SYNTHESIS OF BLASS BEAM FORMING NETWORKS

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I. Introduction

A Blass network[1] would be the most versatile beam forming network(B.F.N.) for a multiple beam array in that numbers of input- and output ports are arbitrary. Although the principle is very simple, the full characteristics are not necessarily known ;e.g. it is not clear if it can be lossless even for a set of orthogonal beams.

The purpose of this paper is to develop an exact synthesis method for such networks which enable to reveal their true nature. An ordinary Blass network is first treated, and then the modified form is devised to remove the unnecessary matched terminations. The network elements determined by the present method for the two forms of network are compared, and the advantages and disadvantages are discussed.

II. An ordinary Blass network

An ordinary form of Blass network in the transmission mode is shown in Fig. 1. One of M londitudinal lines are fed at the bottom by the complex amplitude $\{a_m\}$. The wave is partially coupled to every one of N transverse lines by a factor of $\{C_n^{(m)}\}$,the coupling coefficient of a directional coupler at the n-th intersection. The waves are admitted to couple from longitudinal lines to transverse lines and from transverse lines to longitudinal lines, but the directions of the flow are only upward or from left to right. The input- and output port number,m and n, corresponds to the beam- and antenna element number,respectively.

The fundamental problem in designing this network lies in how to take the multiply coupled waves into consideration. We have solved the problem by the following steps.

(1) Specify the antenna weights to appear in the outputs $\{b_n\}$.

(2) Determine the first transverse line length, $\{L_n^{(1)}\}$,so as to yield an appropriate phase distribution in the output b_n for the first beam, together with the first longitudinal line length.

(3) Fix the unit length of the longitudinal lines $\{d_m\}$ for each m , and give them the differences with m such that the singly coupled wave by itself will have in the output the appropriate phase distribution for the respective beam.

(4) Determine the coupling coefficients of the first longitudinal line,$C_n^{(1)}$, according to the usual method of designing a series fed linear array.

(5) Let the network have been synthesized up to the (m-1)th column network, and the input wave $a_{m'}$ be $\delta_{mm'}(m'=1,...,M)$.

$\{C^{(m)}_n\}$ and $\{L^{(m)}_n\}$ of the m-th column network are then determined as follows. $C^{(m)}_1$ is determined such that the singly coupled wave appearing the first output port is correctly the desired antenna weight for the m-th beam. $L^{(m)}_1$ is arbitrary and is set to a constant.

(6) Calculate x_1 ,...., x_m , the waves entering the directional couplers located on the second transverse line as shown in Fig. 1. From x_1 ,...,x_m , calculate the necessary wave y to enter the directional coupler with the coefficient $C^{(m)}_n$. By the relation between y and x_m determine $C^{(m)}_n$ and $L^{(m)}_n$.

(7) Increase n up to N, and complete synthesizing the m-th column network.

(8) Increase m up to M, and synthesize the whole network.

(9) In the steps (5) through (8), $C^{(m)}_n$ might be greater than unity. If so, return to the step (1), and reduce the antenna weights by a certain value, and repeat the steps from (2) to (8).

III. A modified Blass network

Removing the matched terminations at the ends of longitudinal lines and at the left-side ends of transverse lines, we get the modified Blass network as shown in Fig.2 . By a mathematical manipulation, it has been proved that thus reduced network can be a B.F.N. for any set of orthogonal beams [2].

IV. Numerical results and discussions

Two forms of Blass network are synthesized as B.F.N. with 4 beams and 48 antennas. The results are shown in Fig.3 and 4 for $\{C^{(m)}_n\}$ and $\{L^{(m)}_n\}$, respectively. The orthogonal antenna weights with euual amplitude and progressive phase shift have been prescribed. The ordinary Blass network was synthesized with almost 100 % efficiency. Both $\{C^{(m)}_n\}$ and $\{L^{(m)}_n\}$ vary monotonically in the modified Blass network,while they change irregularly near the ends of the longitudinal lines in the ordinary Blass network. Judging from this point, the modified form seems to be more industrially suited than the ordinary form.

Essentially, the ordinary Blass network is lossy while the modified Blass network is lossless. Consequently, any set of beams may be realized by the ordinary Blass network whether they are orthogonal or nonorthogonal if lowering the efficiency is admitted, but only orthogonal sets of beams may be realized by the modified Blass network.

