MONOPULSE ANTENNA NETWORKS FOR A MULTIELEMENT FEED WITH INDEPENDENT CONTROL OF THE THREE MONOPULSE MODES

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ABSTRACT

This paper deals with the design of a multielement monopulse feed network for which the illumination function corresponding to each of the three beams (SUM, ELEVATION DIFFERENCE, AZIMUTH DIFFERENCE) is independently specified and controlled. This control eliminates the need to tradeoff performance between the sum and two difference beams.

I. Introduction

An important problem in the design of amplitude comparison monopulse multielement arrays has been the requirement to design an antenna feed system which will optimize performance for the sum and two difference beams. When the feed illumination functions are not orthogonal to each other (i.e., linearly independent), one is required to perform a tradeoff between the optimum sum beam and difference beam performance with respect to such antenna characteristics as gain, sidelobes, difference slope, beamwidth and, for optically fed arrays, the spillover loss.

The monopulse antenna feed problem is well defined by Hannan[1] and networks which have been previously used are described by Lopez[2], Jones and Dufort[4] and, Wong, Tang and Barber[3].

This paper defines an antenna feed network for which the illumination function corresponding to each of the three beams is independently specified and one feed is designed to simultaneously provide these illuminations and to achieve the desired antenna performance.

II. Feed Concept

The nested feed concept presented here is based upon the requirement to achieve a specified performance in the secondary pattern of an optically fed phased array antenna. An antenna parameter study was conducted to independently specify (amplitude and phase) the three monopulse aperture illumination functions for a 112 element primary feed array. The incident wave requirements for each of the 112 radiating elements were derived by calculating the effects of mutual coupling and subtracting them from the specified feed aperture illumination functions.

$$\left[\text{Incident waves}\right]_I = \left[\text{Aperture Illum}\right]_I - \left[\text{Mut Coup}\right]_I$$

where I = 1 to 112.

The required set of incident waves for the sum was truncated by deleting the incident wave power for any radiating element which was more than 35 dB down from the peak sum incident wave element excitation. Similarly, truncation of the difference mode incident wave illuminations were made for any element whose excitation was greater than 30 dB down from the peak difference illumination element excitation. Any radiating element which did not require incident wave energy for the sum and two difference functions was load terminated.

The primary feed consists of twelve row modules which contain the nested distribution networks in one dimension for all three orthogonal incident wave functions. The twelve row modules are connected to the vertical distribution modules such that the weighting (phase and amplitude) requirements in the other dimension are properly satisfied. This circuit has a synthesis efficiency of 100 percent, i.e., no power is intentionally dissipated in any terminations to achieve the required illumination functions.

An example of a typical circuit for a single row is shown in Figure 1 for a six radiating element row. Each row module consists of two independent circuit boards which are interconnected by means of appropriate transitions. The sum ports of the nested hybrid networks are connected to a dual ladder circuit. The difference ports of the nested hybrids are connected to a series circuit.

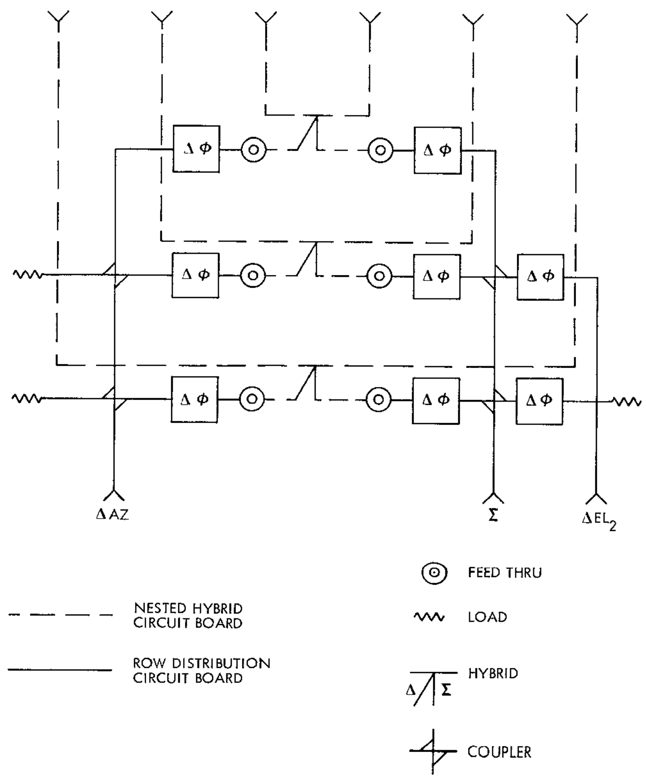

Figure 1 - Nested Row Circuit

One vertical feed module consists of a symmetrical center fed series power divider to feed the Δ Az ports for each of the rows as is shown in Figure 2. The other vertical module necessary to achieve the sum (Σ) and elevation difference (Δ El) functions consists of a network which is connected to both rungs of the dual ladder feed of every row board as is shown in Figure 3.

