BEAM LOCATION FOR A MULTIBEAM PLANAR ARRAY ANTENNA WITH LOSSLESS BFN

T.Umemura, M.Hirabe, N.Kikuma *and* N.Inagaki

Department of Electrical & Computer Engineering
Nagoya Institute of Technology
Nagoya,466,Japan

1 Introduction

An array factor of multibeam planar array is represented by a double Fourier series when a direct lattice and a reciprocal lattice are introduced for the representations of the array and the radiation pattern, respectively. This representation is used to prove analytically the equivalence between the orthogonality of array factors and the losslessness of the BFN satisfied generally by planar arrays as well as by linear arrays[1]. The array factor orthogonality is then used to find what beam locations are possible for planar arrays with lossless BFN. It is found that beam location in triangular grid can be realized. Finally, the planar array BFN for this purpose is synthesized.

2 Beam location of a lossless planar array

Consider a planar array with $M \times N$ elements in the square lattice where every elements are equally excited and $M \times N$ similar beams are to be formed. To such a planar array antenna, the array factor F can be expressed by reciprocal lattice variables h_1 and h_2, as follows, where θ and ϕ are the angular variables in spherical coordinates system.

$$F(h_1, h_2) = I \sum_{m=1}^{M} exp(j2\pi m h_1) \times \sum_{n=1}^{N} exp(j2\pi n h_2)$$

$$(h_1 = \sin\theta\cos\phi, \quad h_2 = \sin\theta\sin\phi) \qquad (1)$$

where I represents the current amplitude of each element. The ith beam factor F_i whose maximum is shifted from the central beam by δh_{1i} and δh_{2i} in respective axes is given as

$$F_i(h_1, h_2) = F(h_1 - \delta h_{1i}, h_2 - \delta h_{2i}) \qquad (2)$$

We define the inner product of Fi by the double integral over the unit cell of the reciprocal lattice as

$$(F_i, F_j) = \int_{-0.5}^{0.5} \int_{-0.5}^{0.5} F_i \cdot F_j^* dh_1 dh_2 \qquad (3)$$

Then it directly follows that the orthogonality among the array factors hold if the excitation vectors are orthogonal to each other or equivalently the BFN is lossless, which is a well known relationship in linear arrays. For the orthogonality $(F_i, F_j) = \delta_{ij}$ to hold, the beam shifts $\delta h_{1i}, \delta h_{2i}, \delta h_{1j}$ and δh_{2j} must satisfy at least one of following relations

$$h_{1i} - h_{1j} = \frac{k}{M}$$

$$h_{2i} - h_{2j} = \frac{l}{N}$$

$$(k, \quad l : integer). \qquad (4)$$

These relations mean that each main beam is located at nulls of other beams. Fig.1 shows nulls associated with the main beam located at the origin by straight lines and main beams by circles or by triangles for 4×4 square planar array. Since we need to satisfy only either of (4), there are flexibilities in beam location. For example we can shift the ○−pattern to the △−pattern along the vertical lines as in Fig.1. As a consequence, it is possible to synthesize a square planar array with lossless BFN which forms patterns of main beams arranged in triangular grid.

3 Feeding method for planar array

Two methods are possible to construct a BFN for planar arrays from the lossless BFN which has been already devised for linear arrays :cross cascade method and rearrange method[2]. The former is to pile an array of such N BFNs on an array of another N BFNs orthogonally and connect the antenna ports of the bottom ones to the beam ports of the top ones. The latter is to rearrange two-dimensionally each of the N^2 antenna ports for N^2 elements linear array to one of the element positions of the $N \times N$ elements planar array. The lossless BFN for a linear array is characterized by the scattering matrix with the element

$$S_{mn} = \frac{1}{\sqrt{N}} exp\{j(\frac{2\pi mn}{N} + \theta_m + \phi_n)\} \qquad (5)$$

