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A sidelobe level reduction (SLL) for planar array antennas with −30 dB attenuators weight precision ☆

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A B S T R A C T

The application of the genetic algorithms to the optimization of planar array weights will be investigated with −30 dB attenuators weight precision. The aim is to adjust the weight coefficients of the array attenuators in −30 dB precision to achieve a minimum sidelobe level (SLL) with narrower beam width. The peak sidelobe level (PSL) of the synthesized beam pattern has been successfully lowered. The results are compared with synthesized pattern using precision like weights such as Gaussian, Kaiser, Hamming, Blackman and Chebyshev weight coefficients and give a significant improvement for a peak sidelobe level (PSL). The minimum achieved peak sidelobe level (PSL) is −32 dB for beam width of 16° and −22.82 dB for beam width of 12°.

1. Introduction

Array signal processing at element level is a crucial technology of phased array radar, for which analog weighting at element level is used for sidelobe suppression of patterns. In radar system, sidelobe suppression is one of most basic and critical themes. It has great advantage as anti-jamming technique. Genetic algorithm is an efficient method with parallel, random and global search and optimization. It is applied widely in array processing, as well as in the analysis and design of patterns. Recently, a genetic algorithm optimization is used to reduce the sidelobe level for linear array antennas [11,12,18,3,16,4,15]. Genetic algorithm is used for optimizing the array element position for planar array antenna [17,2], the array weighting for difference pattern antenna [8], and the array placement for circular array antenna [9]. This paper optimizes the array elements weights with −30 dB precision in order to reduce the sidelobe level of the radar phased array antenna. The results compared with those of the application of Gaussian, Kaiser, Hamming, Blackman and Chebyshev weight coefficients produce a significant improvement for the array peak sidelobe level (PSL).

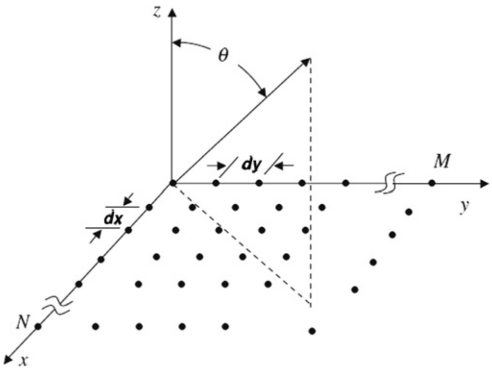

Fig. 1. $N \times M$ rectangular planner array.

2. Theoretical description

Fig. 1 shows a rectangular array in the x–y plane. There are M elements in the x-direction and N elements in the y-direction creating an $M \times N$ array of elements. The mnth element has weight w_{mn}. The x-directed elements are spaced d_x apart and the y-directed elements are spaced d_y apart. The planar array can be viewed as M linear arrays of N elements or as N linear arrays of M elements. Since we already know the array factor for an M or N element array acting alone, we can use pattern multiplication to find the pattern of the entire $M \times N$ element array. Using pattern multiplication we have [7]

$$\mathrm{AF} = \mathrm{AF}_x \cdot \mathrm{AF}_y$$

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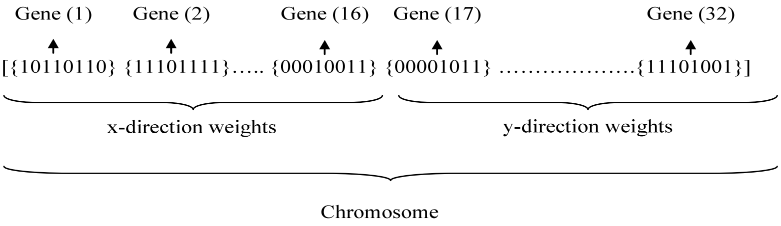

Fig. 2. Chromosome construction.

$$= \sum_{m=1}^{M} a_m e^{j(m-1)(kd_x \sin\theta\cos\phi+\beta_x)} \sum_{n=1}^{N} b_n e^{j(n-1)(kd_y \sin\theta\cos\phi+\beta y)} \tag{1}$$

$$\begin{aligned} \mathrm{AF} &= \mathrm{AF}_x \cdot \mathrm{AF}_y \\ &= \sum_{m=1}^{M}\sum_{n=1}^{N} w_{mn} e^{j[(m-1)(kd_x \sin\theta\cos\phi+\beta_x)+(n-1)(kd_y \sin\theta\cos\phi+\beta_y)]} \end{aligned} \tag{2}$$

where

$$w_{mn} = a_m \cdot b_n$$

The weights a_m and b_n may be uniform or may be in any form according to the designer's needs. This could include the various weights such as the Gaussian, Kaiser–Bessel, Hamming, or Blackman weights. The a_m weights do not have to be identical to the b_n weights. Thus, we might choose the a_m weights to be Hamming weights while the b_n weights are Gaussian. Any combination of weighting can be used and w_{mn} is merely the consequence of the product $a_m \cdot b_n$. These weights are characterized in [1,14].

