VI-1. MONOPULSE COMPARATOR NETWORKS FOR MULTIOCTAVE OPERATION

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Introduction. Antennas with wide bandwidths have been exploited for many applications. Log-periodic and spiral radiators are examples of structures that can be designed to cover any desired bandwidth. One of the most important uses for these antennas is as feed systems for focusing objectives, typified by the parabolic reflector.

Many systems are required to operate in an automatic tracking mode, and various sum-difference monopulse techniques can be used for this purpose. The monopulse comparator networks required for these systems generally consist of particular types of microwave components, that is, hybrid junctions and possibly fixed phase shifters. The subject of this paper is the design of comparators to operate over bandwidths of many octaves, consistent with performance that is now available with "frequency-independent" antennas.

The comparator design discussed here makes use of TEM transmission-line components, specifically, integrated strip-transmission-line assemblies. The range of frequencies over which this technique can be used is about 100:1, from approximately 100 mc to about 10 gc.

A typical wideband monopulse tracking system is shown schematically in Figure 1. The radiator is a four-arm spiral fed by a comparator network to produce radiation selectively from the one-wavelength (sum) and two wavelength (difference) bands on the spiral. The components are 3-db directional couplers and fixed 90-degree phase shifters.

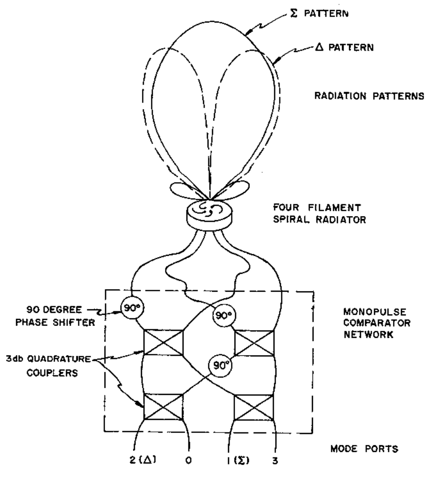
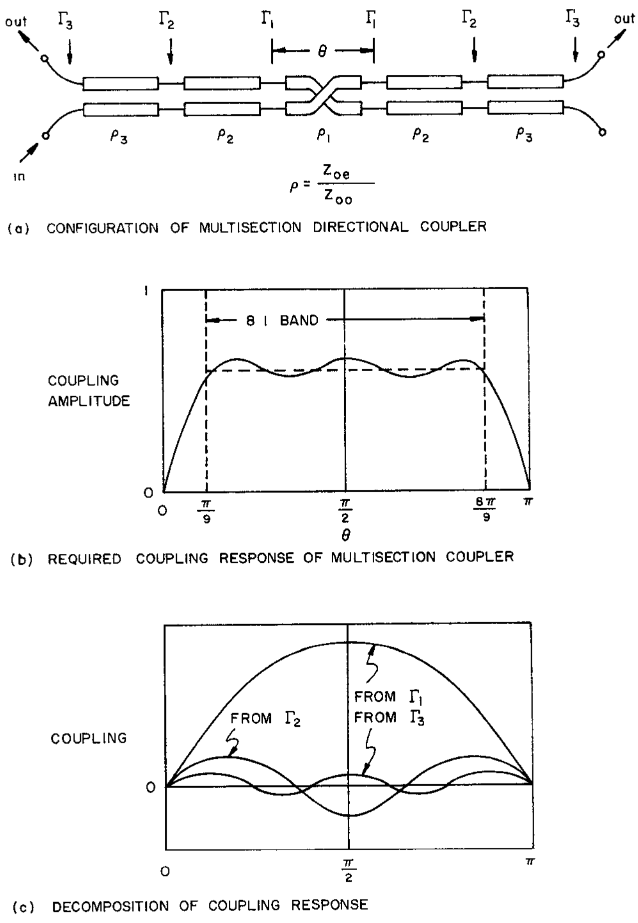


Figure 1. Two-Channel Monopulse Comparator Network for a Four-Arm Spiral Antenna

Basic Component Design. The design approach for the components involves the use of parallel-coupled TEM sections. Several coupled sections, each one-quarter wavelength long at the center of the frequency band, with varying coupling coefficients, are used to obtain the necessary number of degrees of freedom.