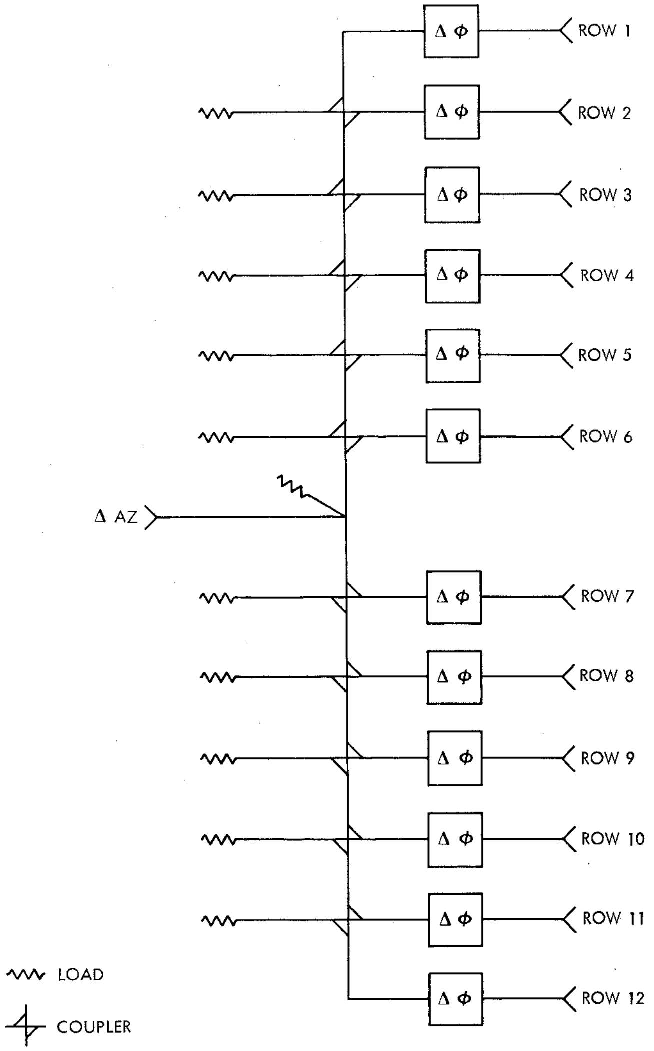

Figure 2 - Azimuth Vertical Feed (Board No. 4)

The nested arithmetic networks utilized in both row and vertical modules permit independent control of the branch phase asymmetry characteristic and physical separability of the various portions of the feed. In this manner, circuit characteristics are easily related to the antenna performance criteria which greatly enhances the engineering control during fabrication.

III. Hardware Implementation

Realization of this nested circuit approach illustrated in the diagrams of Figures 1, 2, and 3 lends itself well to a stripline network implementation. As indicated, the stripline power division scheme for both row and vertical feed assemblies consists of nested arithmetic networks summed up by various combinations of series and ladder distribution networks.

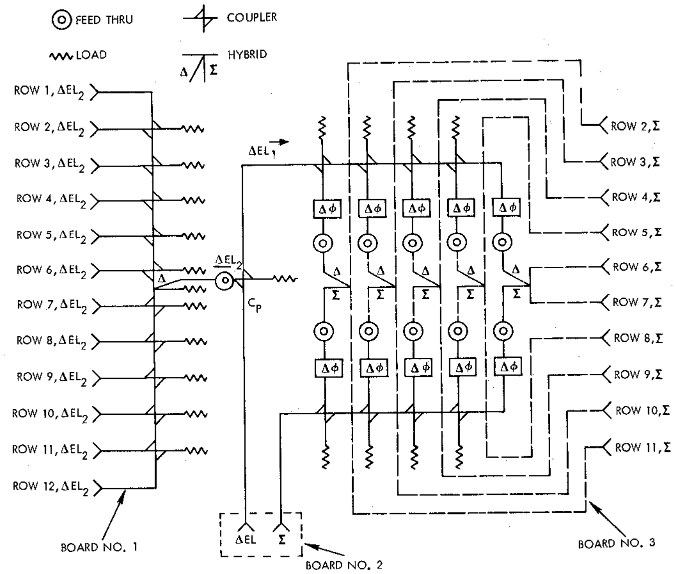

Figure 3 - Sum and Elevation Difference, Vertical Feed

Each individual row feed module consists of two stripline circuit boards which are interconnected by board-to-board feed through transitions. An example of this two board construction is presented in Figure 4 for a typical row module. The top stripline circuit board consists of the set of nested stripline hybrids necessary for splitting power between symmetrically disposed row feed ports. The mating board contains the series and ladder networks indicated in the schematics for providing the required power division via the feed through transitions to the Σ and Δ ports of the hybrids.

