Elements space and amplitude perturbation using genetic algorithm for antenna array sidelobe Cancellation

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Abstract

A simple and fast genetic algorithm (GA) developed to reduce the sidelobes in non-uniformly spaced linear antenna arrays. The proposed GA algorithm optimizes two vectors of variables to increase the Main lobe to Sidelobe power ratio (M/S) of array's radiation pattern. The algorithm, in the first phase calculates the positions of the array elements and in the second phase, it manipulates the amplitude of excitation signals for each element. The simulations performed for 16 and 24 elements array structure. The results indicated that M/S improved in first phase from 13.2 to over 22.2dB meanwhile the half power beamwidth (HPBW) left almost unchanged. After element replacement, in the second phase, by using amplitude tapering further improvement up to 32dB was achieved. Also, the simulations shown that after element space perturbation, some antenna elements can be merged together without any performance degradation in radiation pattern in terms of gain and sidelobes level.

Keywords: Genetic algorithm; antenna array; sidelobe cancellation

1. INTRODUCTION

There are several popular methods available to reduce the sidelobes in the antenna pattern. The most popular techniques are to taper the amplitude using different window functions such as Kaiser or Dolph Cheyshev [1]. Phase tapering of input signals also is very popular way for antenna array radiation pattern optimization. Phase manipulation of inputs signal into antenna elements is technically efficient way to form and shift the main beam in desired direction and also it can be used for null steering in order to mitigate the effect of interferers in the system [2]. Amplitude manipulation of excitation signals of the array elements basically help to improve the main beam power to sidelobe power ratio [3]. The most efficient method in order to both shifting the main beam and reducing the sidelobes is based on full amplitude/phase control of signal fed into array elements. However as long as the sidelobe cancellation is our main interest, the amplitude tapering is adequate to reduce the sidelobes level. In the other hand, the element space perturbation can be an alternative technique to improve M/S by taking advantage of element position as a variable in the arrays [4]. Element space perturbation has attracted the researcher’s attention since early 1970. In [4] the array factor had been reshuffled base on elements position in the array, result in linear equations which then solved by iteration techniques. The result of this technique is considerable reduction in sidelobes. However, this technique is sensitive to choose a parameter controlling the amount of sidelobe reduction for each cycle of iteration. In addition, the complexity of this technique is high since it needs matrix inversion and also it needs to check the resulting antenna pattern after each cycle of iteration. Therefore, it burden in real time element perturbation applications.

Similarly, much research has been conducted base on element space perturbation. However, it is rare to see the researches which merge the amplitude tapering and element space perturbation together for antenna radiation pattern optimization. The element perturbation provides us a degree of freedom for antenna array radiation pattern optimization which should be used beside the other techniques despite increase in complexity. In this research a simple decimal GA algorithm is applied to take advantage of both amplitude and element space perturbation successively, to reduce the sidelobes level. The method is quiet efficient for the application such as radar communication, which the main concern is minimizing the sidelobes. In such an application the position perturbation is only applied during the design and manufacturing process. Therefore time limitation is no longer a constraint criterion for element perturbation. However, for other applications in which real time sensor positioning is needed, the system burden from time constraint. In this case, if both amplitude and position perturbation has applied at the same time on the system the time limitation of the system would be due to element position calculation, because, the amplitude tapering operation takes much shorter time than servo motor operation. Therefore, the critical time is just the time to calculate the amplitude of each signal fed to the arrays elements. In this paper, we use genetic algorithm to calculate the antenna element position and amplitude of excitation feeds. The technique is very simple and efficient. The GA, in the first phase finds the best place of element in order to have minimum level of sidelobe, and then the amplitude of each signal furthermore is manipulated to have further sidelobe cancellation. The subsequent section provides the clear picture of this technique.

