# ON THE APPLICATION OF OPTIMUM CODES TO THE DESIGN OF OMNIDIRECTIONAL NONCOHERENT ANTENNA ARRAYS

**Said E. El-Khamy,** *Senior Member IEEE.*

Department of Electrical Engineering, Faculty of Engineering,
Alexandria University, 21544 Alexandria, Egypt. FAX: 203-597-1853

## 1. INTRODUCTION

Code-fed arrays has been recently proposed as an approach for the synthesis of omnidirectional acoustical arrays [1]-[3]. This approach is based on relating the intensity pattern of an array to the auto-correlation function of the sequence used to feed the array elements, henceforth referred to as the feeding code. As this relation is on the form of a discrete Fourier transform, optimum feeding codes with sharp autocorrelation functions result in almost omnidirectional patterns. The results can be applied to acoustical, optical as well as noncoherent electromagnetic (antenna) arrays such as radio telescopes [5].

Optimum binary codes known as Barker codes [2] are considered to feed linear arrays of length not exceeding thirteen. They are also used to feed planar arrays with one Barker code feeding the rows and another Barker code feeding the columns of the array. In both cases of linear and planar arrays fed by Barker codes, the resulting intensity patterns are shown to be characterized by some sharp peaks or deep nulls superimposed on omnidirectional patterns. On the other hand, good non- binary sequences such as Huffman codes [3] have correlation functions that are characterized by almost zero sidelobes. These codes are shown to result in extremely good omnidirectional patterns of linear and planar arrays.

## 2. FIELD-CODE RELATIONS

For an M-element linear with a spacing d between any two successive elements, the normalized intensity $U(v)=|E(v)|^2$ can be shown to be equal to the discrete Fourier transform of the aperiodic discrete autocorrelation function $C_I(m)$ of the feeding current sequence, i.e.

$$U(v)=\sum_{m=1-M}^{M-1} C_I(m)e^{jkmdv} \tag{1}$$

where $C_I(m)$ is given by

$$C_I(m)=\sum_{r=0}^{M-1-|m|} I_r I_{r+|m|}, \qquad |m|<M-1 \tag{2}$$

and equal to zero for $|m| \geq M-1$. A good measure of the isotropy or uniformity of the two-dimensional pattern U(v) of radiation intensity among the different directions is the normalized variance V which has been shown to be related to $C_I(m)$ as [2]:

$$V = 2\left[\frac{\sum_{m=1}^{M-1} C_I^2(m)}{C_I^2(0)}\right] \tag{3}$$

From (3) it is seen that V equals the ratio of the sum of the squares of the side lobe values of $C_I(m)$ to the square of its main lobe value. These show why optimum codes with minimum correlation sidelobes are needed to feed omnidirectional arrays.

Consider a rectangular planar array of M x N isotropic elements uniformly spaced with spacings $d_1$ and $d_2$ in the x and y directions respectively, as shown in Fig. 1. The far field intensity pattern U(u,v) due to that array can be shown to be related to the correlation function $C_I(m,n)$ of the feeding code by a double discrete Fourier transform relation. The pattern variance fin this case can be shown to be given by [2]:

$$V = \left[\frac{\sum_{\substack{n=1-N \\ n\neq 0}}^{N-1} \sum_{\substack{m=1-M \\ m\neq 0}}^{M-1} C_I^2(m,n)}{C_I^2(0,0)}\right] \tag{4}$$

This formula means that V can be visualized as the total side-lobe energy of the two-dimensional discrete autocorrelation function $C_I(m,n)$ divided by its main-lobe energy.

## 4. EXAMPLES

The intensity pattern of a typical Barker code fed array (viz. that for $B_{13}$) is plotted in Fig. 2. As examples of Huffman codes fed arrays, the intensity patterns of linear arrays fed by Huffman codes {H(7,2)} and {H(15,1)} are plotted in Figs. 3a and 3b. These arrays are characterized by highly omnidirectional patterns with less than 0.1 db level variations among all directions (less than about 0.025 db for {H(15,1)}). The three dimensional pattern planar arrays fed by the multiplied Huffman code, {H(7,1)} x {H(7,1)}is given in Fig. 4. This figure shows clearly that this array is characterized by almost omnidirectional properties with less than 2 db level variations among all directions.

