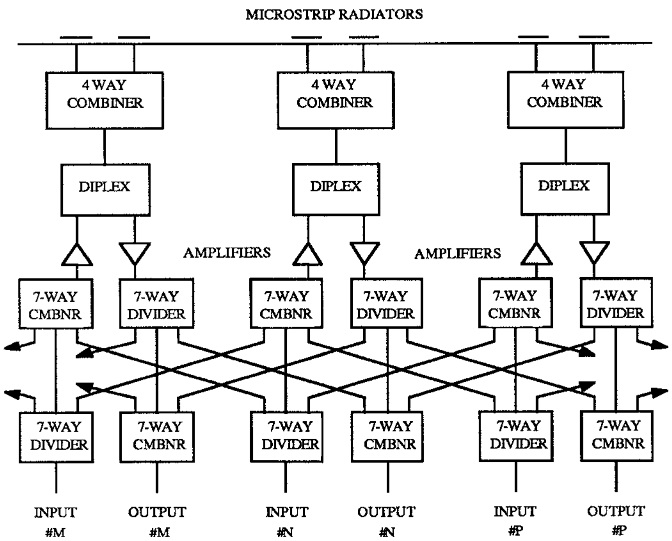

Figure 1 A Portion of the Beam Forming Network for a Satellite for Mobile Communications

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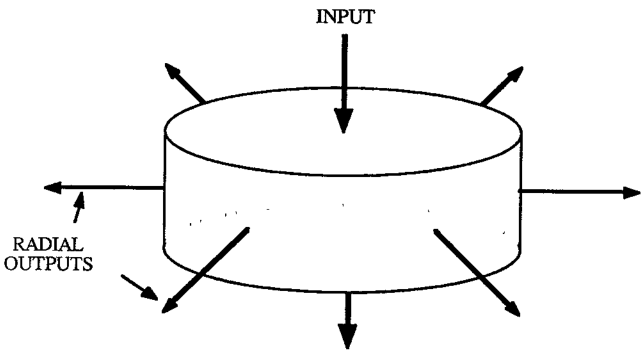

Figure 2 Desired Configuration for the Seven Way Divider/Combiners

Table I - Requirements for Compact Power Divider/Combiner

Frequency-	2% Bandwidth centered at 1.6 GHz
Power Division-	Power to the six radial ports to be 7.5 dB below power to center port
Loss-	Total Dissipation less than 0.7 dB
VSWR-	<1.15:1, all ports
Isolation-	> 20 dB
Size-	Diameter<8.1 cm , Thickness < 0.8 cm

Two realizations of such a seven-way divider have been analyzed, built, and tested. Each approach has particular advantages. Both approaches, and the experimental results obtained with each of them are described in this paper.

Design of Divider #1

The first approach uses six pairs of quarter wavelength long broadside coupled lines as shown in Figure 3. By choosing the appropriate even and odd mode impedances of the coupled lines, the desired power division is obtained and the 50 ohm connections at the radial ports will be transformed to 300 ohms at the input to each of the coupled lines so that the parallel combination of the six lines results in 50 ohm impedance at the center input and output ports. Resistors between the output ports provide isolation.

The divider was constructed using two etched circuits with a ground plane spacing of .20", separated by a layer of dielectric,about .010" thick,using a PTFE substrate with dielectric constant 2.2. In order to closely approximate lumped isolation resistors, the coupled lines were tightly spiraled to minimize the distance between adjacent output ports. A tradeoff was required between accepting degradation due to lengths of transmission line between adjacent output ports and the need to avoid mutual coupling between adjacent coupled lines. The two stripline circuits are mirror images except for a provision for a resistor to ground on the output side, instead of the port to port resistors on the input side. When the two circuits are carefully aligned and separated by the correct dielectric spacing, the proper power division is obtained between the input and output. Figure 4 shows a photograph of the divider.

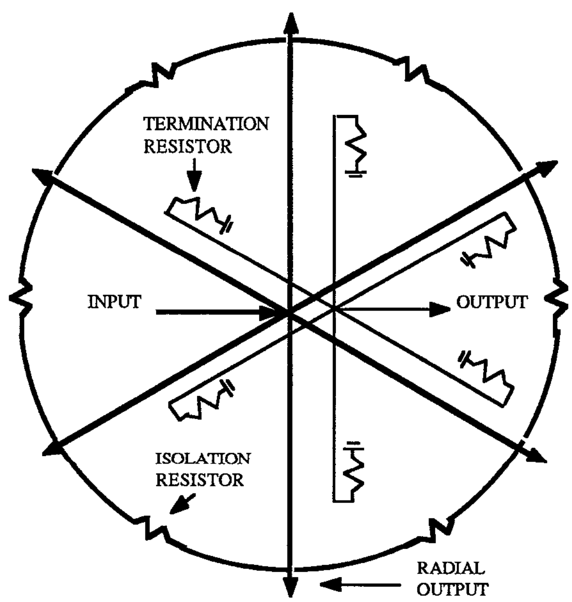

Figure 3 Electrical Configuration of Seven Way Divider #1 Using Six Pairs of Coupled Lines