2. THE LINEAR ARRAY STRUCTURE

The array structure considered for this research is linear. However, the technique can be applied to any type of array with unknown geometrical shape. The array factor of linear array antenna with M antenna elements and equal distance of d can be written as equation (1).

$$AF1 = \sum_{k=1}^{M} e^{j(k-1).\frac{2\pi}{\lambda}.d(\sin(\theta)-\sin(\theta_0)).\cos\phi} \qquad (1)$$

Where, λ is the wavelength of the impinging signal, θ represent the azimuth angle of radiation pattern while the φ represent the elevation angle and θo is the azimuth angle of the desired impinging signal. The array factor with uniform distance and different amplitude of excitation signal can be written as equation (2)

$$AF2 = \sum_{k=1}^{M} w(k).e^{j(k-1).\frac{2\pi}{\lambda}.d(\sin(\theta)-\sin(\theta_0)).\cos\phi} \qquad (2)$$

Change in the position of the elements can be set in the equation as a coefficient of d which is the distance between uniform linear array elements. Therefore, the modified array factor with two vectors of variables namely W and D can be rewritten as equation (3). This equation is used as a fitness function in developed genetic algorithm in following section.

$$AF3 = \sum_{k=1}^{M} w(k).e^{j(k-1+D(k)).\frac{2\pi}{\lambda}.d(\sin(\theta)-\sin(\theta_0)).\cos\phi} \qquad (3)$$

3. THE GENETIC ALGORITHM

The decimal genetic algorithm due to its simplicity is developed to calculate both position and amplitude of each element in the array. The structure of the GA is similar to the algorithm we have developed in [5]. However, the only difference comes from fitness function which needs to be modified. In addition, in this research real continues decimal number as chromosomes are used. Since, we only deal with the position and amplitude of each element which are real decimal continues numbers.

3.1 THE FITNESS FUNCTION

The two stage fitness function can be explained as follow. In the first stage, the element space perturbation is operated. In this phase, the signals amplitude for all antenna elements is equal. In this case, the fitness function can be represented by Equation (4).

$$f = \frac{P_M}{\max\limits_{sidelobe}(abs(P_S))} \qquad (4)$$

Where, P_M and P_S are the normalized main beam and sidelobe power respectively and they can be calculated using following Equations (5) and (6).

$$P_M = (normalaized(AF))^2 \qquad \theta\text{=Main beam angle} \qquad (5)$$

$$P_s = (normalaized(AF))^2 \qquad \theta\text{=Sidelobes angle} \qquad (6)$$

Where, AF can be calculated by using equation (3) if w (k) is assumed unity for all antenna elements. The results of GA at this stage will give us the optimum value of D(k). After achieving optimum value of antenna elements location, the algorithm calculates the optimum antenna weights result in further improvement of M/S. At this stage again we use the fitness function represented by equation (4), however, the array factor can be calculated using equation (3) with variable w (k) and constant D (k). In this case, the value of D (k) is the results of former GA process.

4. SIMULATION RESULTS

The simulations have done for two linear arrays with 16 and 24 numbers of antenna elements. Table 1 is shown the resulted statistical information of the simulations.

#.of array elements	Technique	HPBW degree	Sidelobe dB
16	Without perturbation	6	-13.20
16	Space perturbation	6.9	-22.22
16	Space & Amplitude perturbation	8	-31.00
24	Without perturbation	4	-13.20
24	Space perturbation	4	-22.00
24	Space & Amplitude perturbation	5	-31.18

Table 1: HPBW and sidelobe reduction

The results indicate that the M/S in both cases, 16 and 24 elements is about -13.2 dB. This value decreases to -22.00 dB for both cases after one hundred iterations in first phase. The M/S further improved to approximately -31 dB in second phase of the algorithm.

16 elements antenna array			
Element number	Element disposition	amplitude value	Eliminated elements
1	0.0039	0.2880	-
2	0.4295	0.5160	-
3	0.8272	0.6146	-
4	0.9388	0.7866	-
5	0.9890	0.7326	x
6	0.8326	0.8471	-
7	0.7856	0.6291	-
8	0.3027	0.8509	-
9	0.3129	0.7003	-
10	0.0032	0.8770	-
11	0.0671	0.7115	-
12	-0.1806	0.7211	-
13	-0.1467	0.6458	-
14	-0.1872	0.5776	-
15	0.1691	0.5074	-
16	0.8741	0.2996	-

Table 2: The value of element disposition and weights for 16 elements linear array

The results in Table 2 and 3 show the disposition of each element in the array as well as the optimum amplitudes of excitation signal for each element. As the results are indicated, some of the elements have to relocate from their original place about one unit. This means that these elements can be merged with the elements after or before them. Cross mark in column four of these two tables show the elements which can be combined or eliminated in the array. The results shown after combining these elements from the array, the results have been left almost unchanged.

