Linear Array Thinning using the Cross-Entropy Method and Parameter Choice

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Abstract —The main motivation to thinning is the reduction in cost and weight. A new approach for the synthesis of thinned uniformly spaced linear arrays is presented. The method is based on Cross Entropy theory.200 elements uniformly spaced symmetrically weighted array was thinned using the Cross Entropy to achieve a sidelobe power of less than –20dB. Thinned arrays' first null beam width is 13.5% wider than the original uniform array. The simulation results to synthesis were compared with the GA, and study of CE parameter choice was simply presented. It was benefit work utilizing the Cross Entropy method for solving electromagnetic optimization problems.

I. INTRODUCTION

Thinning antenna arrays is the strategic elimination of a subset of active elements in the array in order to maintain similar radiation properties as the full array, but using a smaller number of elements in doing so. The main motivation to thinning is the reduction in cost and weight. Achievable designs by statistical array thinning of large arrays are presented by some scholar [1].In modern times, some intelligence methods [2] have all been used to thinning large arrays with great success. This paper addresses a different statistical approach for thinning linear arrays based on cross-entropy theory[3,4] .Lower sidelobes and wider first null beam width can be obtained as for the same filled array illuminated with uniform weighting.

II. CROSS ENTROPY METHOD

Cross-Entropy (CE) is general stochastic optimization technology based on a fundamental principle of information theory called cross entropy (or Kullback-Leibler).In 1997, CE was first introduced by Reuven Y.Rubinstein[5] as an adaptive importance sampling for estimating probabilities of rare events and was extended soon thereafter to include both combinatorial and continuous optimization.

The CE method involves an iterative procedure which each iteration can be broken down into two steps:

1) Generate a random data sample (trajectories, vectors, etc.) according to a specified mechanism.

2) Update the parameters of the random mechanism based on the data to produce a "better" sample in the next iteration.

The fundamental characteristic of the CE is that it operates on a parameterized probability density distribution during the optimization procedure, as opposed to similar stochastic techniques such as the Genetic Algorithm (GA) or Simulated Annealing (SA), which operate directly on the samples in the candidate population.

The basic CE method is summarized with the following algorithm,

1) Initialize parameters

2) Adaptive update γ_t

3) Adaptive update $\mathbf{v}_t$

4) Optimization of $\mathbf{v}_t$

5）When $t = t + 1$，repeat step 2）to 4）until it fits standard of the loop stops.

III. NUMERICAL EXAMPLE

In the following, the presented array thinning synthesis results refer to a 200-element linear array for various degrees of thinning and for symmetrical positions of the turned ON element distributions. The considered array features an embedded isotropic element pattern and the inter-element distance d is equal to 0.5λ.

The score function is defined as the maximum sidelobe power of the far-field magnitude in the sidelobe region $\lambda/Nd < |u| < 1$of the original uniformly spaced array,

$$Score = \max\left|\frac{EP(u)}{FF_{\max}} 2\sum_{n=1}^{N/2} w_n \cos(k\cdot(n-0.5)d\cdot u)\right|^2$$

N = Number of elements in the array = 200

w_n = Amplitude weight of element n, $w_n \in [0,1]$

d = Spacing between elements of original uniform array = 0.5λ

k = Wave number = $2\pi/\lambda$

u =cos φ, 0 < φ < 180o with 1000 equally spaced sample points between [0,1]

$EP(u)$ = Element pattern = 1 for isotropic sources

$FFmax$ = Peak value of far-field pattern = $2\sum_n w_n$

The goal is to minimize this score function in the sidelobe region of the original uniformly spaced array. The optimized result represents the minimum peak sidelobe power for this design.

IV. RESULTS AND DISCUSSION

The design parameters for the CE method are given in Table I. The initial values for the success probabilities of the N/2 Bernoulli distributions for the amplitude weights areset equal to 0.5. This gives each weight an equally likely chance of converging to 0 or 1.Initializing these values towards the extremes of 0 or 1 can help bias the thinning process.