Gaussian. The Gaussian weights are determined by the Gaussian function

$$w(k+1) = e^{-\frac{1}{2}(\alpha \frac{(k-N)/2}{N/2})^2}$$
$$\text{where } k = 0,1,2,\ldots,N,\ \alpha \geqslant 2 \tag{3}$$

Kaiser–Bessel. The Kaiser–Bessel weights are determined by

$$w(k) = \frac{(\pi\alpha\sqrt{1-(\frac{k}{N/2})^2})}{I_o(\pi\alpha)}$$
$$\text{where } k = 0,1,2,\ldots,N/2,\ \alpha > 1 \tag{4}$$

Hamming. The Hamming weights are given by

$$w(k+1) = 0.54 - 0.46 \cdot \cos\bigl(2\pi k/(N-1)\bigr) \cdot k$$
$$\text{where } k = 1,2,\ldots,N-1 \tag{5}$$

Blackman. The Blackman weights are defined by

$$\begin{aligned} w(k+1) = 0.42 - 0.5 \cdot \cos\bigl(2\pi k/(n-1)\bigr) \\ + 0.8 \cdot \cos\bigl(2\pi k/(n-1)\bigr) \end{aligned}$$
$$\text{where } k = 0,1,2,\ldots,N-1 \tag{6}$$

The price of reduction of sidelobes is in the form of loss gain, then

$$L_G = \frac{\left(\sum_{n=1}^{N} g_n\right)^2}{N\sum_{n=1}^{N} g_n^2} \tag{7}$$

where g_n is the weight factor of the element n and N is the total number of elements.

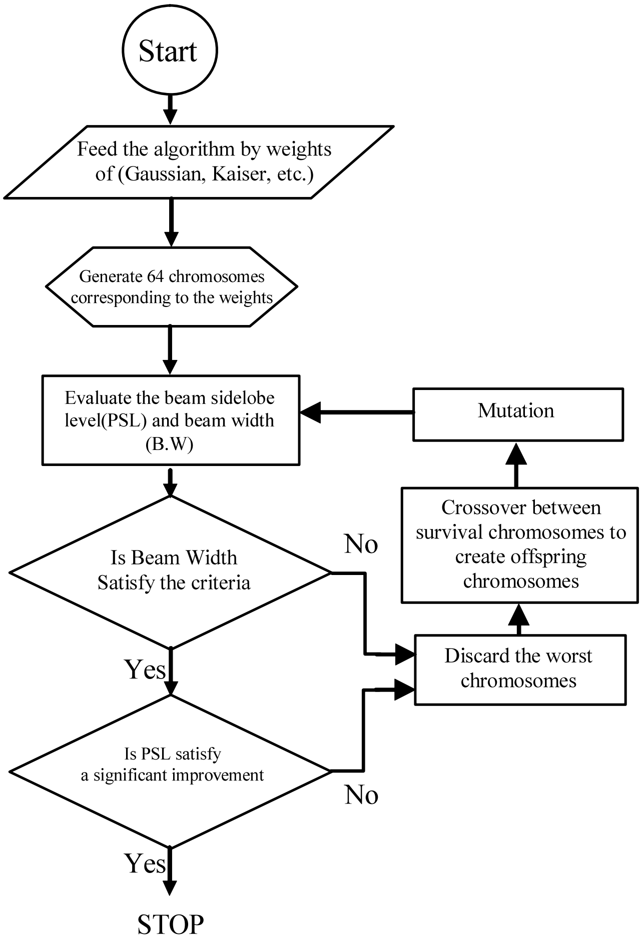

Fig. 3. Genetic algorithm flow chart.

3. Optimization process

This section presents the detailed description of the genetic algorithm to optimize the array weights with −30 dB precision of the planar array antenna. This algorithm is produced to achieve a minimum peak sidelobe level (PSL) for the beam pattern. The simulated antenna is a phased array antenna with 16 × 16 elements. The value of the element weight is encoded using binary encoding scheme and is represented by 8 bits for each element weight including 256 quantized values between 0 and 1. Fig. 2 shows the construction of the chromosome, which contains thirty two genes each corresponding to the element weight.

The population size is taken as sixty four chromosomes during the optimization process. The algorithm uses a random crossover rate with no more than 1% mutation rate. Elitism is used to save the best solutions to improve the performance of the genetic algorithm [10,13,5,6]. The algorithm is started with a set of solutions represented by chromosomes called population. Solutions from one