16 elements antenna array			
Element number	Element displacement	amplitude value	Eliminated elements
1	-1.1137	0.2099	-
2	-0.6527	0.3241	-
3	0.1296	0.3958	-
4	0.8235	0.5948	-
5	1.0755	0.5172	x
6	0.9541	0.5763	-
7	0.9633	0.6492	x
8	0.9818	0.7511	-
9	0.9939	0.7206	x
10	0.9615	0.9031	-
11	1.3268	0.7163	x
12	0.2962	0.5698	-
13	0.8127	0.8359	-
14	0.2729	0.5069	-
15	0.4268	0.7687	-
16	0.0722	0.5927	-
17	0.8222	0.5405	-
18	-0.7532	0.6323	x
19	0.1809	0.8129	-
20	0.5072	0.4846	-
21	0.3343	0.3880	-
21	0.6957	0.4681	-
23	1.2027	0.2865	-
24	1.6351	0.1506	-

Table 3: The value of element displacement and weights for 24 numbers of elements

Note that the combination of the elements which are close together must be done prior to the second phase of the algorithms otherwise the elements combination and elimination would degrade the M/S and disfigure the antenna radiation pattern.

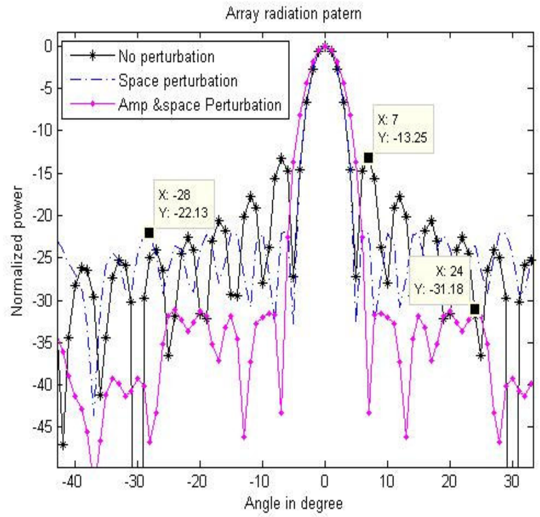

Figure 1: Results for 16 elements linear antenna array

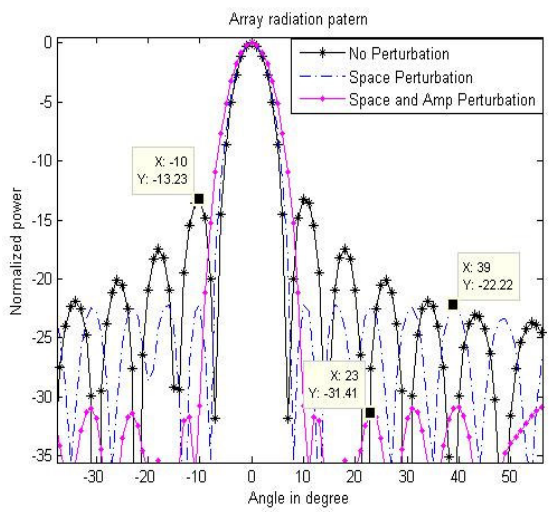

Figure 2: Results for 24 elements linear antenna array

Figure 1 and 2 are shown the resulting radiation pattern after applying the GA for two continues phases. The star solid line is original beam pattern without any perturbation. The dashed lines are the results after the first phase of the GA coming from elements disposition. Finally the dotted line is results of GA algorithms after space and amplitude perturbation which has the lowest amount of sidelobes. In regards of HPBW, different number of simulation has been done, in essence it can be concluded that the element space perturbation can keep the HPBW as the same as its original value, however the amplitude perturbation change the HPBW in all cases and it can not be avoided.

5. CONCLUSION

Satisfactory results indicate that the integrated space and amplitude perturbation using GA can be a excellence technique to reduce the sidelobes. The GA algorithm provides more flexibility to play with the variable and set the variety of constraint to achieve desirable results. Although the iteration time of GA seems high for real time application, the flexibility and ease of solution still make it worth for future applications.

6. REFERENCES

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