A LINEAR 32x1 ELEMENTS ANTENNA ARRAY FAILURE CORRECTION USING BRAIN STORM OPTIMIZATION ALGORITHM

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Abstract

The radiation characteristics of antenna array may be disturbed by the faults related to its elements. The presented paper exploits the problem solving ability of brain storm optimization (BSO) which indicates the collective human behavior replica to resolve antenna-element failure problem of linear 32x1 elements antenna array. The amplitude excitations of healthy antenna elements of the array have been re-assigned with the help of the proposed method to obtain the pre-failure characteristics of considered case. The result of numerical example shows the ability of BSO to solve faulty element problem of antenna system in very effective manners.

Keywords

Antenna Array, Linear 32x1 elements Array, SLL, Element malfunctioning, Optimization, brain storm optimization.

1. Introduction

The antenna array plays a crucial role in efficient designing of terrestrial communication link. An antenna-array subsystem finds numerous roles in system viz. wireless sensor networks, Internet of things, radar etc. as acquisition system for signal. Generally, antenna system contains huge elements and there is chance of malfunctioning of antenna element. The failure conditions occur in the antenna system causes disturbance in the space distribution of the elements in antenna subsystem. It causes distortion of the original characteristics (side lobe level etc.) of antenna system. Sometimes there is low possibility to repair the dead element with the fresh element under critical conditions. Luckily, the recovering of original characteristics of antenna system with minimal error may be achieved without replacing the faulty elements by controlling the amplitude or phase or both excitation of non-disturbing units (element) of the antenna subsystem. The numerous traditional procedures are adopted in the open literature to solve the array failure and correction problems. Some of the techniques include conjugate gradient algorithm based on redistribution of complex excitation of healthy elements [1]; a numerical technique to recover original characteristics under single element failure condition [2]; a digital beamforming array method [3]; and applying an orthogonal process [4].
The numerical methods find it difficult to regain the desired beam shape of the antenna array with disturbed conditions due to randomization of the layout of geometric of healthy antenna array elements. Under such situations, the optimization techniques may play an important role in solving antenna array failure issues because of their capability to identify more than one solution instantly without any prior information. Several optimization methods employed in mitigating the failure problem at antenna element level. Some of these listed as genetic algorithm (GA) [5-7], firefly algorithm [10-12], and bat algorithm [13].

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In the presented work, a flexible approach based on brain storm optimization (BSO) [14] has been used to re-optimize a linear 32x1 elements antenna array design under element failure condition. The proposed technique has been already successfully applied in different engineering fields [15-16]. The proposed technique is effectively applied to above mentioned sub-system with the help of modified assignment of the element excitation to healthy elements for recovery of antenna's original characteristics.

2. Problem formulation

The array factor of the linear array of *32* identical elements shown in Figure 1, having uniform half wavelength spacing *d* between two elements is generally given as

$$AF = W^{K} S(\varphi, \varphi_c) \tag{1}$$

where,

$$W^{K} = \{w_1, w_2, w_3 ....w_{32}\}^{T}, \quad w_z \in C^{N}, \quad z = 1,2,...32 \tag{2}$$

The equations (1) and (2) contains various parameters including the weighting vector W^K, the steering vector S , the direction variable and direction of main beam φ, φ_C . The real number set/subset C^N is used as weight factors of 32 elements linear antenna array.

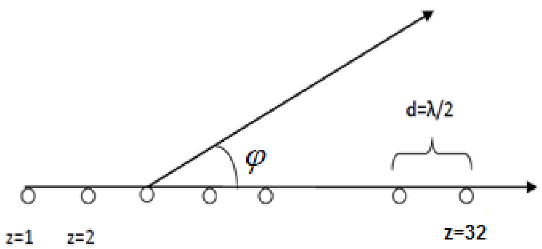

Figure 1: A 32 elements based antenna array

The steering vector represents by symbol *S* in (1) is given as

$$S = exp\left\{\frac{j2\pi d}{\lambda}\left(z - \frac{32-1}{2}\right).(cos\,\varphi - cos\,\varphi_c)\right\} \qquad z = 1,2,...32 \tag{3}$$

The failed conditions have been introduced in the antenna array by replacing the weights of the particular element or elements with 0. Then the distorted pattern is corrected with revised distribution of the excitation weights in the array using BSO method. A template is constructed and taken as ideal pattern of the array. The template with pre-failure pattern of array system is demonstrated in Figure 2.

