PREDICTION OF FAR-FIELD PATTERNS USING SYNTHESIZED STEERABLE SPATIAL FILTERING FUNCTIONS

M. Tuncay Birand
Electrical and Computer Engineering Department
University of Illinois at Urbana-Champaign
(on leave of absence from the Middle East Technical University, Ankara, Turkey)

1. Introduction

In this paper an improved version of the integral equation formulation proposed earlier ([1],[2]) for predicting the far-field patterns of aperture antennas from measured near-field data is presented. It is shown that the numerical computational work can be significantly reduced by performing the near-field measurements over a large surface so as to realize a "band-pass spatial filtering function" which is inserted into the integrand. This filtering function, corresponding to the pattern of a synthesized array can be beam-steered by means of multiplying the near-field measurement values with appropriate sets of coefficients and then summing them up vectorially. The 'synthesized array' may have a semi-cylindrical or spherical surface as well as a planar one as reported earlier [3]. The solution of the integral equation is based upon converting it into a simple matrix equation by expanding the unknown plane wave spectrum (PWS) functions of the measured antenna into sampling series with unknown coefficients. The sampling series may assume different forms according to the type of the zero-one function of the aperture.

2. Formulation

To simplify the present analysis, both the measured and probe antennas are assumed to be linearly polarized along the X-direction with their apertures always being parallel. Let $F^T(\alpha,\beta)$, $F^R(\alpha,\beta)$ denote the PWS functions of the measured and receiving antennas. F^R is known, through measurements or otherwise. The direction cosines in the PWS formulation are related as $\alpha^2 + \beta^2 + \gamma^2 = 1$. Let $\bar{r}_{pq}$ be the position vector from the origin (center of measured antenna) to the $(p,q)^{th}$ point on the measurement surface. With $P \leq p \leq P$ and $-Q \leq q \leq Q$ (p,q: integers) a $(2P+1) \times (2Q+1)$ measurement matrix will be obtained. Let $D_{pq} = D_{pq}(\bar{r}_{pq})$ denote an entry of this matrix. Now, the spatial filtering function (SFF) can be realized by multiplying all entries by a "set" of coefficients and summing up the values. Let us denote these coefficients by $a^i_{pq} e^{jk_o w^i_{pq}}$

CH2654-2/89/0000-0072 $1.00 ©1989 IEEE

where $k_o = 2\pi/\lambda_o$, λ_o is the free-space wavelength and a^i_{pq}, $k_o w^i_{pq}$ are the amplitudes and phases of the i^{th} set of coefficients which are multiplied by the corresponding D_{pq} values. Using the coupling formula in ref. [3], it can be shown that the sum of the received signals after being multiplied by the i^{th} set of coefficients is given by the expression

$$S^i = \frac{\lambda^2}{2Z} \int_{\Delta\beta} \int_{\Delta\alpha} \frac{1-\beta^2}{\gamma} F^T(\alpha,\beta) F^R(-\alpha,\beta) F^S_i(-\alpha,\beta)\, d\alpha\, d\beta \qquad (1)$$

in which Z is the free-space impedance, $F^S_i(-\alpha,\beta)$ is the synthesized SFF and $\Delta\beta$, $\Delta\alpha$ are the reduced integration ranges. Note that

$$S^i = \sum_p \sum_q D_{pq}\, a^i_{pq}\, e^{jk_o w^i_{pq}} \qquad (2)$$

and

$$F^S_i(-\alpha,\beta) = \sum_p \sum_q a^i_{pq}\, e^{-j(\bar{k}\cdot\bar{r}_{pq} - k_o w^i_{pq})} \qquad (3)$$

in which $\bar{k} = k_o(\hat{a}_x\alpha + \hat{a}_y\beta + \hat{a}_z\gamma)$.

Solution of eqn. 1 can be obtained by expanding $F^T(\alpha,\beta)$ into a sampling series [2];

$$F^T(\alpha,\beta) = \sum_m \sum_n C_{mn}\, G_{mn}(\alpha,\beta) \qquad (4)$$

$G_{mn}(\alpha,\beta)$ are the composing functions, the functional form of which is determined by the choice of the zero-one function of the aperture. Inserting this expansion into eqn. 1 yields the following matrix equation.

$$[S^i] = [I]\,[C] \qquad (5)$$

in which $[S^i]$, [C] are the signal (sum) and coefficient matrices respectively (both are column matrices) and [I] is the "system matrix" the entries of which are determined by numerical integration. Once [C] is determined then $F^T(\alpha,\beta)$ and hence the far-field pattern can be evaluated readily.

3. Discussion

The computational work involved in the solution of the integral equation can be reduced considerably by the filtering action of the synthesized SFF's. Formulation offers the flexibility of realizing various steerable SFF's using different synthesized array geometries and related sets of complex coefficients. The present approach differs from various plane wave synthesis techniques [4] in that it actually is based upon an integral equation formulation which uses the SFF's as means for reducing the computational work involved. It should be noted that the system matrix that has been computed for a measured aperture of given size can be stored and used for determining the PWS functions of smaller sized apertures as well. Currently the use of circular synthesized array geometries are being investigated.

Acknowledgements

This work is being carried out at the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign under a Fulbright Program. The author is thankful to both institutions.

References

[1] Birand, T., Marincic, A. "Determination of Aerial Far-Field Radiation Patterns from Near-Field Measurements", IEE Electronics Letters, Vol. 7, pp. 296-298, June 1971.

[2] Birand, T. "Integral Equation Formulation for Prediction of Far-Field Patterns from Near-Field Measurements," Proc. of the 6th European Microwave Conf., pp. 91-95, Rome 1976.

[3] Clarke, R. H., Brown, J. "Diffraction Theory and Antennas", pp. 111-117, Halsted Press; division of John Wiley and Sons, N.Y., 1980.

[4] Hansen, J. E. (ed.) "Spherical Near-Field Antenna Measurements", Peter Peregrinus Ltd., London, 1988.