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OPTIMIZATION OF ANTENNA PROPERTIES

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Antenna pattern synthesis is in general a difficult subject for two reasons. First, only for relatively simple cases do the synthesis problem have a solution, and if practical constraints like bandwidth and low sidelobes for certain specific angles are included the problems are more or less insolvable. Second, in the cases where the problem has been solved, the result is usually the current distribution, which may only be realizable with great practical difficulties. The theme of this paper is how to get around both of these difficulties by a direct numerical approach, using non-linear optimization techniques.

The general problem (which will be exemplified later) considered here is that of an antenna or antenna system which may be modelled by the network equations

$$\underline{\underline{Z}} \cdot \underline{I} = \underline{V} \quad , \qquad (1)$$

where the voltage vector $\underline{V}$ is given. The impedance matrix is a function of the independent variables $\underline{x}$,

$$\underline{\underline{Z}} = \underline{\underline{Z}}\,(\underline{x}) \quad , \qquad (2)$$

and the current vector $\underline{I}$ is desired in order to compute some performance index PI

$$PI = PI(\underline{I}) = PI(\underline{\underline{Z}}^{-1}(\underline{x})) \quad , \qquad (3)$$

which is a non-linear function of $\underline{x}$. Further some constraints may be defined:

$$\underline{C}(\underline{I}) < \underline{C}_{max} \quad . \qquad (4)$$

Now the task is to maximize PI defined by (3) subject to the constraints defined by (4). It is worth noting that this description covers a great many antenna types such as wire antennas, loaded or unloaded, variable reactance antennas, Yagi-Uda arrays, etc.

Many problems of numerical nature arise when solving an optimization problem like this, the main one being computing time. Since a complete antenna analysis has to be carried out hundreds of times during the optimization, a considerable amount of time (up to 70%) may be saved by modelling $\underline{\underline{Z}}$ by a multidimensional surface with sufficient accuracy. Another possibility which arises due to the fact that $\underline{x}$ often changes very slowly, is to solve eq. (1) by some perturbational technique. In the talk, a comparison of different attempts to cut down computing time will be reported.

As an exemplification of the general model outlined above, consider the Yagi-Uda array. In this case the classical synthesis-technique fails completely. It can tell us, say, the optimum current distribution on a driven array of half-wave dipoles, but this current distribution is in general not realizable with a parasitic array.

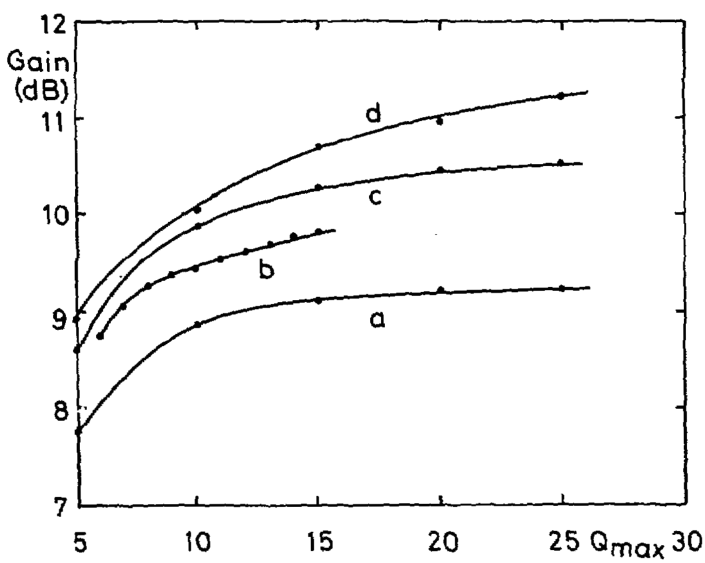

Fig. 1 Maximum gain with constraint on Q.

a: (4,2), variable spacing.

b: (5,2), d = 0.3λ.

c: (5,2), variable spacing.

d: (6,3), variable spacing.

To start with a very simple model of the Yagi-Uda array, an equidistant array of infinitely thin loaded half-wave dipoles is considered, the reactive loadings being the independent variables. Results from this model are reported in |1|.

We now turn to the more complicated problem, namely to end up with a realizable antenna that has maximum gain with constraints imposed upon the Q-value. In fig. 1 some results are shown, all of which have been obtained by means of Rosenbrock's method of optimization [2]. The curves are the maximum obtainable gain as as a function of the maximum allowable Q-value for different antennas, (4,2) being a 4 element antenna with element no. 2 excited etc.

The same method has been applied to obtain maximum gain Yagi-Uda arrays with constraint on the front-to-back ratio. Fig. 2 shows results for a specific equidistant array together with measurements.

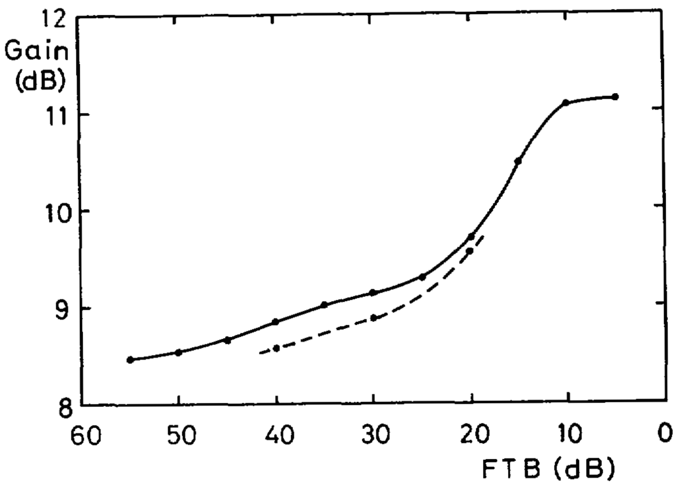

Fig. 2 Maximum gain with constraint on FTB.

(6,3), $d = 0.345\lambda$, $r = 0.01\lambda$

●——● Theory.

●- - -● Experiment.

Other examples of pattern synthesis for Yagi-Uda arrays using this method will be given in the talk. The results have been extensively verified by experiments carried out in The Radio-anechoic Chamber at this laboratory.

REFERENCES:

1. J.H. Bojsen, H. Schjær-Jacobsen, E. Nilsson and J. Bach Andersen (1971 Electronics Letters 7, p. 531).

2. H.H. Rosenbrock (1960 Computer Journal 3, p. 175).