3. Brain Storm Optimization algorithm

Shi (Y. Shi, 2011) proposed the imitation of an innovative thinking methodology through which the effective ideas have been facilitated among small group of people and named it BSO algorithm. Every person in the group belongs to different culture, presents an idea or solution. The algorithm starts by generating K number of ideas from *K* individuals. These ideas or solutions have been separated in M number of groups based on resemblance in their opinion. The best solution belongs to each group are selected to judge the global best solution. At last, new *K* numbers of ideas are generated taking consideration of four Osborns rules namely No Bad Idea, Anything Accepted, Combination of Ideas and Go for Quantity. The pseodocode of the algorithm has been presented in

Figure 3. The combined idea is generated with the help of weighted sum of two ideas and it is given as

$$x_{selected} = T * x_{sel\_1} + [1-T] * x_{sel\_2} \tag{4}$$

A refined idea is generated with the help of the following expressions,

$$x_{refined} = x_{selected} + \zeta * \rho(0,1) \tag{5}$$

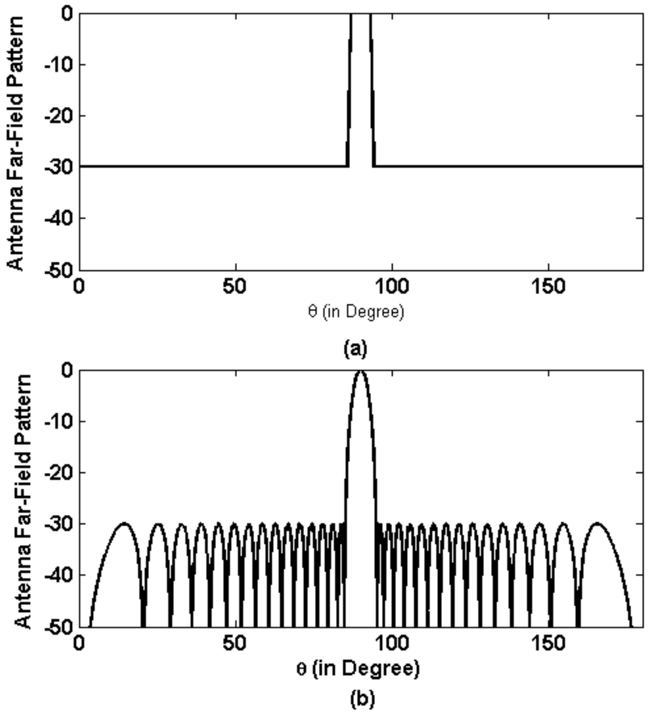

Figure. 2: (a) Template as ideal characteristics
(b) Original pattern (SLL=− *30 dB*)

Initialize the population of K ideas
$x_n(0) \leftarrow \{x_1(0), x_2(0) \ldots x_K(0)\}$
Define parameters P_{rep}, P_{gen}, P_1 and P_2
$gn \leftarrow 0$
Choose clustering algorithm and divide the ideas (K) into groups (N) based on their similarity level
while the terminating conditions at unsatisfactory level, **do:**
Compute the ideas within groups using fitness function
Rank the ideas and select the best idea as group head in each group
If (rand $<P_{rep}$):
A new idea is generated and replaces the cluster head
end if
If (rand $<P_{gen}$):
Select one-cluster idea generation for the solution
If (rand $<P_1$): Select cluster head
else Select random idea from the same cluster
end if
else Select two-cluster idea generation for the solution and choose two clusters randomly
If (rand $<P_2$):
Select cluster heads of chosen clusters and combine by weighted sum
else Pick ideas at random from the selected clusters and combine them by weighted sum
end if
end if
Generate refined idea using equation (5)
Compare the solution with the global best and keep the best x*
$gn \leftarrow gn+1$
end while