References

[1] J.Blass,"The Multidimensional Antenna :A New Approach to Stacked Beams,"1960 IRE International Convention Record,pt.1,pp.48-50.

[2] N.Inagaki,"Synthesis of a lossless feed network for M-beams N-antennas multiple beam arrays,"to be published in The Transactions of the Inst. of Electronic and Communication Engineers of Japan.

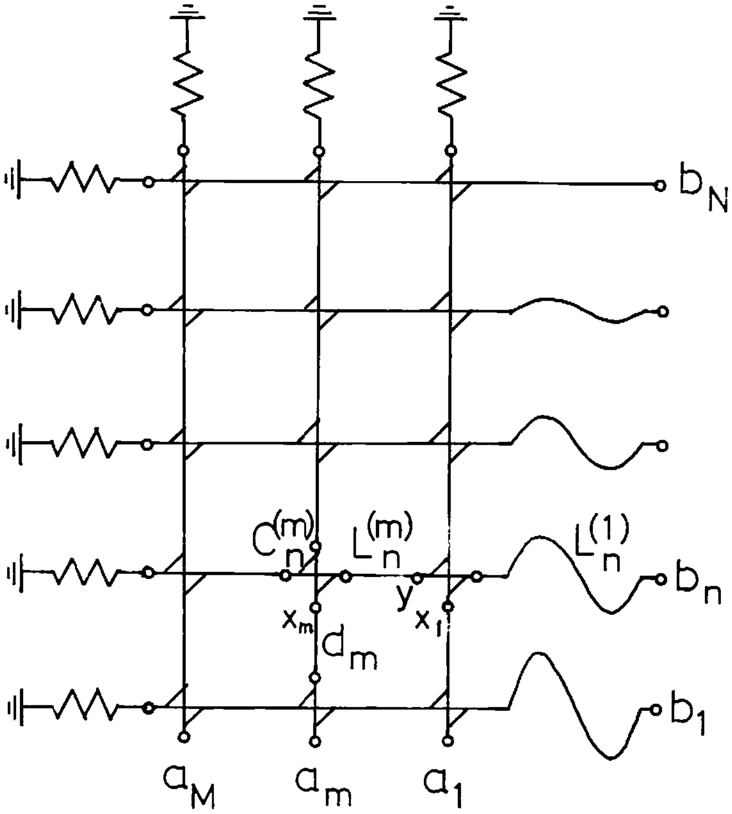

Fig.1

An ordinary Blass network.

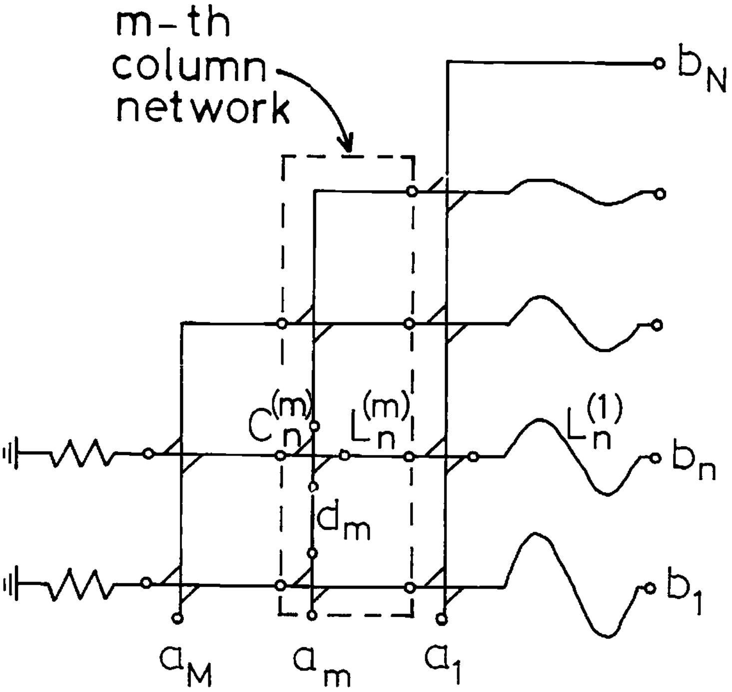

Fig.2

A modified Blass network.