where m is a number of beam port and n is a number of antenna port,both taking from 1 to N, and θ_m and ϕ_n are fixed phase shifts for a beam port and antenna ports, respectively. When a planar array is fed by a BFN composed of a linear array BFN with this property, the beam locations realizable are limited to three kinds as shown in Fig.2. To get a more flexible beam location of Fig.1, we synthesize a planar array BFN with the scattering matrix satisfying

$$S \cdot S^{\dagger} = \bar{\bar{I}} \qquad (6)$$

where $\dagger$ means Hermite conjugate and $\bar{\bar{I}}$ is the identical matrix. This can be achieved with the application of the improved Blass network[3] which is shown in Fig.3. Fig.4 shows the coupling coefficient distribution of the synthesized BFN, by which the beam location of Fig.5 is realized.

References

[1] J.P.Shelton "Multibeam Planar Arrays", *Proc. IEEE*, vol.56, No.11, pp.1818-1821, Nov.1962

[2] J.L.Allen "A theoretical limitation on the formation of the lossless multiple beams in linear arrays", *IRE Trans. Antennas Propagat.*, AP-9,4, pp.350-352, July, 1961.

[3] N.Inagaki ,"Synthesis of Lossless Feed Network for M-Beams N-Antennas Multiple Beam Arrays", *Trans. IECE of Japan*, J68-B, 6, pp.729-731., June, 1985.

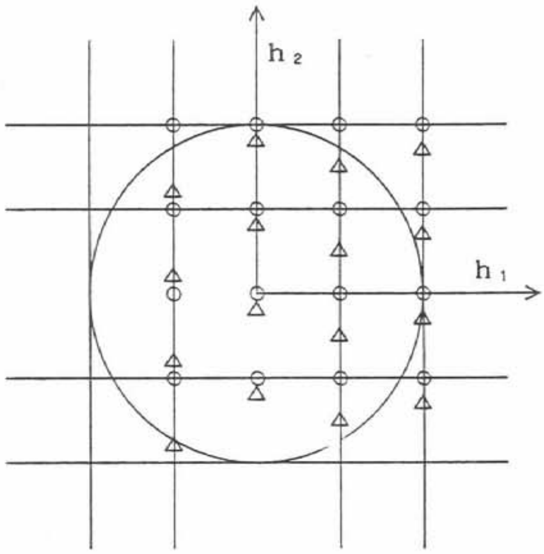

Figure 1.
An example of the beam locations realized by the lossless BFN

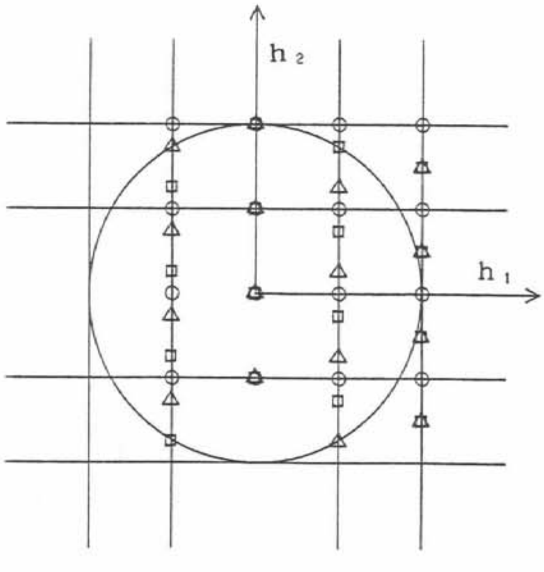

Figure 2.
The beam locations realized by a BFN composed of linear array BFNs whose property is expressed by Eq.(5)