Figure 3: Pseudo code of the brain storm optimization

The Gaussian random value is represented by $\rho(0,1)$ and the contribution of this factor is decided by the factor ζ which depends upon maximum iteration G and the current generation g and it is given by

$$\zeta(t) = \frac{1}{4} * (x_{mx} - x_{mn}) * rdm(\ ) * \exp\left(1 - \frac{G}{G-g+1}\right) \tag{6}$$

4. Simulation results and discussion

The brain storm optimization technique has been realized in MatLab and then the same has been applied to the complicated problem of 32 element linear antenna array failure problem. The various parameters of BSO have been set as per Table 1 during simulation of the algorithm.

Table 1
Control Parameters for BSO

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
No. of Generation	300	Population size	100	No. of clusters	5	μ	0
P_{rep}	0.2	P_1, P_2	0.4, 0.5	P_{gen}	0.8	σ	1

In the presented work, the Dolph-Chebyshev 32 elements symmetric linear antenna array has been taken. The elements of the array are uniformly placed at half wavelength distance from each other. There are six-element failures conditions have been introduced in the array at 1st, 2nd, 3rd, 5th, 6th, 27th, 28th, 30th, 31st and 32nd locations.

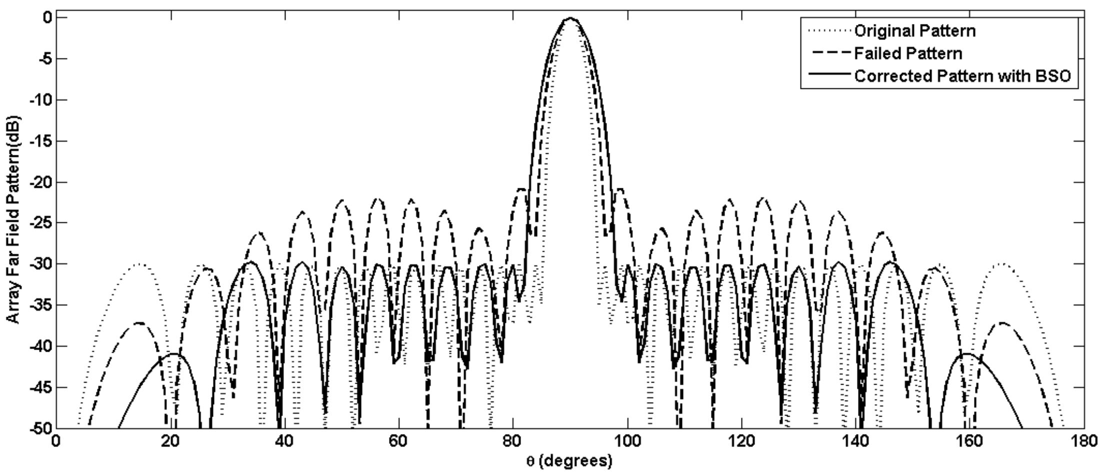

Figure 3: The modified antenna characteristic patterns of symmetric Dolph-Chebyshev under test linear