This general approach was originated by workers at Stanford Research Institute, and is the only feasible technique at the present time. Log-periodic components are being investigated by Du Hamel and show promise. However, it is felt that they are not sufficiently well developed to permit either practical application or comparison with components described here.

The operation of the basic multisection directional coupler is outlined in Figure 2. To a first-order approximation, the frequency response is described in terms of odd harmonics, the fundamental being $\sin \frac{2\pi L}{\lambda}$, where L is the length of the individual sections.



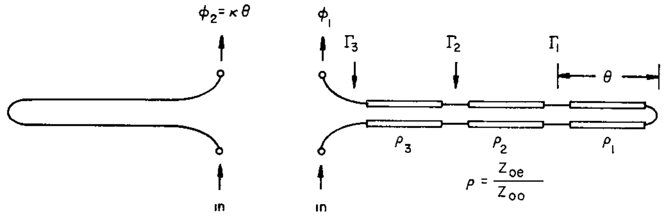
(a) CONFIGURATION OF MULTISECTION DIRECTIONAL COUPLER

(b) REQUIRED COUPLING RESPONSE OF MULTISECTION COUPLER

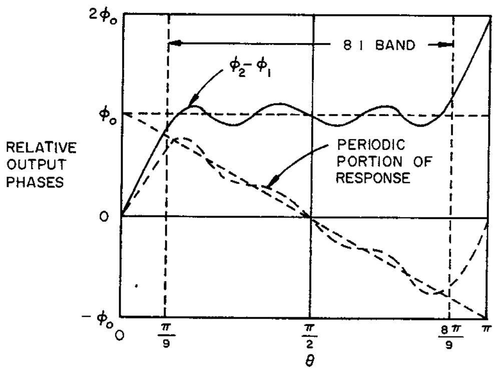
(c) DECOMPOSITION OF COUPLING RESPONSE

Figure 2.

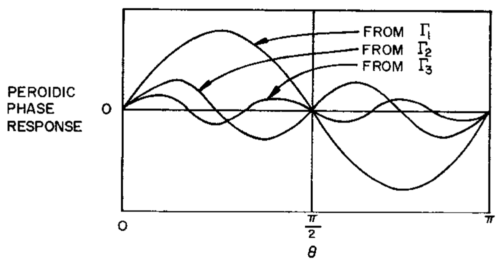
The operation of the prototype phase shifter is illustrated in Figure 3. The required nearly constant differential phase shift is made possible by the dispersive characteristic of the coupled region. This dispersion is described, also to a first-order approximation, by even harmonics, the first of which is $\sin 2\left(\frac{2\pi L}{\lambda}\right)$.



(a) CONFIGURATION OF MULTISECTION PHASE SHIFTER



(b) REQUIRED RESPONSE OF MULTISECTION PHASE SHIFTER



(c) DECOMPOSITION OF PHASE RESPONSE

Figure 3.

There is no precise synthesis technique for realizing component designs with equal-ripple performance. An iterative procedure, which uses electronic computation, has been developed. Although the procedure is not described here, it is sufficient to state that prototype parameters of any desired precision can be achieved (Reference 1)

Practical Considerations. Even though the synthesis problem can be overcome, the conventionally designed directional coupler or phase shifter presents serious practical limitations. For example, if the overall coupling and coupling tolerance are held constant while the bandwidth increases, the coupling coefficient of the center section of a directional coupler also increases. Thus, it is normally impossible to set an upper limit on coupling coefficient and still obtain arbitrary coupling and bandwidth, even though, from a practical standpoint, one would like to do so. A similar situation holds for the phase shifter.

