

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

FLEURIAULT J.M., GONNET P., FUCHS J.J., TERRET C.

IRISA (URA CNRS 227) and Laboratoire "Structures rayonnantes" (URA CNRS 834).  
Campus de Beaulieu. 35042 RENNES Cedex.FRANCE.

### 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 developed for years but most of them require planar arrays of equispaced elements : one can think of analytical methods such as Schelkounoff, Woodward, Tchebychev,... 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 variational method.

### The array factor :

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

$$f(\mathbf{r}, \theta, \varphi) = \left(\frac{1}{r^2}\right) \cdot \left| \sum_{p=1}^N I_p \cdot f_p(\theta, \varphi) \cdot \exp\left(\frac{2i\pi}{\lambda} \cdot \vec{OM}_p \cdot \vec{u}_r(\theta, \varphi)\right) \right|^2$$

where  $(r, \theta, \varphi)$  are the spherical coordinates of the point where the power emitted by the array is measured,  $\lambda$  is the wavelength,  $\vec{OM}_p$  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  $F(\theta, \varphi) = r^2 \cdot f(r, \theta, \varphi)$  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  $(\theta_i, \varphi_i)$ , with  $M \gg N$ .

### 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  $A \cdot I_k$  meets the desired pattern for the M directions , stop.
- 2) if not, project each component of  $A \cdot I_k$  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 :  $I_{k+1} = \underset{I}{\operatorname{argmin}} \| A \cdot I - F^{k+1} \|$   
set  $k \rightarrow k + 1$  and return to 1).

### The variational 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 :

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

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

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 :

$$\mathbf{S} \cdot \mathbf{I} = \mathbf{B}(\mathbf{I})$$

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

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

### Comparison on an example :

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

The two methods allow to find a solution in a few iterations. The variational 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.