DESIGN AND PERFORMANCE OF A WIDEBAND MULTILAYER FEED NETWORK

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ABSTRACT

This paper describes the design and construction of a novel, high performance broadband, stripline, 8x8 port feed network. Hybrid ring couplers with improved performance are used as building blocks. The division of the circuit into two stackable even-mode and odd-mode subcircuits has greatly simplified the realization and the testing of the feed network. Experimental results for various phase modes are presented.

INTRODUCTION

Several microwave applications, such as electronically scanned antenna arrays, phased array receivers, and direction finding systems, require the use of a feed network[1]. A typical feed network (or beam forming network) is usually composed of 2N ports: **N** input ports and an equal number of output ports or radiating elements. A signal introduced at one port produces a specific set of excitations at the output ports. While a signal introduced at another input port results in a different set of excitations. Therefore, each input port of the feeding network is capable of exciting a separate phase mode. By exciting these modes, with appropriate values of amplitude and phase, one can synthesize a specific far field pattern in terms of its constituent Fourier harmonics.

The performance of a beam forming network depends upon the basic components or building block units being used. A typical building block unit could be a 3 dB directional coupler, a magic tee, or a hybrid ring. In this investigation, several types of couplers were considered and an improved hybrid ring coupler was selected.

Ten of these couplers are needed to design an 8x8 port broadband feed network. The packaging constraints dictated that the final design be shieldable and fit entirely within a 3.5 inch diameter circle (a total volume of 5.0 in^3 or less).

Utilizing a stripline design and adopting a multilayer topology the desired product has been realized. The feed circuit is divided into two subcircuits, even-mode subcircuit and odd-mode subcircuit. The even-mode subcircuit is composed of seven hybrid ring couplers and capable of independently producing four even phase-modes $m=0,\pm2,+4$. The second subcircuit encompasses three hybrid ring couplers and together with the first layer produces the odd phase modes $m=\pm1,\pm3$. Both circuits are etched on separate soft copper-clad substrates and connected together via short sections of 50Ω coaxial lines.

In summary, many of the cogent issues surrounding the hardware realization and testing of a wideband, compact, shieldable RF circuit have been addressed. Issues surrounding fabrication techniques employed in the wideband methods are also discussed.

DESIGN OF THE FEED NETWORK

The microwave feed network needed in our application has 16 ports: 8 input ports and 8 output ports and is matched at all ports. The desired performance of this network is outlined in Table I. This table describes the resulting excitation at each output port for all of the desired eight modes. A block diagram of the 8x8 port feed network is shown in Figure 1.

Table I. Desired Performance

MODE DESIGNATION	OUTPUT PORT EXCITATIONS							
	1	2	3	4	5	6	7	8
0	+1	+1	+1	+1	+1	+1	+1	+1
+1	+1	$+\frac{1}{\sqrt{2}}$	0	$-\frac{1}{\sqrt{2}}$	-1	$-\frac{1}{\sqrt{2}}$	0	$+\frac{1}{\sqrt{2}}$
-1	0	$\frac{1}{\sqrt{2}}$	+1	$+\frac{1}{\sqrt{2}}$	0	$-\frac{1}{\sqrt{2}}$	-1	$-\frac{1}{\sqrt{2}}$
+2	+1	0	-1	0	+1	0	-1	0
-2	0	+1	0	-1	0	+1	0	-1
+3	+1	$-\frac{1}{\sqrt{2}}$	0	$+\frac{1}{\sqrt{2}}$	-1	$+\frac{1}{\sqrt{2}}$	0	$-\frac{1}{\sqrt{2}}$
-3	0	$-\frac{1}{\sqrt{2}}$	+1	$-\frac{1}{\sqrt{2}}$	0	$+\frac{1}{\sqrt{2}}$	+1	$+\frac{1}{\sqrt{2}}$
+4	$+\frac{1}{\sqrt{2}}$	$-\frac{1}{\sqrt{2}}$	$+\frac{1}{\sqrt{2}}$	$-\frac{1}{\sqrt{2}}$	$+\frac{1}{\sqrt{2}}$	$-\frac{1}{\sqrt{2}}$	$+\frac{1}{\sqrt{2}}$	$-\frac{1}{\sqrt{2}}$

