Sidelobe Reductions in Rectangular-Lattice Planar Arrays with Reconfigurable Element Spacing

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***Abstract*— The transformative approach to sidelobe reductions using the electronically displaced phase enter antenna technique is investigated in a planar array configuration in this paper. A physically periodic rectangular-lattice array is electronically reconfigured into an aperiodic planar array to lower the sidelobe levels without any physical displacement while maintaining the same array size. The sidelobe reduction capability of the E-DPCA technique is further bolstered by combining it with the array thinning method to achieve about 8.6 dB reduction in a 7×7 planar physically-periodic rectangular array without any mechanical movement.**

***Keywords*— Planar Array, sidelobe level (SLL), electronically displaced phase center antenna (E-DPCA).**

I. Introduction

Phased array antennas are often utilized in wireless communication and detection/tracking applications as they increase the overall gain of the system and electronically control different radiation pattern characteristics such as beamwidth, side and minor lobe levels, null location, and main beam position. Large sidelobe levels (SLLs) in the radiation pattern lead to a loss in the antenna directivity and overall signal-to-noise ratio and may cause unwanted interference. A number of array pattern synthesis techniques have been developed over the years to reduce the SLLs and maintain the desired gain values. Some of the classical techniques for the SLL reduction include amplitude-/phase-control only, amplitude and phase tapering in equally-spaced arrays, and physical redistribution/thinning in aperiodic arrays [1-5]. On the one hand, physically redistributing the base elements of aperiodic arrays to generate different desired radiation characteristics makes the overall system rigid, expensive, and difficult to implement in practice. Largescale thinning, on the other hand, leads to a drastic drop in the overall gain of the array and degrades its performance. Therefore, a novel technique of electronically rearranging the phase center locations of the base elements inspired by [6], and thus their relative coordinates, in N-element, equally-spaced linear arrays to achieve SLL reductions without any physical displacement was introduced in [7-8]. The electronically-displaced phase center antenna (E-DPCA) technique facilitates the realization of different electronically aperiodic structures, out of an equally-spaced array, generating radiation patterns with low side and minor lobe levels. It was proven that the E-DPCA technique, when combined with the array thinning method, provides a substantial SLL reduction in equally-spaced linear array antennas [8]. Herein, the application of the E-DPCA + thinning technique is further investigated in a rectangular-lattice planar array. The phase center locations of the dual-mode base elements in a 7×7 element periodic planar array are electronically repositioned to create an aperiodic structure that lowers the SLLs without any physical displacement, while maintaining the same array size.

II. 7 × 7 Rectangualr Planar E-DPCA Array

The phase center location of an antenna element is its effective source of radiation from which it generates spherical waves with constant wave fronts. The phase center location of a single mode circular patch antenna, exciting either the TM_{11} or TM_{21} mode, coincides with its physical center. When both the TM_{11} and TM_{21} modes are excited simultaneously in a dual-mode circular patch antenna the phase center location can be electronically displaced away from its physical center [6]. The direction and magnitude of the phase center displacement is controlled by the elements' mode content factor, i.e. $A_{21}=|A_{21}|\angle\alpha_{21}$, where $|A_{21}|$ and α_{21} represent the magnitude and the phase shift between the two modes, respectively. Due to this intriguing phase center displacement property, the dual-mode circular patch antenna is utilized as the base element of a 7×7-periodic rectangular planar array, in which the relative coordinates of its base elements are reconfigured by the E-DPCA technique. The base elements of the planar array are uniformly spaced $0.7\lambda_0$ apart, where λ_0 is the free space wavelength at 10 GHz. Initially, when only the TM_{11} mode is excited, the phase centers of the base elements are coincident with their physical centers and the antenna generates a radiation pattern with the SLL of -13 dB. This equally-spaced 7×7 planar array is electronically transformed into an aperiodic planar antenna by simultaneously exciting the TM_{21} modes along with the TM_{11} modes in the base elements of the array and displacing their phase center locations away from their physical centers. The electronically aperiodic array developed using the E-DPCA technique is illustrated in Fig. 1. The elements of the 7×7 array are symmetrically excited about the *Y*-axis. The elements along the *Y*-axis are considered as the reference elements and their phase centers are kept at their physical centers by exciting only the TM_{11} mode. This is represented by a column of black "eye" symbols along the *Y*-axis in Fig. 1. The elements in the columns on left and right of the *Y*-axis are excited with the same magnitude but opposite phase shifts. The elements of column 1, 2 and 3 are excited with $|A_{21}|$=0.88, 0.7 and 0.1 and the phase shifts of α_{21}=180°, 180°, and 0°, respectively. The in- and out-of-phase excitations within the base elements are graphically depicted by the blue and green "eye" symbols, respectively, in Fig. 1. The resultant planar E-DPCA array lowers the SLL from -13 dB to -18.2 dB. To further suppress the SLL, the corner elements of the 7×7 rectangular array are turned off. This is represented by the red "cross" symbol across the corner elements in Fig. 1. Such a slightly-thinned planar E-DPCA array further reduces the SLL to -21.6 dB. The radiation patterns of the conventional 7×7 equally-spaced and the E-DPCA+ thinned rectangular planar array are compared in Fig. 2. Due to the symmetry of the array, only the optimal mode content factors of the elements in columns 1, 2 and 3 are given, which are displayed in a histogram in Fig. 3. The effective distances between the adjacent elements in columns 1, 2 and 3 of the equally-spaced and E-DPCA + thinned arrays are detailed in Table I.