## 5. DISCUSSION AND CONCLUSIONS

An interesting problem in array synthesis has been investigated. It deals with the use of codes with good correlation properties, which are familiar in the design of modern pulse compression radar and spread spectrum communication systems, for feeding arrays to result in omnidirectional patterns. Extensions of this work to a new antenna array synthesis technique is now being investigated.

## REFERENCES


[1] **H. Kuttruff and H. P. Quadt**, "Ebene Schallstrahlergruppen mit Ungebundelter Abstrahlung (Plane sound source arrays with omnidirectional radiation)," ***Acoustica,*** Vol. 50, pp. 273-279, 1982.

[2] **S. E. El-Khamy, O. A. Abdel-Alim, A. H. Banah,** "Code-fed omnidirectional arrays," ***IEEE Journal of Oceanic Engineering,*** Vol. 14, pp. 384-395, October 1989.

[3] **S. E. El-Khamy and A. H. Banah,** "Huffman Codes-Fed Omni-directional arrays," ***IEEE Transactions on Acoustics, Speech and Signal Processing***, Vol.38, No. 4, pp. 577-585, April 1990.

[4] **B. D. Steinberg,** ***Principles of Aperture and Array System Design***, John Wiley & Sons, New York, 1976.


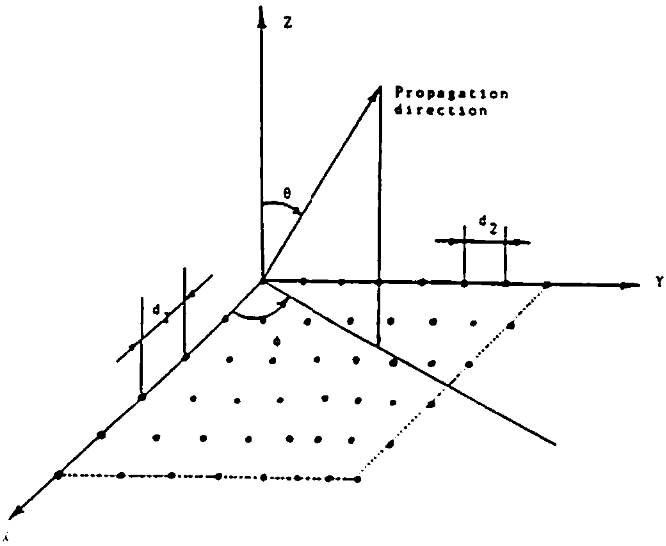


Fig. 1 Planar array configuration with M=6 and N=8.

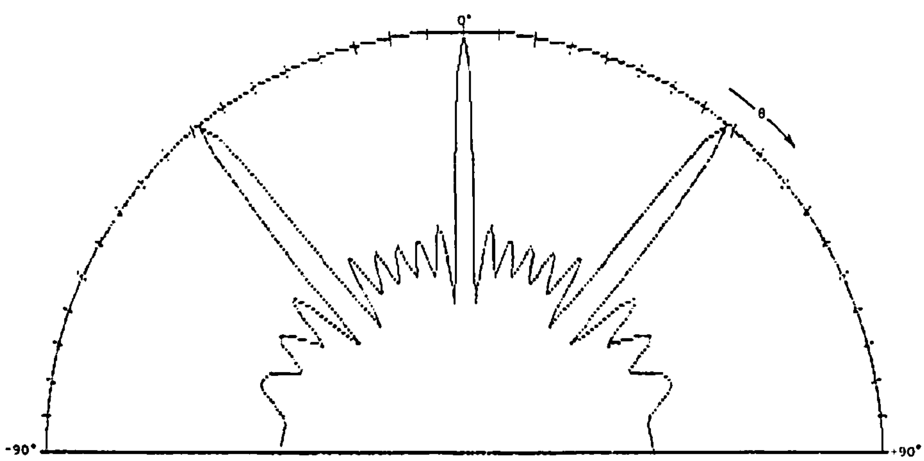


Fig. 2 Intensity pattern of Barker code-fed linear array of 13 elements with kd=5 (linear scale).