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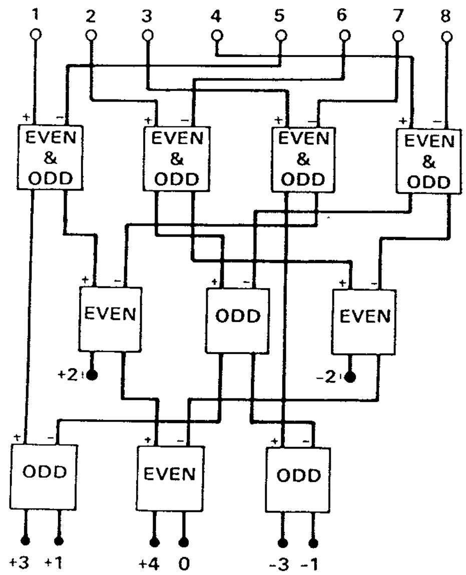
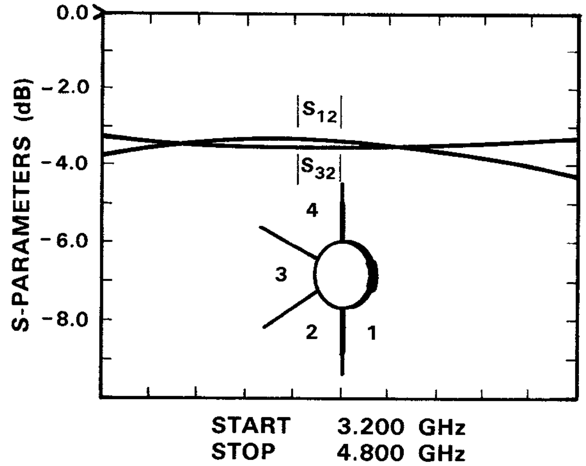
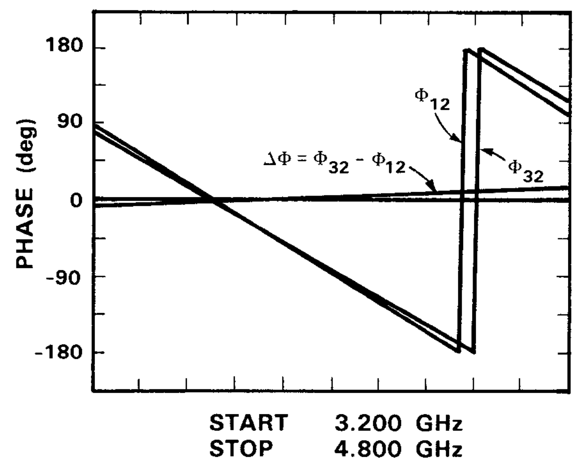


BLOCK DIAGRAM OF THE FEED NETWORK

Figure 1



(a) Amplitude characteristics

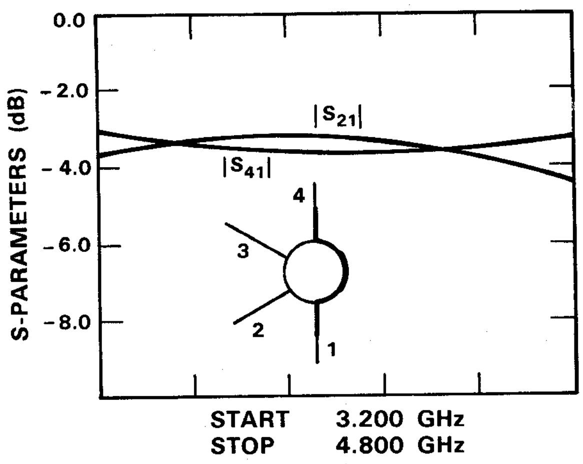


(b) Phase characteristics

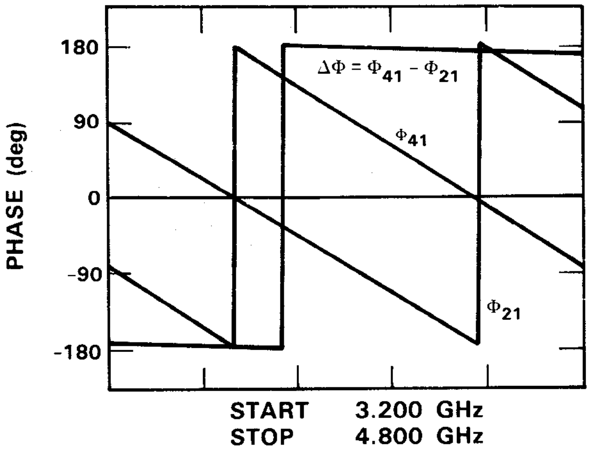
Fig. 2. Amplitude and phase characteristics of the sum ports.

The bandwidth of this network is strongly dependent on the performance of the basic building block element being used, namely the hybrid ring coupler. Conventional hybrid ring couplers have a narrow bandwidth of the order of 10% of the design frequency. However, there are alternate(2) hybrid ring versions which are less frequency dependent. The simplest of these alternatives is a broadband hybrid ring. The bandwidth of a conventional hybrid ring can be broadened simply by dividing the three-quarter-wave equal admittance section on the ring of the conventional version into unequal admittance sections of appropriate value and by adding quarter-wave transformers to the feeding ports(3). An experimental model has been constructed and tested. Its performance is outlined in Figures 2 and 3. As it can be seen from the curves, a useful bandwidth (in terms of ±0.2 dB amplitude imbalance and ±5° phase variation) of about 35% has been achieved.