The practical design limitation is avoided by using coupled sections in tandem for the directional coupler and in series for the phase shifter. These techniques, together with some sample designs, are illustrated in Figure 4. The basis for the tandem directional coupler is best understood by relating the coupling coefficients of the individual couplers (each of which may have many sections) to angles. Thus, the coefficient of one coupler is $K_1 = \sin \alpha$, and of the second $K_2 = \sin \alpha_2$, the coupling of the two couplers in tandem is given by $K_3 = \sin (\alpha_1 + \alpha_2)$ Therefore, the analytical procedure for adding couplers in tandem is straightforward and, in fact, similar to that used for phase shifters.

In the Table of Figure 4, two general types of tandem components are represented. One utilizes identical multisection coupled regions in tandem, and the 8:1 bandwidth coupler and phase shifter are representative. It should be noted, however, that the maximum coupling coefficient required in these cases is relatively high, and it can easily be appreciated that bandwidth cannot be indefinitely increased without increasing the number of tandem units. The more practical design approach is to define a maximum coupling coefficient and to use unlike couplers. In the examples, the coupling coefficient has been limited to 0.542, and it is seen that an 8:1 band 3 db coupler of this design actually uses fewer coupled sections than the identical-unit version.

NOMINAL COUPLING OR PHASE SHIFT		3 db	3 db	3 db	3 db	3 db	90°	90°	90°
BANDWIDTH		1.3:1	1 3 1	8:1	8:1	17:1	2:1	8.1	17 1
COUPLING OR PHASE TOLERANCE (±)		0 01db	0 02db	0.23db	0.24db	0.4db	3°	4°	6°
VOLTAGE COUPLING COEFFICIENT FOR λ/4 SECTION	K11	.707	382	.636	.542	.542	.480	.658	542
	K12			238	453	542		.375	542
	K13			.099	.208	.436		.187	.542
	K14			.034	.073	.286		.079	.483
	K15					.181			.315
	K16					.116			.180
	K17					.061			
	K21		.382	636	.412	542		658	.542
	K22			.238		.162		.375	.542
	K23			.099				.187	.199
	K24			.034				.079	
	K31				.412	.506			.542
	K32								.156
	K41								.421

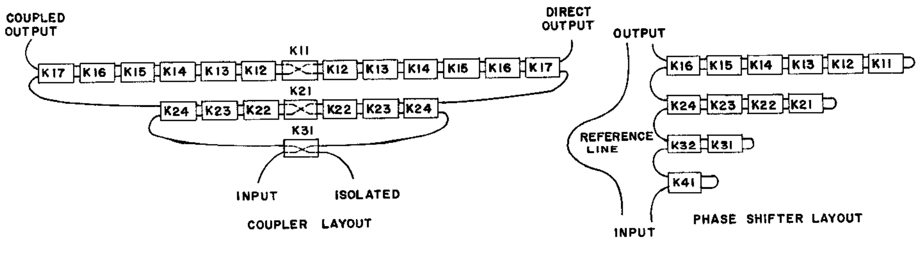


Figure 4. Coupling Parameters Required for Various Quadrature Couplers and Phase Shifters

The final practical problem is the coupled transmission line configuration. It is required that mechanical simplicity be maintained while coupling is varied from the maximum value to very loose levels. The selected configuration utilizes three layers of dielectric material between ground planes. Offset coupled strip transmission lines are contained between the dielectric layers. The maximum coupling is obtained when the strips are located one above the other and it is determined by the ratio of dielectric thickness.

Figure 5 is a photograph of a 17:1 bandwidth 3 db directional coupler with one dielectric layer removed to expose the coupling region. The dielectric material is copper-clad polyolefin, in layers of 1/8 inch, 1/16 inch, 1/8 inch. The strip configuration is obtained by a photoetching process. The operating frequency range is 88 to 1550 mc, and the performance of the unit is plotted in Figure 6.

