Review of Modern Thinned Array Methods for Optimizing Randomly Scattered Elements

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***Abstract*—Modern thinned array methods focus on optimizing full arrays with as little computation as possible. This reduced computation comes at the cost of decreasing the amount of control over the element weighting factors. By reducing the control over the weighting factors for the optimization of each element there is actually an increased computation cost when the techniques are applied to randomly scattered elements, instead of a full array. Applying the modern thinned array methods to randomly scattered elements becomes more important as communication technology increases the number of simultaneously connected elements. This paper discusses some of the information that was gained from doing a review of these modern methods. Specifically, how not including a non-binary element weightings cause an increase in computation time when considering random scattered elements.**

I. Introduction

Optimizing randomly spaced elements into an antenna array system has mainly been a conceptualization in thinned array optimization research. The ability to network and accurately control the number of elements needed without physical connection was not possible when the randomly spaced element optimization research was done in the late 60's to early 70's [1]–[3]. As communication technology advances the number of elements that can be connected to a single wireless control point, or base station, increases along with the propagation abilities of each wireless element. With 5G on the horizon, it is estimated that wireless nodes will have the capability to actively connect to thousands of users or sensors [4]. The increase in the number of elements that can be connected to and controlled means that the previous research into randomly spaced array optimization can now be applied to a physical system.

Most Modern thinned array optimization methods do not focus on optimizing element populations with random positioning or pre-thinning scenarios. Modern closed and open loop thinned array techniques focus on increasing the convergence speed of the optimization, but they assume full arrays. The optimization methods start with a full array of equally spaced elements. For this research the want is to apply the modern thinned array optimization techniques to element populations with random distributions. Therefore, it is beneficial to analyze modern closed loop and open loop techniques effectiveness when considering a population of randomly distributed elements.

The most recent thinned array optimization methods also only allow a solution state that has binary weightings for the elements. Only allowing a binary weighting for the elements allows for simplified elements to be used in the system but reduces the optimization capabilities. With modern communication technology it is acceptable to assume that wireless elements have amplitude control, therefore, modern research should include this possibility in the optimization.

This paper compares a modern closed and open loop thinned array method [5], [6] with different array thinning scenarios. These two methods represent the trend of research paths in thinned array optimization methods.

II. Comparison Setup

The qualities that are going to be compared are the ability to achieve a wanted side lobe level (SLL) and the amount of computation needed to find a solution. The SLL comparison will be done by finding an element optimization solution that achieves a peak SLL (PSL) lower than the current scenario. Most thinned array research focuses on a average SLL but this is not helpful when on side lobe has a magnitude high enough to allow significant interference from a source outside the main beam. Using the PSL does create a more difficult task for the optimization techniques, but creates a more usable real world system. As mentioned several times so far, modern thinned array techniques for the most part focus on increasing the convergence speed of the optimization. The convergence speed is usually measured in the number of iterations needed to find an element configuration that achieves the wanted far field radiation pattern. In this research, a focus will be put on the computation time it takes to find a solution. Computation speed is highly dependent on the computation hardware used, but in this case it will give a better idea of what is accomplishable in a realistic time frame using common hardware.

The techniques are computed against multiple different array and computations setups. The array distributions implemented in this paper are a 32 by 32 (32x32) element square array. Larger arrays have been studied but not included in this paper. Pre-thinning scenarios advance from no elements removed to 95 percent removal. The PSL tasking ranges from

-5 dB below the main beam peak to -30 dB. The two array sizes gives the results the ability to give insight into ability to control small and large array sizes. Modern research usually only goes down to 50 percent thinning, which is known as massive thinning; however, older research has gone as far as 90 percent thinning in the testing of thinned array optimization techniques. The higher thinning percentages will give a better indication of the closed and open loops abilities to optimize element distributions with a more difficult scenario. The PSL levels range are there to get an idea of the capabilities of each technique compared to the average SLL (ASL).

III. Results

The testing setup is a 32x32 square array with no modifications to the methods and then the same methods with non-binary element weightings allowed. Each paper has presented results for array sizes at or similar to a 32x32 square array [5], [6]. This is meant to be an initial view of the two techniques based on similar setups presented in each of the papers. The optimization computation time for each scenario is capped at an hour to allow for insight into each techniques application to a practical setup. Each scenario is a combination of maximum PSL allowed and thinning percentage (TP) of elements removed before optimization was applied. The results of this testing can be seen in tables I - III.

TABLE I
Haupt Taylor Distribution method total optimization times in seconds for a 32x32 square array

PSL/TP	0	25	50	75	85	90	95
-5	16.75	14.40	11.52	8.32	6.35	4.77	2.44
-10	16.52	15.44	11.40	9.85	6.41	4.35	22.86
-15	116.50	99.78	112.68	104.74	OTC	OTC	OTC
-20	135.96	255.29	OTC	OTC	OTC	OTC	OTC
-25	OTC	OTC	OTC	OTC	OTC	OTC	OTC
-30	OTC	OTC	OTC	OTC	OTC	OTC	OTC

TABLE II
Ha M-cGA total optimization times in seconds for a 32x32 square array allowing element weighting

PSL/TP	0	25	50	75	85	90	95
-5	202.69	171.30	143.45	99.24	79.66	56.75	35.99
-10	205.34	172.75	134.13	121.16	75.33	435.64	1517.7
-15	OTC	OTC	OTC	OTC	OTC	OTC	2417.8
-20	OTC	OTC	OTC	OTC	OTC	OTC	1460.8
-25	OTC	OTC	OTC	OTC	OTC	OTC	1239.2
-30	OTC	OTC	OTC	OTC	OTC	OTC	2057.5

Table I shows the computation time needed to reach the wanted PSL using the open loop Taylor distribution method. The closed loop modified compact genetic algorithm (M-CGA) is not shown because there were no successful scenarios in the time limit. Tables III and II show the computation

TABLE III
Haupt Taylor Distribution method total optimization times in seconds for a 32x32 square array allowing element weighting

PSL/TP	0	25	50	75	85	90	95
-5	19.55	17.08	13.79	9.57	7.76	5.29	3.33
-10	19.73	16.98	12.91	11.95	7.09	163.96	OTC
-15	128.59	98.10	78.30	56.97	OTC	OTC	OTC
-20	117.80	99.88	126.26	OTC	OTC	OTC	OTC
-25	134.44	OTC	OTC	OTC	OTC	OTC	OTC
-30	OTC	OTC	OTC	OTC	OTC	OTC	OTC

times for each scenario with non-binary weightings allowed. Automatically the closed loop M-CGA was improved by allowing more control of the element weightings and the open loop case was able to solve for a few more cases with more stringent maximum PSL requirements. In the cases of the randomly scattered elements, pre-thinning was applied, having more control over the elements is more computationally efficient than trying to what the modern methods are moving towards.

IV. Conclusion

This paper discusses issues with modern thinned array methods decreasing the optimization weighting factor control. When the optimization process reduce the amount of control of elements the thinned array methods become less applicable to randomly scattered element scenarios. The effects of reduced control are especially seen in the higher thinning scenarios where the reduced number of elements naturally reduces computation time but needs more refined optimization to be successful.

References

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