As we proceeded in the design of the feed network, further decisions needed to be made. A stringent size requirement dictated the use of a stacked or a multilayer topology and a high dielectric constant substrate (RT/duroid 6006, ε_r=6). The overall feed network configuration consists of two stripline layers. The first layer is called the even mode layer and it houses the even mode (m=0,±2,+4) circuit as shown in Figure 4. This layer consists of seven hybrid rings interconnected together as outlined by the block diagram. The second layer, also shown in Figure 4, encompasses three hybrid rings which together with the first layer produces the odd mode (m=±1,±3) circuit. Both layers are then stacked on top of each other yielding a multilayer circuit with all the interconnections running vertically, from one layer to the other. The lengths of the coaxial line interconnections are carefully matched in the design so that the overall phase balance of the feed network is retained.



(a) Amplitude characteristics



(b) Phase characteristics

Fig. 3. Amplitude and phase characteristics of the difference ports.

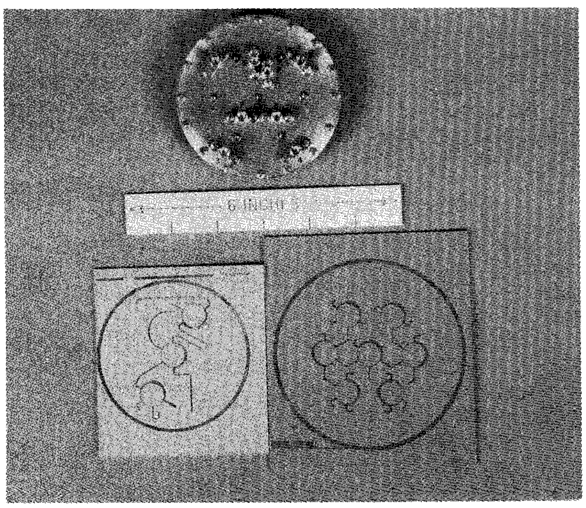


Fig. 4. Photograph of the feed network

EXPERIMENTAL RESULTS

Scattering parameters were measured to characterize the designed feed network. The variation of amplitude and phase was measured over the frequency range 3.2 GHz to 4.8 GHz with an HP8510 Automatic Network Analyzer. Curves describing the amplitude variation with frequency (at the eight output ports) of the m=0,+1,-1,+2, and -2 modes are outlined in Figures 5 through 9, respectively. A maximum variation of ±0.4 dB in amplitude and ±7° in phase was achieved. Return loss of better than 15 dB has been realized and mode isolation of better than 28 dB was obtained. Indeed, the isolation between modes is a function of the isolation of the individual couplers and the number of power divisions taking place. Figure 10 demonstrates the mode isolation between the m=0,+2, and -2 modes.

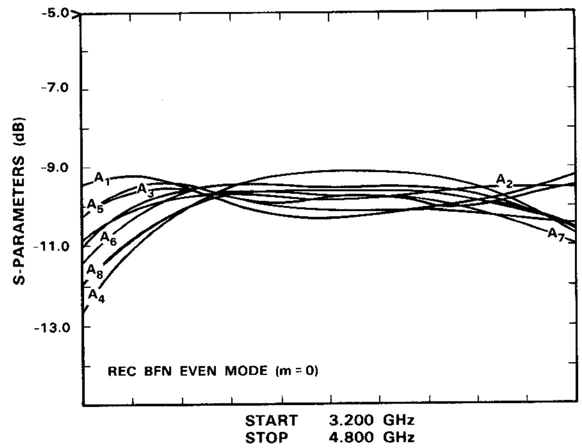


Fig. 5. Amplitude characteristics of the m=0 mode.

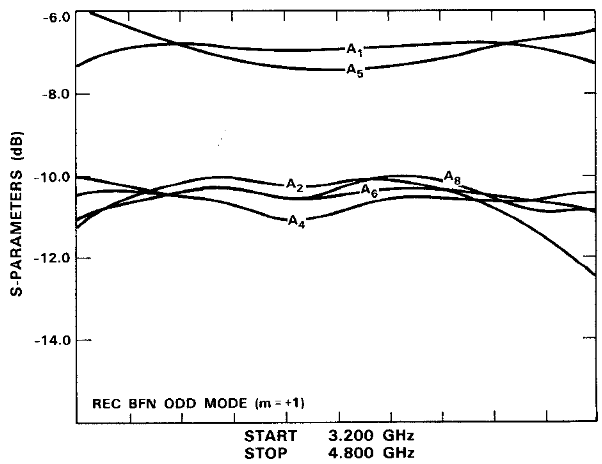


Fig. 6. Amplitude characteristics of the m=+1 mode.