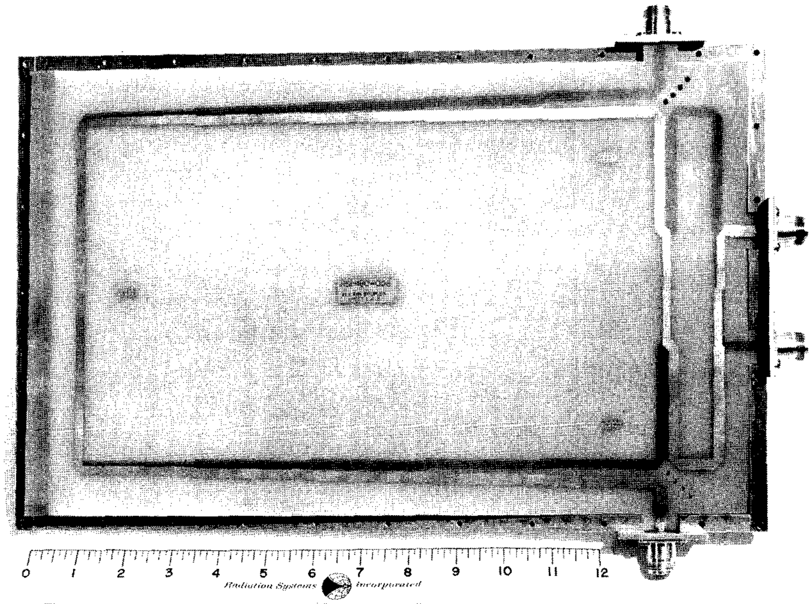


Figure 5.

Monopulse Comparators. One of the basic advantages of strip transmission line is the ease of designing many components into a single assembly with no interconnections. Such configurations are ideal for hybrid networks, such as monopulse comparators, in which phase and amplitude must be carefully controlled. The only limitation is the available dielectric sheet size. As an example, a monopulse comparator covering the frequency range 1 to 8 gc has been photoetched on a dielectric sheet measuring 10 by 10.5 inches.

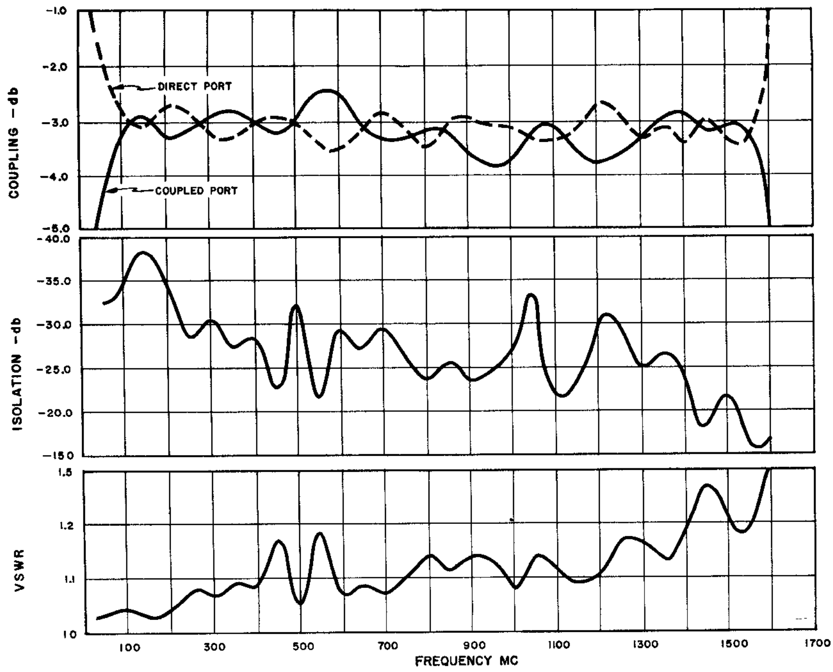


Figure 6. Performance of 17:1 3-db Coupler

REFERENCE

1. Shelton, P., "Synthesis and Design of Wideband TEM Directional Couplers and Phase Shifters," Presented at International Conference on Microwaves, Circuit Theory, and Information Theory, Tokyo, September 1964.