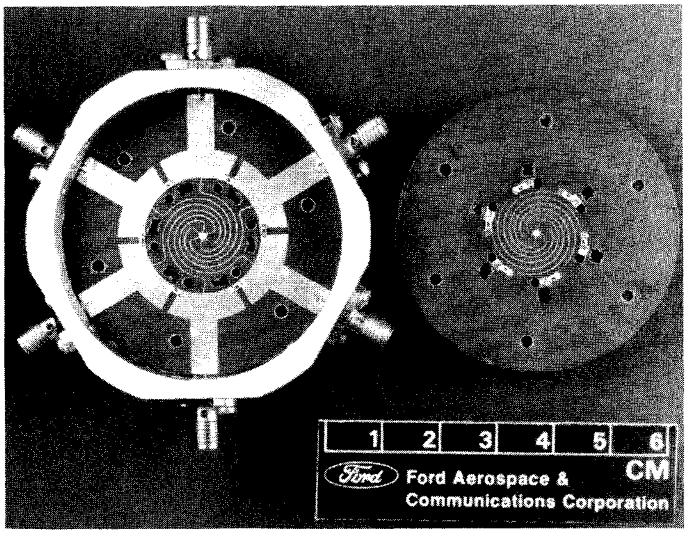

Figure 4 Realized Seven Way Divider #1 Showing Spiraled Coupled Lines

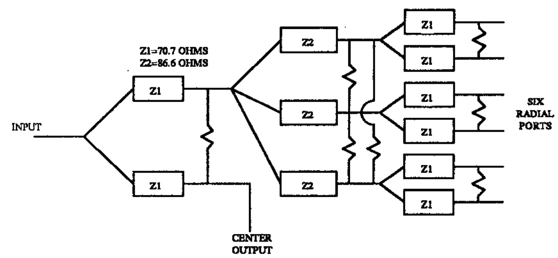

Figure 5 Electrical Configuration of Seven Way Divider #2 Using Multiple Dividing Sections

Design of Divider #2

A second divider was conceived in order to realize higher isolation between radial ports, since a planar divider like the one previously described is fundamentally limited to 17.6 dB maximum isolation(4). Thus, in order to meet the physical requirements and higher isolation, two layers were required. The chosen configuration used three sections of power division. The first was a single Wilkinson (5) two way divider to provide the power split to the output port. Next, a three way radial divider, capable of theoretically infinite isolation(4), was used to feed 3 separate Wilkinson two way dividers which then provided the 6 radial outputs. Each divider had 50 ohm impedance in and out. Figure 5 shows the electrical configuration of this divider.

In realization of the divider, two layers of stripline with .125" ground plane spacing with a dielectric constant of 2.2 were used. In order for the three way divider to work properly, its isolation resistors have to be in close proximity. This requirement resulted in the splitting of the three way divider in two, with the top half splitting three ways from a common center, feeding through to the bottom half and recombining at the center of the bottom half. Critical to achieving good performance with this design is ensuring that all ground planes are closely connected at the feedthrough points. Figure 6 shows a photograph of the divider.

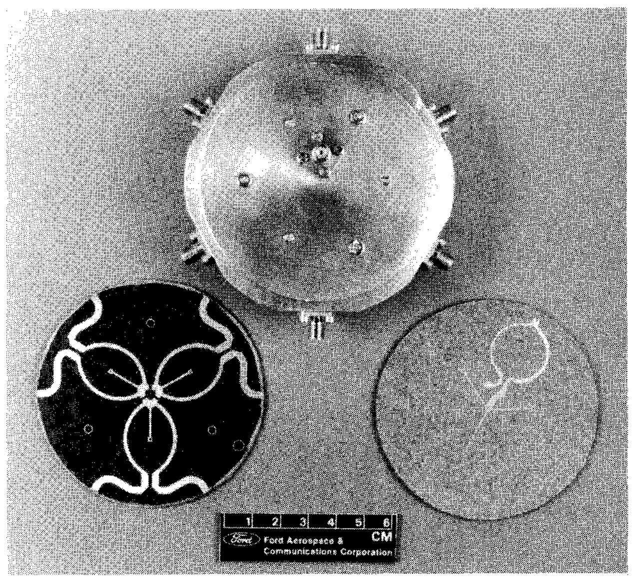

Figure 6 Realized Seven Way Divider #2

Experimental Results

Table II shows the measured worst case performance of each divider. Several iterations were required with the first divider to optimize the coupled line widths. Since they were narrow (~ 7 mil) compared to the substrate thickness, the usual approximations for line impedance were not accurate. The second divider, using separate sections of power dividers proved easier to build and test, because of the straightforward design of its individual sections, the ability to test the sections separately with a properly designed test fixture, and wider line widths. However, it has greater dissipation loss and is larger than the first divider. The higher dissipation loss is due to the longer physical length of the second divider.

Table II - Measured Performance of the Seven Way Dividers

	Measured Data	
Parameter	Divider #1	Divider #2
Frequency	1.6 GHz	1.6 GHz
Loss to Center Output Port	3.25 dB	3.4 dB
Loss to Radial Ports	10.7 to 10.8 dB	10.7 to 11.0 dB
Isolation Between Output Ports	15.3 dB W/C	22.7 dB W/C
VSWR	<1.15:1, Center Port 1.25:1	1.18:1 W/C
Dissipation Loss	.1 dB	.25 dB

Conclusion

Both of the dividers described provide a low loss power division/combination physically compatible with the requirements for a novel satellite beam forming network. The first divider described has the advantages of physical simplicity, circular symmetry, use of a single pair of ground planes, and low loss. If high isolation and easier construction is required the second divider is preferred.

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