ANTENNA PATTERN SYNTHESIS FOR CONFORMAL ARRAYS. COMPARISON OF TWO DIFFERENT METHODS.

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Abstract :

This paper deals with antenna power pattern synthesis in the case of a conformal array of N elements. A lot of synthesis methods have been developped for years but most of them require planar arrays of equispaced elements : one can think of analytical methods such as Schelkounoff, Woodward, Tchebytchev,... These techniques are unable to handle conformal arrays. This is why some recent techniques have arisen (see [1] and[2]). Two of them are presented and compared in this paper : the projection method and the variationnal method.

The array factor :

The far-field radiation power pattern of a N sensors array can be written as :

$$\mathbf{f}(\mathbf{r},\theta,\varphi) \;=\; (\tfrac{1}{\mathbf{r}^2})\,.\;|\sum_{\mathrm{p}=1}^{\mathrm{N}} \mathbf{I_p}\,.\,\mathbf{f_p}(\theta,\varphi)\,.\,\mathbf{exp}(\tfrac{\mathbf{2.i.}\pi}{\lambda}\,.\,\mathbf{O\vec{M}_p}.\mathbf{\vec{u_r}}(\theta,\varphi))\;|^{\mathbf{2}}$$

where (r,θ,φ) are the spherical coordinates of the point where the power emitted by the array is measured, λ is the wavelength, $O\vec{M}_p$ is the position of sensor number p, I_p is the complex weight of sensor number p and $f_p(\theta,\varphi)$ is the element number p radiation pattern (in a conformal array, the patterns of the elements point in different directions).

The problem is then to find the N complex weights I_p, such that the function $F(\theta,\varphi) \;=\; r^2\,.\,f(r,\theta,\varphi)$ meets a desired pattern defined, for instance, by lower and upper bounds : $G_m(\theta,\varphi) \;\leq\; F(\theta,\varphi) \;\leq\; G_M(\theta,\varphi)$. These conditions are generally discretized and enforced on M directions (θ_i,φ_i), with M $>>$ N.

The projection method :

This technique has been introduced in [1] and is based on a iterative two-projections technique.

One builds a (M,N) matrix A and a $(N,1)$ vector I such that the modulus of the components of AI are the powers $F(\theta,\varphi)$ in the M directions of interest

Step number k $>$ 1:

1) if $A.I_k$ meets the desired pattern for the M directions , stop.

2) if not, project each component of $A.I_k$ on the (boundary of the) desired pattern and denote the resulting complex vector F^{k+1}.

3) the new complex weight vector I_{k+1} is then defined by :$I_{k+1} \;=\; argmin_I \;\|\; A.I \;-\; F^{k+1}\;\|$

set $k \;\longrightarrow\; k+1$ and return to 1).

The variationnal method :

This technique has been adapted to the pattern synthesis in [2]. It is an iterative fixed point method based on the following criterion function to be minimized :

$C(I) \;=\; \int\!\!\int_{side\;\;lobes} |\; F(\theta,\varphi)\;|^2\;.d\theta.d\varphi \;+\; \int\!\!\int_{beam}(G(\theta,\varphi)+\;|\;G(\theta,\varphi)\;|).d\theta.d\varphi$

where : $G(\theta,\varphi) \;=\; (G_M(\theta,\varphi)-\;|\;F(\theta,\varphi)\;|).(G_m(\theta,\varphi)-\;|\;F(\theta,\varphi)\;|)$

The conditions for a weight-vector I to be a stationary point of this criterion are then written as a non-linear system of N equations : **S.I = B(I)**

where S is a square N-matrix which does not depend on I.

This system is solved iteratively : $I_{k+1} \;=\; (S^{\dagger}.S)^{-1}.S^{\dagger}.B(I_k)$ ($S^{\dagger}$ is the transpose conjugate of S)

Comparison on an example :

These two methods have been used to synthetize the weights to be applied to a circular array (in the $\varphi \;=\; 0$ plane) of 32 elements with inter-element spacing d=0.73.λ. The desired pattern has side-lobe level lower than $-25dB$ and a main lobe going from θ =-30 deg to θ =+30 deg in the plane $\varphi = 0$ deg.

The two methods allow to find a solution in a few iterations. The variationnal method gives actually lower side-lobe levels than required. Several other examples will be given during the presentation.

References :

[1] O.M.Bucci, G.Franceschetti, G.Mazzarella, G.Panariello, "Intersection approach to array pattern synthesis", *IEEE Proc.*, vol 137 ,december 1990.

[2] C.Audoux, H.Diez, D.Renard, "Synthèse d'antennes réseaux conformées.", *séminaire antennes actives"*, pp.212-217, Arles, april 1994.