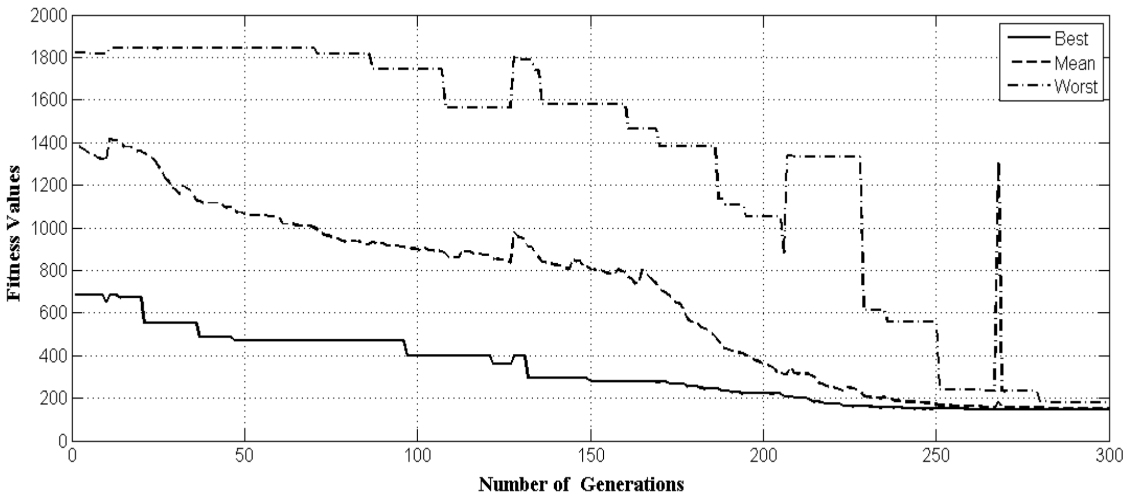

Figure 4: Fitness curve

Table 2
Normalized Excitation amplitude value for ideal, Damaged and modified Radiation characteristics with 1st, 2nd, 3rd, 5th, 6th, 27th, 28th, 30th, 31st and 32nd element malfunctioned condition(SLL= −30 dB)

Element	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Original	0.4439	0.2433	0.3035	0.3684	0.4367	0.5072	0.5785	0.6490
Corrected	0	0	0	0.0184	0	0	0.0691	0.0765
Element	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Original	0.7170	0.7809	0.8392	0.8904	0.9330	0.9660	0.9886	1.0000
Corrected	0.1054	0.1279	0.1487	0.1825	0.1975	0.2242	0.2341	0.2434
Element	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Original	1.0000	0.9886	0.9660	0.9330	0.8904	0.8392	0.7809	0.7170
Corrected	0.2434	0.2341	0.2242	0.1975	0.1825	0.1487	0.1279	0.1054
Element	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Original	0.6490	0.5785	0.5072	0.4367	0.3684	0.3035	0.2433	0.4439
Corrected	0.0765	0.0691	0	0	0.0184	0	0	0

The maximum side lobe level (SLL) of the considered array with malfunctioned conditions has been distorted and reached up to −20.86 dB level at 81° and 99° from original level of −30 dB. The proposed BSO has been applied in order to obtain the ideal characteristics of the antenna array and it has been observed that SLL restored its value up to −29.74 dB level at 34° after corrected measures as shown in Figure 3. It is further noticed that the first null beamwidth (17°) of the corrected array pattern is larger than of the original pattern (10°) because there are large number of failed elements present (31.25%) in the considered case. The first null beamwidth value of the corrected pattern is expected to resemblance with the ideal characteristics pattern if the number of failed elements is small <15%).

Figure 4 presents the fitness curve of 32 element antenna array with the 10 elements failed conditions which pointed that the BSO algorithm converges in 220 generations approximately to achieve the required objective. The normalized excitation coefficients of 32 elements antenna array has been noted in Table 2. The malfunctioned conditions of elements of the antenna array have been introduced by setting the value of 0 at failed location as shown in Table 2.

5. Conclusion

The radiation characteristics of the antenna array faced serious distortion when certain elements of antenna array undergo the failed conditions. In this work, an advanced and flexible approach based on BSO has been suggested to obtain the result of the complex problem of 32 elements uniform antenna array under 10 failed elements conditions. The proposed method has effectively improved the antenna array characteristics by re-arrangement of weights of good elements of antenna array. The work can be further expanded by applying the BSO algorithm to other antenna structures

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