TABLE I TYPES SIZES FOR CAMERA-READY PAPERS

Symbol	Quantity	Value
α	Smoothing Parameter	0.7
ρ	Sample Selection Parameter	0.1
K	Population Size	100
w_n	Values of Array Element Weights	[0,1]
$P_m^{(0)}$	Initial Values for Success Probability	0.5

The overall best score achieved during optimization was –20.1647 dB and was located at the first sidelobe of the thinned array. The resulting radiation pattern and progression of Bernoulli success probabilities are shown in Figure 1. The resulting weight coefficients are presented in Table II. It is apparent that the density of elements is greatest towards the center of the array and both element 1 and 100 are turned on maintaining the same aperture length as the original uniform array.

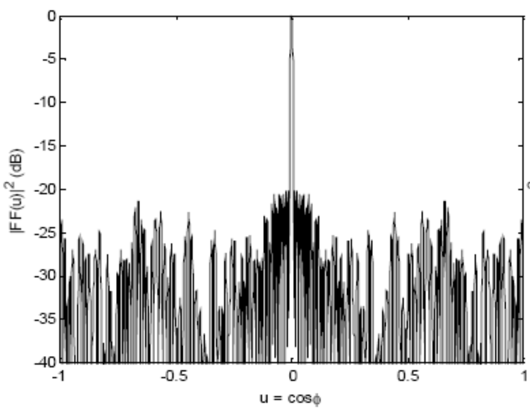

Fig.1. Magnetization as a function of applied field

TABLE II SOLUTION OF ARRAY THINNING PROCEDURE FOR SYMMETRIC, LINEAR ARRAY

Solution	Score (dB)	Element No.	Array Weights
CE	-20.16	n=1,2,…,50	111111111111111111111111111111 101111110111111111011
		n=51,52,…,100	10110111110011101110110010110 11010001011111111111
GA	-22.09	n=1,2,…,50	111111111111111111111111111111 111111111111111001111
		n=51,52,…,100	10011111110111110100001010111 001001011100010101101

The results achieved using CE are similar to those presented in [6]. The measurable for the array pattern computed using GA is given in Table III.

TABLE III COMPARISON OF CE RESULTS TO LITERATURE

Solution	PSP(dB)	BW(deg)	No. Active Elements	Element Gain(dB)
CE	-20.1647	1.295	164/200(82%)	22.15
GA	-22.09	1.46	154/200(77%)	21.8

V. STUDY OF CE PARAMETER CHOICE

Two measurable quantities were recorded:

1)The average peak sidelobe power

2)Number of iterations required for convergence

The results of the study are given in Figure 2. Overall, there are obvious tradeoffs between speed of convergence and the number of elite samples required for accurately calculating the best score.

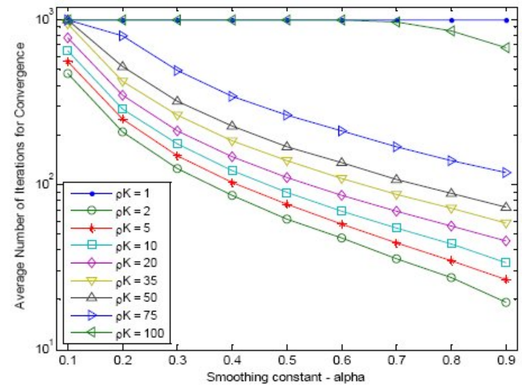

Fig 2 Average number of iterations before convergence

VI. CONCLUSIONS

This paper introduced the use of the CE theory for thinning periodic linear arrays to obtain the lowest possible peak sidelobe level. The presented results demonstrate that the new method is quite effective to synthesize both highly filled as well as massively thinned linear arrays. A comparison with published results for similar thinned array designs proved that the new method achieved the lower peak sidelobe and wider first null beam width results for all considered cases.

VII. REFERENCES

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