BFN CONFIGURATION for LOSS MINIMIZATION

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INTRODUCTION

The true versatility and uniqueness of antenna systems, such as reflector anthnas with array-feed and direct radiation array anthnas [1] , manifests itself in the beam forming network (BFN) capability; the performance of antenna systems closely depends on the BFN performance. In particular, the BFN insertion loss is an important parameter, which determines the total antenna performance. Therefore, a BFN configuration with low insertion loss is one of the design goals in the BFN design, although other BFN performances often require attention.

A commonly used BFN employs a corporate tree configuration similar to that shown in Fig.1 [2], [3]. As shown in Fig.1, an appropriate pair of ports, located close to each other, are connected by (fixed or variable) power divider at each level of the BFN (referred to as Category I) is given by L=dlog_N where d is the loss factor for power divider and N equals to the number of array elements. However, there may be a degree of freedom which can be exploited to reduce the insertion loss in the BFN configuration.

This paper deals with the EFN design problem. The descussion is focused on the synthesis procedure which permits optimizing the BFN configuration in the sense of loss minimization.

PROBLEM DESCRIPTION

Consider a corporate tree configuration BFN capable of realizing the required power distribution,

 $P = (p_1, p_2, \dots, p_N),$ on the array face with N-array elements. In the BFN, power dividers, which are usually lossy components, are employed at each junction. The insertion loss for the such a BFN is defined by

 $L = P_{out}/P_{in}$, $(0 \le L \le 1)$, is the input power fed to the beam port and P_{out} is the total power over the array face.

As mentioned previously, BFN is required in practical use to minimize insertion loss. Thus, it is interesting and useful to solve the design problem to synthesize a BFN which provide the minimum insertion loss. This problem is the same as the problem in deriving a BFN configuration capable of minimizing input power, P_{in}, when the total power over the array face, P_{out}, was specified.

The latter problem is discussed in this paper. In the

following discussions, three assumptions are made:

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The corporate tree configuration is employed;

2) All power dividers are identical, having constant inser-

tion loss, d (0 d 1), at any power ratio; and 3) Insertion loss is due only to power divider loss, i.e., the other components in the BFN are lossless ones.

SYNTHESIS PROCEDURE

Before preseting an answer to the above problem, the synthesis procedure used in the next section is given. A beam forming network will be synthesized in the "backward" sense; namely, BFN is synthesized by the step-by-step design precedure from the array face (the array element port) toward the beam port.

In order to initialize the synthesis procedure, "input" power distribution, P, for the 1st step is defined:

$$p^1 = (p_1^1, p_2^1, \dots, p_N^1)$$

where P is the given power distribution in (1).

At the 1st spet(k=1), an appropriate pair of element ports p_1^l and p_{i+1}^l , are connected by a power divider. (To avoid excessive use of the symbols, the same symbol, p_i , is used to represent the port name and the power at its port.) The power needed to excite these ports, the input power to the power divider, is given by (see Fig.2)

$$p_1^2 = (p_i^1 + p_{i+1}^1) / d.$$

 $p_1^2 = (p_i^1 + p_{i+1}^1) / d.$ Define input power distribution, p^2 , for the 2nd step as follows:

$$p^{2} = (p_{1}^{2}, \dots, p_{i-1}^{2}, p_{i}^{2}, \dots, p_{N-1}^{2})$$

$$= (p_{1}^{1}, \dots, p_{i-1}^{1}, p_{i}^{2}, \dots, p_{N}^{2}).$$
(2)

Note that the number of entries in P² was reduced from N to N-1.

At the 2nd procedure step (k=2), input power distribution, P², defined by (2), is regarded as the given power distribu-

tion. Therefore, the synthesis procedure is the same as that at the 1st step just described, replacing P by P.

After N-1 steps, the entire BFN configuration can be synthesized; the input power distribution, defined at the (N-1)th step, P = (p1), is exactly identical to the input power at the beam port, Pin. Figure 2 shows a typical BFN configuration synthesized by the present design procedure.

The remaining problems to be considered in this paper now becomes to find an appropriate pair of ports at each procedure step, in orther to minimize the input power, Pip.