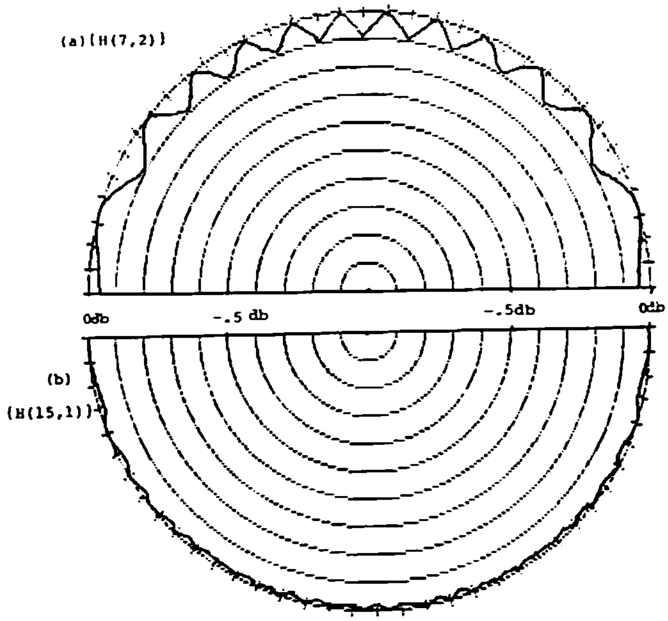


Fig. 3 Intensity patterns of Huffman code-fed linear arrays: a: 7-element array fed by {H(7,2)}. B: 15-element array fed by {H(15,1)}. (Kd=5, log scale: 0.1 db/circle).

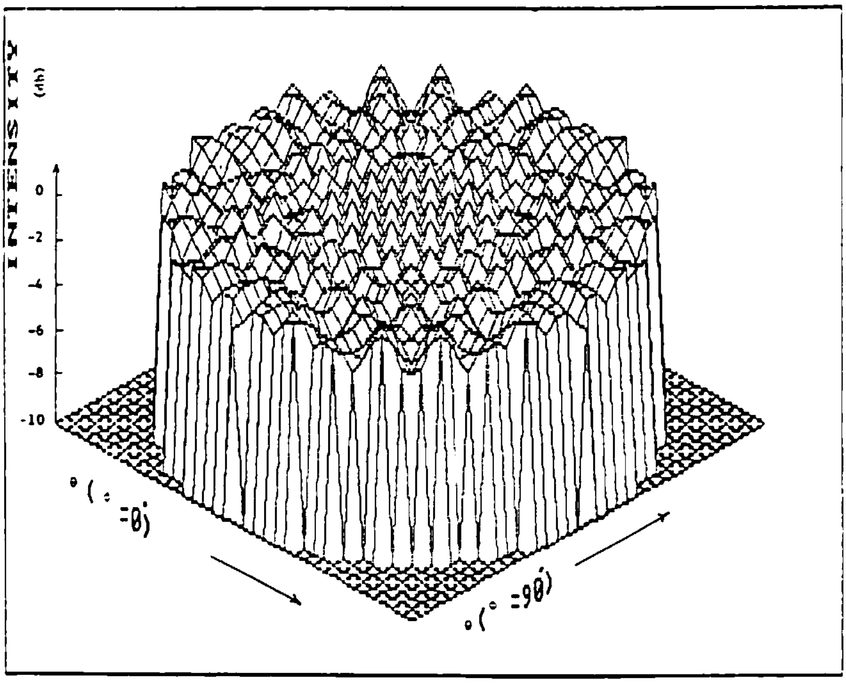


Fig. 4 Three-dimensional intensity pattern of a 7x7 planar array fed by multiplied Huffman codes {H(7,1)} x {H(7,1)}. ($k_1d=k_2d=6$)