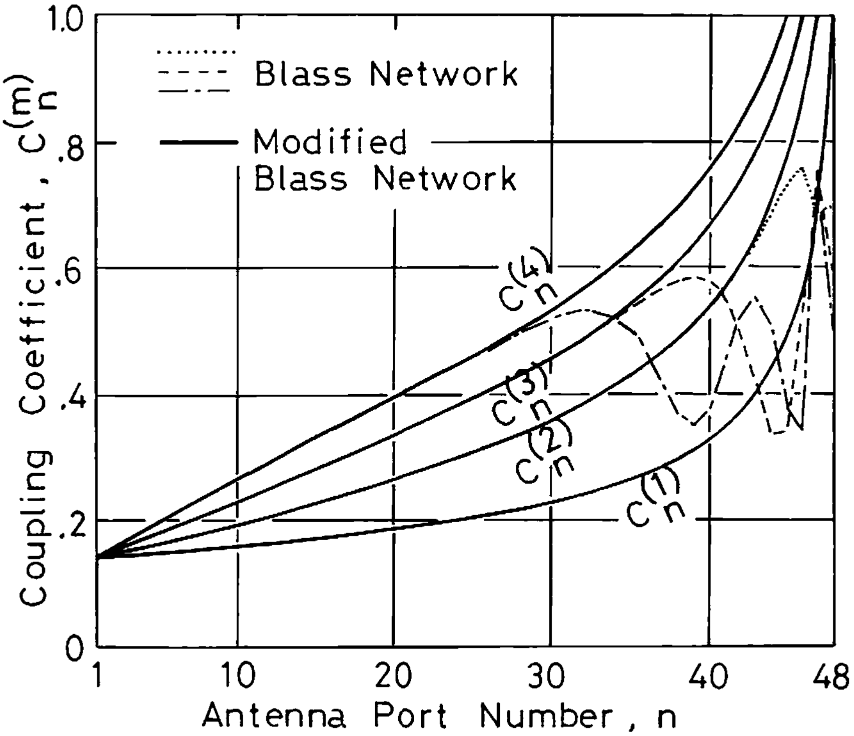

Fig.3 Determined coupling coefficients of the directional couplers for two forms of Blass networks.

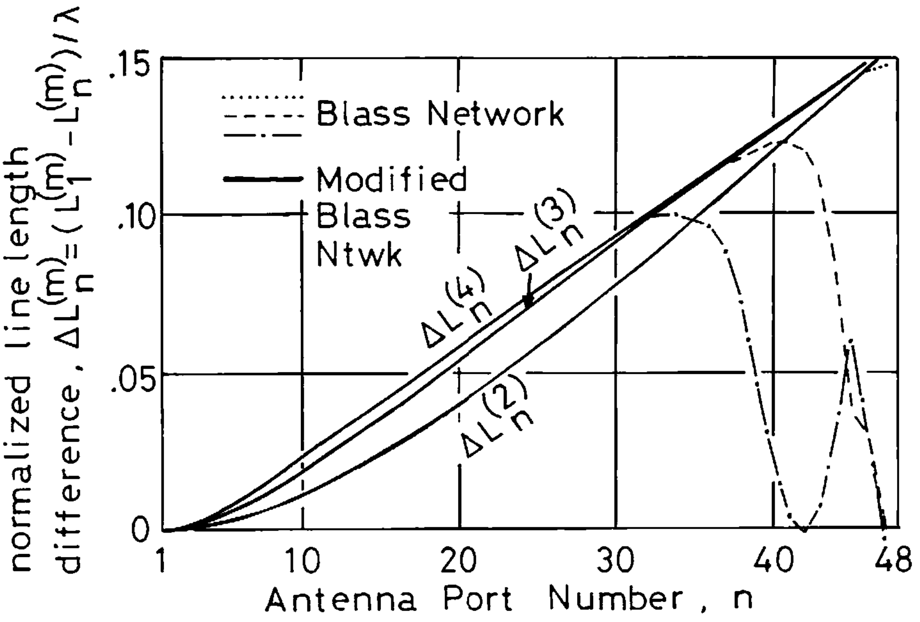

Fig.4 Determined unit line length differences of the transverse lines for two forms of Blass networks.