The stripline nested hybrid circuits were designed utilizing standard 3/2 λ stripline ratraces while the indicated phase shifts (Δ φ's) are provided by suitable differences in total stripline line lengths. The board-to-board feed through transitions were realized by short coaxial line sections designed to match the characteristic impedances of the two mating stripline circuits. The power division required in the series and ladder networks was provided through the use of 1/4 λ overlay stripline couplers.

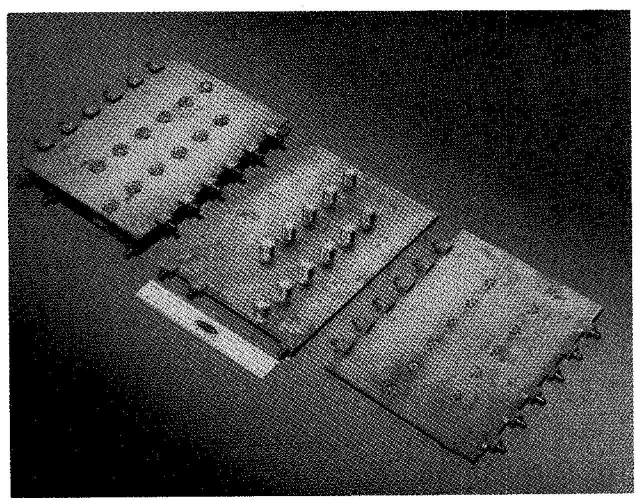

Figure 4 - Typical Row Module Two Board Construction

The complex vertical feed network diagramed in Figure 3 was realized by an interconnected three board stripline assembly shown in Figure 5. Two of the boards form a network similar to a row assembly and provide the vertical sum (Σ) power division between the array rows. A third board which is interconnected to the other two boards by the primary coupler (CP) provides power to the secondary rungs of the row ladder feeds necessary to provide an independent Δ El distribution. A fourth stripline board (top in Figure 5) provides the centerfed series feed for the Δ Az circuit shown in Figure 2. The outputs of the vertical feed assembly are connected to the input ports of the row feed modules via semirigid coaxial cables and the row feed outputs in turn are connected to appropriately matched radiating elements of the multielement array as shown in Figure 6.

The resulting assembly is suitable for receive and medium power transmit monopulse feed functions. For high power transmit applications a comparable implementation in waveguide would be required.

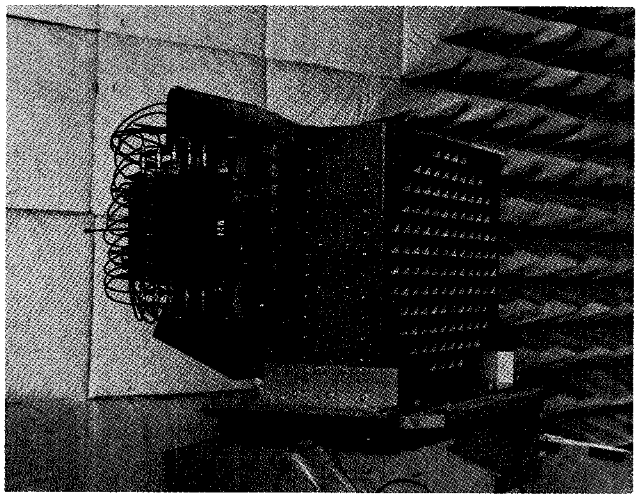

Figure 6 - Assembled Primary Monopulse Feed Array for an Optically Fed Phased Array Antenna

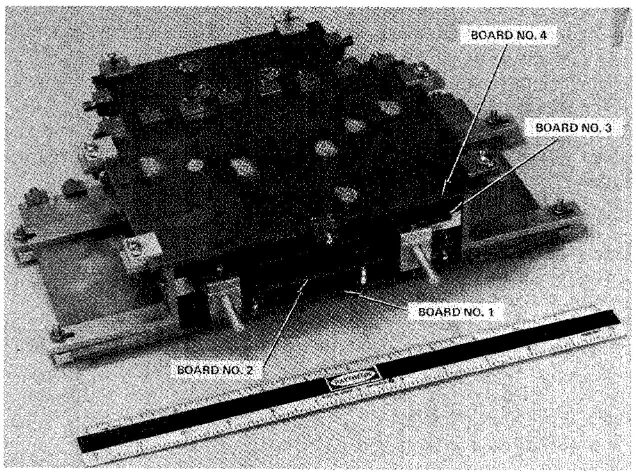

Figure 5 - Vertical Feed Network Four Board Assembly

IV. Acknowledgement

The authors wish to acknowlege the valuable contribution of M. Fassett in the development of the feed concept.

V. References

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