MINIMUM LOSS BFN CONFIGURATION

In this section, an answer to the loss minimization problem will be shown. As described in the previous section, the BFN synthesis procedure was divided into the simple synthesis step flow. Therefore, Bellman's principle of optimality [4] can be exploited to derive a solution for the problem in this paper. Bellman's principle of optimality leads to the fact that a BFN providing the minimum input power, Pin, a BFN with the minimum insertion loss, should be a BFN that minimizez the total "input" power

 $p_{in}^k = \sum_{i=1}^{N-k+1} p_{i}^k$ at each synthesis step. Namely, if the port pair, p_i and p_{i+1} is chosen so as to minimize the corresponding total input power, p_{in}^k , at kth step, the resulting total input power at (N-1)th step, p_{in}^N , (note that $p_{in}^N = p_{in}$) can be minimized. The algorithm governing the above design procedure is, then, as follows:

Procedure: (BFN LOSS MINIMIZATION); Let $P = (p_1, p_2, \ldots, p_N)$ be the given power distribution over the array face; For k=1 step 1 until N-1 do

Find an integer i such that $p_i^k + p_{i+1}^k \le p_j^k + p_{j+1}^k, \text{ for } j=1, \ldots, N-k+1;$ Define input power distribution p_i^{k+1} $p_i^{k+1} = (p_1^k, \ldots, p_{i-1}^k, (p_i^k + p_{i+1}^k)/d, p_{i+2}^k, \ldots, p_{N-k+1}^k)$ end
end

EXAMPLE

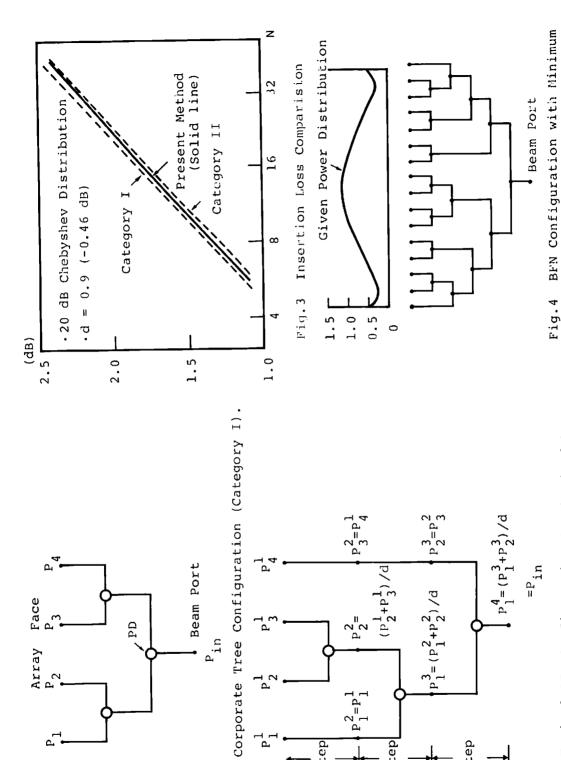
Figure 3 shows insertion loss for the BFN synthesized by the optimum design procedure described in the pervious section; the insertion loss for the Category I BFN and for the BFN such that any two ports are allowed to be connected at each step (referred to as Category II), are also presented as a reference. The optimum BFN configuration for the array with Chebyshev power distribution (N=16) is shown in Fig.4.

CONCLUSION

An optimal BFN design method, in the sense of insertion loss minimization, has been presented. The optimality of the presented design precedure was dereved, based on Bellman's principle of optimality. However, no substantial improvement was made in the BFN insertion loss characteristics, even though the optimum design procedure was employed. In other words, it can be concluded that the BFN with Category I configuration already has an almost optimal property, at least from the insertion loss minimization view point.

REFERENCES

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- [4] R.Bellman, Dynamic Programming, Princeton, 1957.



Beam Port

PD

Face

Array

Typical BFN Configuration Synthesized by Presented Design Procedure Fig.2

 $\frac{3}{100} = \frac{100}{100}$

 $P_1^3 = (P_1^2 + P_2^2)/d$

3rd Step

 $P_1^4 = (P_1^3 + P_2^3)/d$

Insertion Loss (Chebyshev Power Distribution, N=16)

Fig.1

lst Step

 $P_{1}^{2} = P_{1}^{1}$

2nd Step