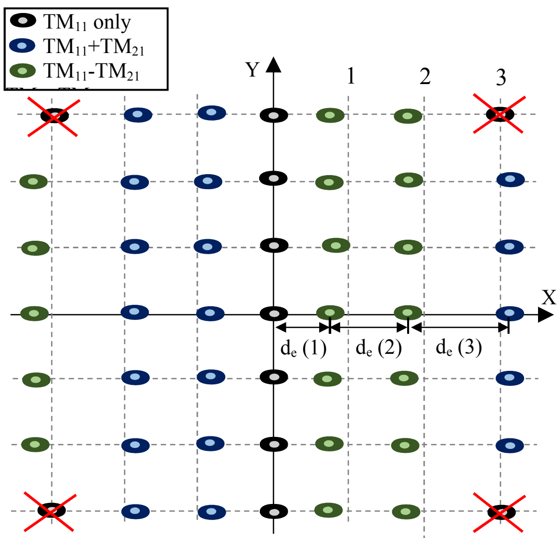

Fig. 1. Geometry of the 7×7-element planar E-DPCA + Thinned array, whose elements are physically placed 0.7λ_0 apart and 4 corner elements are turned off. The effective distance between the adjacent element in column 1, 2 and 3 i.e. $d_e(1)$-$d_e(3)$ are summarized in Table I.

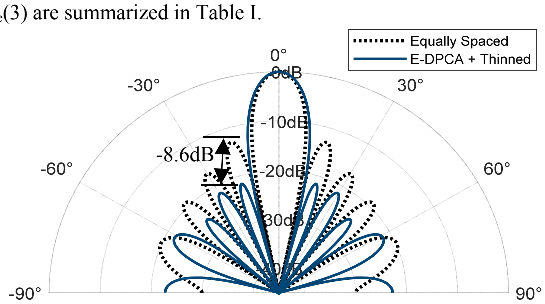

Fig. 2. Radiation patterns of equally-spaced (TM_{11} only) and E-DPCA +Thinned 7×7 planar array in Fig. 1, with SLLs of -13 dB and -21.6 dB, respectively.

III. Conclusion

In this paper, the intriguing phase center displacement capability of a dual-mode circular patch antenna was investigated in a 7×7-element equally-spaced, rectangular lattice planar array. The effective distances between the adjacent elements of the array were electronically altered to realize a planar aperiodic array without any physical movement. The resultant aperiodic configuration generated a radiation pattern with a 5.2 dB reduction in the side and minor lobe levels. To further suppress the SLLs, the corner elements of the 7×7 E-DPCA array were turned off. This supplementary 8.2% thinning led to an additional 3.4 dB reduction in the SLL. Thus, the combined E-DPCA + thinning technique when applied to the 7×7 planar rectangular lattice array generated a pattern with an overall ~8.6 dB reduction in the SLL. The proposed concept has promising potential to improve the performance of different planar arrays in terms of SLLs and null steering which will be presented at the conference.

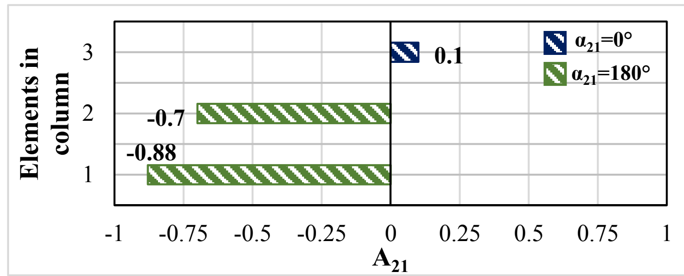

Fig. 3. Optimal A_{21} of the elements in columns 1, 2 and 3 in the 7×7-element planar E-DPCA + Thinned array shown in Fig 1.

TABLE I
Effective distances between Adjacent Elements of columns 1, 2 and 3 of the 7×7-Element Planar Equally-Spaced and E-DPCA +Thinned Arrays

	d_e (1) λ_0	d_e (2) λ_0	d_e (3) λ_0
Equally-Spaced (TM_{11}) SLL = -13 dB	0.7	0.7	0.7
E-DPCA + Thinned SLL = -21.6 dB	0.57	0.73	0.82

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