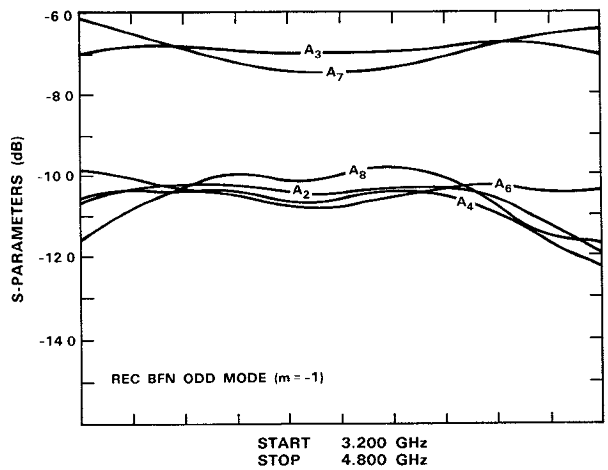


Fig. 7. Amplitude characteristics of the m=-1 mode.

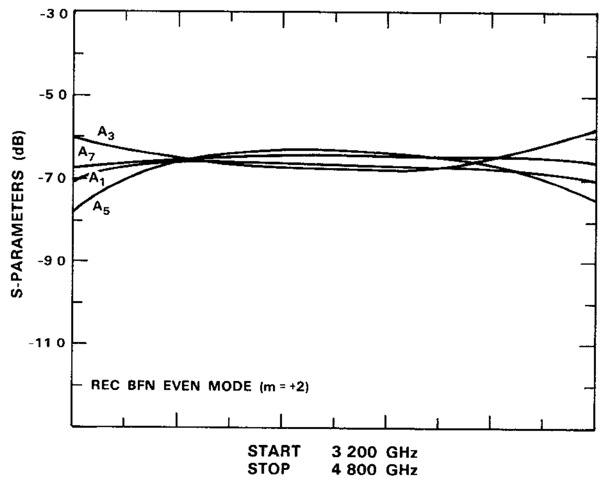


Fig. 8. Amplitude characteristics of the m=+2 mode.

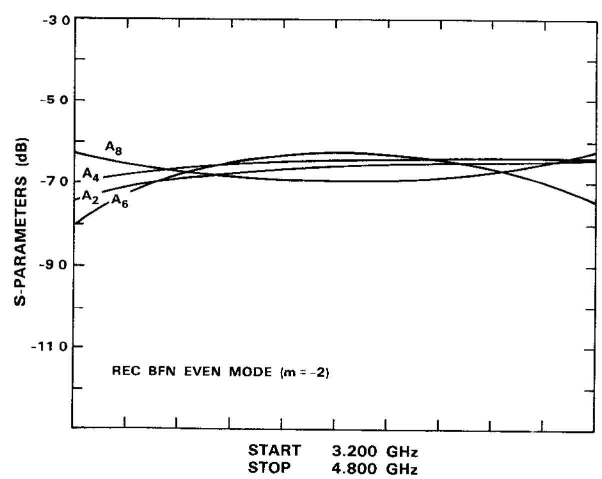


Fig. 9. Amplitude characteristics of the m=-2 mode.

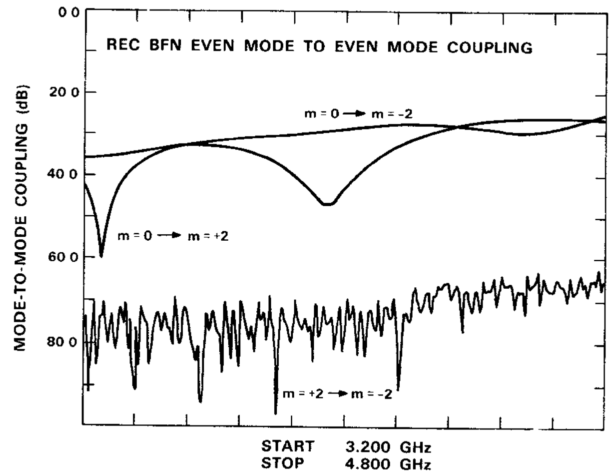


Fig. 10. Mode-to-mode coupling characteristics of the feed network.

CONCLUSIONS

A broadband multilayer feed network has been developed. The wideband performance of the basic component has led to an improvement in the performance of the overall circuit. The division of the circuit into two subcircuits, even mode and odd mode, has tremendously simplified the construction and testing tasks. The results are only a preliminary one and better performance can be achieved.

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