Assumptions Needed for a Valid Average Element Pattern in a Three Dimensional Array

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Abstract—**Three dimensional antenna array systems are a possibility with the advances in communication technology coming in a few years. Before that time comes there should be algorithms and methods in place to take advantage of the greatly increased density of wireless elements. Taking advantage of these communication advances requires a better understanding of the complications when creating three dimensional antenna arrays. One area of research that is needed is the bounding assumptions that will allows for an average element pattern to be applied to all elements in a three dimensional array system. This paper discusses the considerations that need to be made for these assumptions.**

I. INTRODUCTION

With communication technology advancing the number of wireless elements that can be connected simultaneously is increasing substantially. This increase in the number of elements will allow for antenna arrays to be created using thinned array methods. The issue with the thinned array optimization methods is that using them in three dimensions has not been done before and the limitations of such techniques is unknown.

Modern thinned array methods focus on optimizing a periodic one or two dimensional antenna array without using complicated internal hardware. There are several different types of optimizing techniques [1]–[4]. Each technique solves for the element weightings that make the greatest effect on the wanted antenna array pattern. The issue with the methods, when applied to a random distribution of elements, is that they have not been specifically designed with this task in mind. The interesting part of thinned array optimization research is that it started as methods for optimizing randomly spaced elements into coherent array system [5]–[7]. With these historical beginnings it means that there needs some adjustments to the modern methods for the randomly spaced three dimensional element array scenario and wireless communication elements could be combined into coherent arrays.

Modifying the modern thinned array techniques requires multiple steps, with one of the major steps being determining how to adjust for the electromagnetic (EM) effects in a three dimensional array. It has been found that it is possible to assume an isotropic radiation pattern for each element in the array [8]. This approach explains that assuming a randomly distribution of antenna elements with random pointing directions the average element pattern can be assumed to be isotropic with lower overall power that the single element scenario. This approach does have several boundary conditions that need to be discussed because they not only effect the assumption for isotropic elements but the limitations that the thinned array methods can operate in.

II. BACKGROUND

Assuming an isotopic element for each element in the array requires some conditions to be present. Before the assumption can be true there are several aspects of the array that need to be true, otherwise there will be considerable errors in the resulting far field pattern. These considerations range from the type of elements in the array, the pointing direction of the elements, the number of elements, and the spacing between elements. All of these aspects effect the active element to single element pattern comparison which is the key to the isotropic radiator assumption.

The first aspect is the minimum distance between elements in the array to reduce the mutual coupling issues. Due to the random nature of the array reducing the mutual coupling is the best way to reduce extreme computations that would be needed otherwise. Reducing the mutual impedance is the first part of this aspect because it allows each element to independently operate as before without complication to internal hardware. The second part to the minimum distance between elements is the reduction in the active element pattern changes. The minimum distance between elements should have few difference between the single element and active element patterns. With these two steps determining the minimum distance between elements, there is a significant reduction in the mutual coupling effects allowing the separation of the element and array factor in the antenna array far field pattern estimation.

The second aspect is the type of element that is being used in the antenna array. Assuming a homogeneous element population the type of elements being used has a large effect on the mutual coupling issues and ability to assume an isotropic average element pattern. Elements that are less directive can be located in tighter groupings than more directive elements. For example, an array of dipole like elements can have a closer minimum distance than a grouping of horn antennas. The more omni-directional original antenna pattern allows for easier inclusion or determination of the mutual coupling issues.

After the type of elements being used the next aspect to consider is the pointing direction of all the elements. The pointing direction of each element has a very significant effect on the ability to assume a isotropic element and it also has the biggest application to a real life scenario for randomly scattered wireless elements. With elements having random pointing directions there is a wider distribution of the array power in all directions. The random pointing directions would require one to consider the element pattern and array factor at the same time if there was no average element pattern. If the elements do not have random pointing directions the spacing between elements actual has to be increased as well because the mutual coupling effects are stronger.

The last aspect to consider is the number of elements that currently comprise the array system. Using more elements in the array with random pointing directions allows for the assumption of isotropic elements to be more accurate. Adding more elements into the array increase the coverage of the three dimensional space with overlapping main beam energy. With the increased coverage of energy the average isotropic element assumption becomes easier to use without accounting for error.

III. RESULTS

Figure 1 shows comparison of single element pattern to three different active element patterns. The plot suggests that as the number of elements increases in the array the active element pattern has less variation from the single element pattern. They may be more spikes in the pattern but the overall average difference between the single element and active element is smaller when there are more elements.

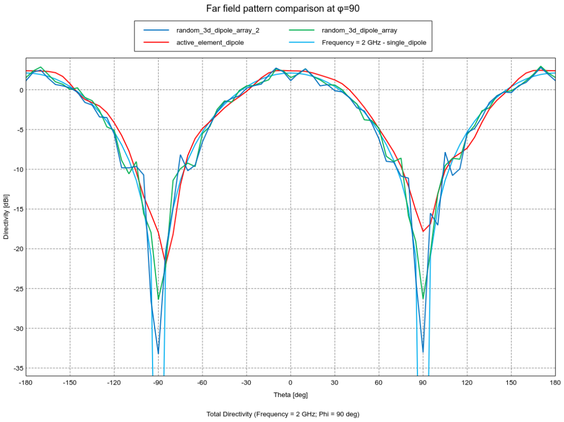

Fig. 1. Cartesian plot of a far field pattern slice ($\Phi = 0$) of dipole active and single element patterns. The light blue line is the single element pattern. Dark blue and green lines are active element patterns with 126 surrounding elements with random pointing directions. The red line is an active element pattern with 26 surrounding elements with random pointing directions.

Figure 2 shows a polar plot with a single and active element pattern for horn antennas. This shows the differences when considering the type of elements used in the array. Due to horns having more directive pattern the back scatter from the elements in front of the active element make a larger change to the far field pattern. This larger change can be seen in the 180 theta region. This area is supposed to be lower power but in this simulation the back lobe region is 7 dBi higher than the single element pattern.

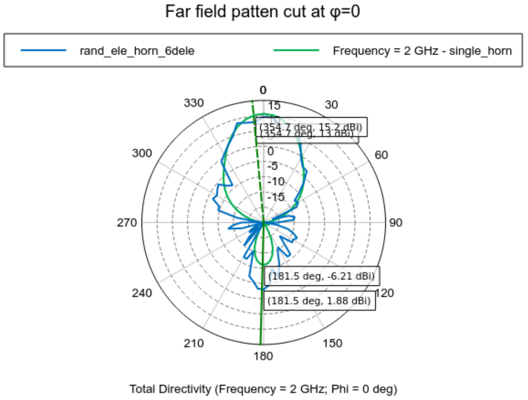

Fig. 2. Polar plot of the single element pattern (green) and the active element pattern of a horn with 26 surrounding horns with random pointing directions (blue).

IV. CONCLUSION

This paper discusses the considerations that need to be taken care of before an average element pattern can be applied to a three dimensional array and thinned array optimization be used. There are four aspects that need to be considered: element spacing, type of element, number of elements, and the element pointing positions. If all of these aspects hold to the specifications presented out in the paper an isotropic average element can be used.

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