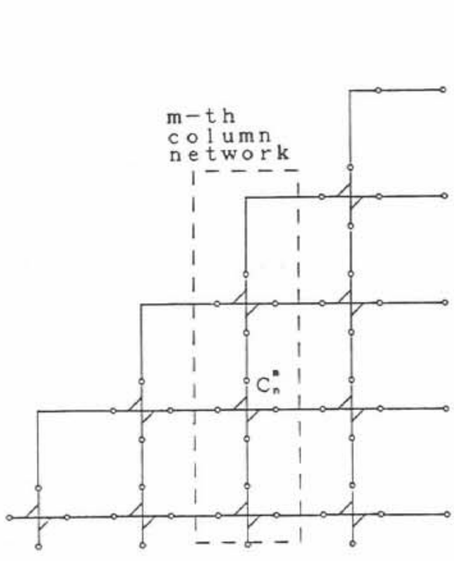

Figure 3.
Improved Blass network

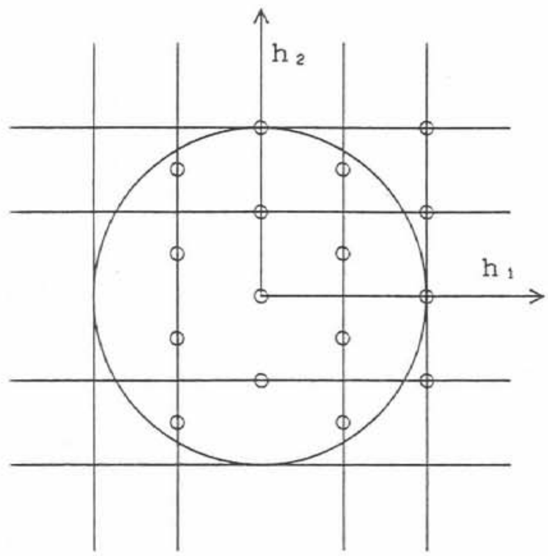

Figure 5.
The beam locations realized by the synthesized improved Blass network

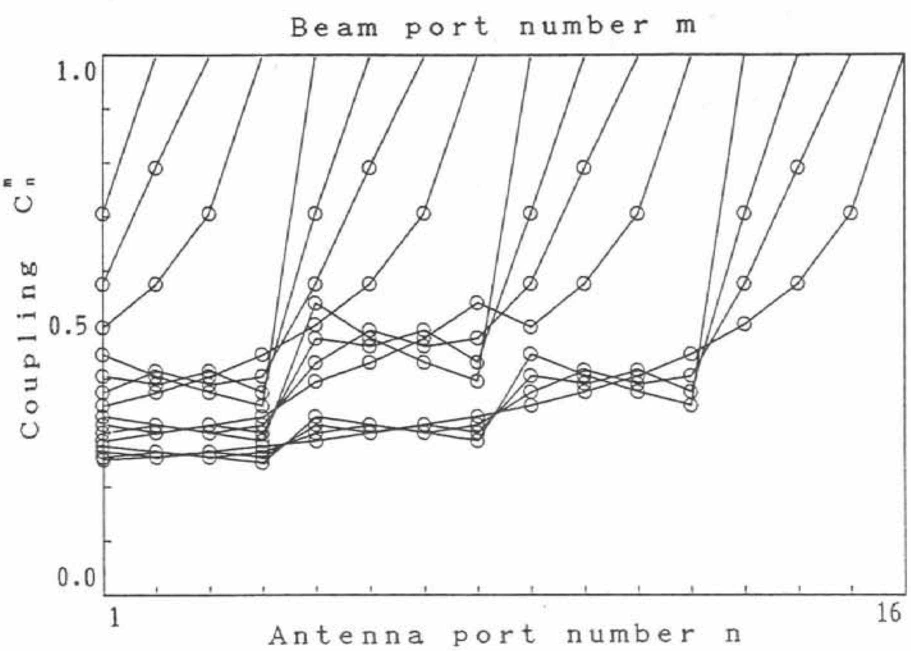

Figure 4.
Coupling coefficient distribution of the improved Blass network synthesized for the beam location of figure 5.