Revisiting the Appearance of Grating Lobes in Antennas with Circular Periodicity

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The appearance of grating lobes in structures with periodicity is an interesting phenomenon and has been studied for a long time by scientists and engineers. When the periodicity conforms to a rectangular grid, the grating lobe appearance in the far field patterns of antennas are well understood. Closed form mathematical expressions exists for predicting their location and to estimate their levels with certain accuracy. This apparently cannot be said when one encounters circular periodicity, which can be observed in circular array antennas and reflector antennas with umbrella like structures. To the authors' best knowledge, post reviewing many books and published articles, there has not been a comprehensive and definite characterization of the grating lobe phenomenon for circular periodicity. This, in particular, becomes more complex when one wants to accurately estimate of locations of grating lobes in both azimuth and elevation directions. It is the purpose of this paper to revisit the appearance of grating lobes in antenna structures with circular periodicity.

As an example we first consider phased array antennas that have clearly gained significant interests for emerging technologies due to their ability of providing high gain while allowing precise control of beam pointing and characterization of the radiation patterns. The geometry of the array plays a key role in determining its radiation performance. The overall shape and size of the array decides the directivity and sidelobe levels, whereas the spacing between the elements decides the position and level of grating lobes for the array. For large periodic arrays, where the spacing between the elements can become larger than one wavelength, the grating lobe can occur close to the main beam, significantly reducing the directivity of the array. This work particularly focuses on the analysis of grating lobes for circular arrays, which are attractive for a variety of applications. We begin our investigation by analyzing the array factor for uniform circular arrays in depth. Special attention is paid to the dependencies of the array factor on elevation angle θ and azimuth angle φ. The approximate locations of grating lobes in both elevation and azimuth planes are analytically derived and related to the periodicity of the array.

The formulations presented in this work can readily be extended to other antenna geometries that possess circular periodicity. As a representative example, we use our analytical derivations to predict the grating lobes for other class of antennas like umbrella reflectors. The deviation of such reflectors from the ideal parabolic reflector creates a circular periodicity that can be appropriately modeled by the techniques developed for circular arrays. The theoretical predictions are validated through simulations and some existing measured data to verify our formulations.