**IOSR Journal of Engineering (IOSRJEN)** **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 08, Issue 4 (April. 2018), ||VII|| PP 66-70

# Smart Antenna of Aperiodic Array in Mobile Network

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**ABSTRACT:**Aperiodic or non-uniform antenna arrays are used for highly directive beam generation with reduced side lobe levels. In this paper, aperiodic antenna array, with non-uniform inter-element spacing, is used for beamforming of smart antenna. Sample matrix algorithm (SMI) algorithm is used for adaptive beamforming of smart antenna. Reduced side lobe level (SLL) of antenna radiation beam causes less interference for other users in mobile network. Aperiodic array produces lower side lobe level compared to uniform array while producing main beam and null towards the desired directions. Performance of adaptive beamforming at different angles using aperiodic array are compared with the performance of smart antenna of periodic array. Maximum side lobe level reduction of 3 dB is achieved using smart antenna of aperiodic array compared to periodic array.

**KEYWORDS:** Smart antenna,aperiodic antenna array, SMI algorithm, side lobe level

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Date of Submission: 31-03-2018 Date of acceptance: 16-04-2018

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## I. INTRODUCTION

Smart antenna technology is one of the major technologies for mobile communication in 4G and beyond. Smart antenna system provides high security by forming radiation beam only toward the user and generating null toward the interferer[1,2]. Efficient spectral utilization and power saving in cellular network are possible by using smart antenna technology. After estimating direction of arrival of user signal, smart antenna generates desired beam toward the user using adaptive signal processing algorithm[1,3]. In literature, research works are available for beamforming of smart antenna using various types of adaptive signal processing algorithms and popular method of adaptive beamforming is use of least mean square (LMS) algorithm[4,5]. Most of these works are devoted to beamforming using periodic or uniform antenna arrays.

In an aperiodic array inter-element spacing in the array is non-uniform. Reports on array antennas using aperiodic array are available [6,7,8,9,10,11], where aperiodic arrays are used for side lobe reduction and grating lobe reduction in phased array applications. Research work on smart antenna of aperiodic arrays is insufficient. In this paper, performance of smart antenna using aperiodic array is presented. Adaptive beams are formed for aperiodic arrays at different user directions using SMI algorithm and the results are compared with those of periodic arrays. Lower SLLs are achieved for aperiodic array than periodic array.

## II. SAMPLE MATRIX ALGORITHM

One of the discontinuous adaptive algorithms is sample matrix inversion. It's used in discontinuous transmission, however it requires the number of interferers and their positions remain constant during the duration of the block acquisition. Sample matrix inversion has faster convergence rate[4] since it employs direct inversion of the covariance matrix. The sample matrix is defined as the time average estimate of the array correlation, which uses $N$ samples, and if the random process is ergodic in correlation, then the time average estimate is equal the real correlation matrix[4]

$$R_{xx} \approx \frac{1}{N}\sum_{n=1}^{N} x(n)x^{H}(n) \quad (1)$$

$$r = \frac{1}{N}\sum_{n=1}^{N} d^{*}(n)\, x(n) \quad (2)$$

Matrix $x_N(n)$is defined as the $n$ th block of vectors $x$ ranges over $N$ -data snapshots[4], where, $n$ represents the block number, and $N$ is the block length. So, $R_{xx}$ can be given by

$$R_{xx}(n) = \frac{1}{N}\, x_N(n)x_N^{H}(n) \quad (3)$$

Take a hypothesis that the desired signal is

$$d(n) = [\, d(1+nK)d(2+nK)d(3+nK) \ldots \ldots \ldots d(N+nK)\, ] \quad (4)$$

Then,

$$r = \frac{1}{N} d^{*}(n)x_N(n) \quad (5)$$

Error in SMI algorithm is determined as $e(n) = d(n) - w^{H}(n)x(n)$ (6)

Finally, the sample matrix inversion weights of the $n$ th block can be computed as[4]

$$w_{SMI}(n) = R_{xx}^{-1}(n)r(n) = [x_N(n)x_N^H(n)]^{-1}d^*(n)x_N(n) \quad (7)$$

## I. Beamforming of Adaptive Smart Antenna of Aperiodic Array

In a uniform linear antenna array the inter-element spacing (d) is same for all the elements which is shown in Fig. 1. Antennas are fed by current having progressive phase shift 'α'.

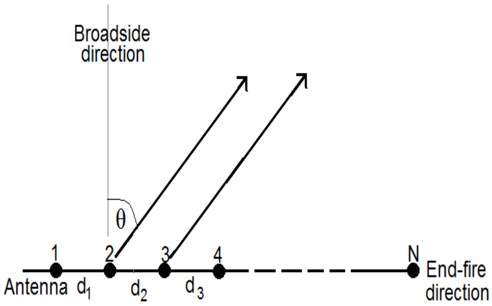



**Fig. 1.** Linear antenna array

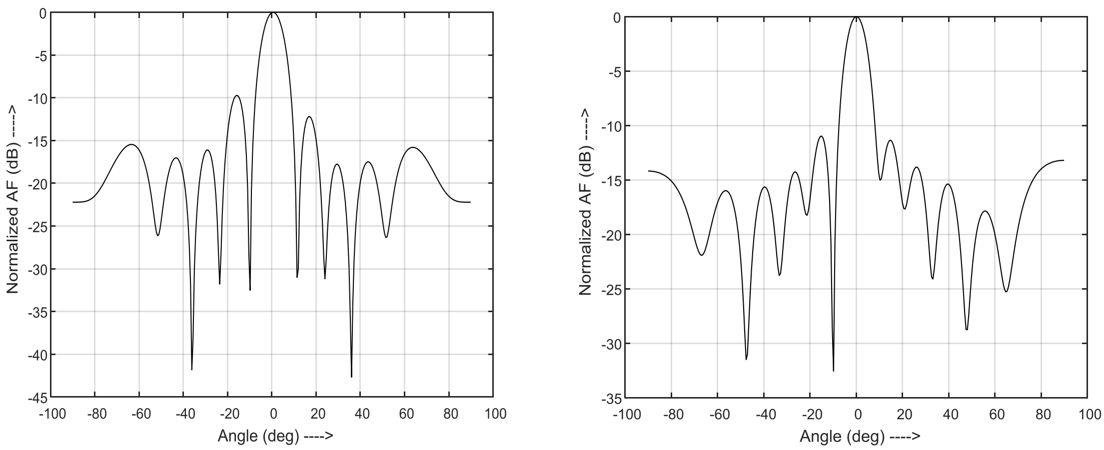
Aperiodic array produces lower side lobe level compared to uniform array. The aim of this research work is to investigate nature of adaptive beamforming at different angles using aperiodic array with reduced side lobe level while producing main beam and null towards the desired directions. The array factor (AF) of an aperiodic array of N number of isotropic elements is given by[12]

$$AF = \sum_{n=1}^{N} A_n e^{j(n-1)\beta d_{n-1} sin\theta} \quad (8)$$

Here, inter-element spacing $d_{n-1}$ is the aperiodicity of the array. For a periodic array, $d_{n-1}$ is constant.
Normalized array factor is

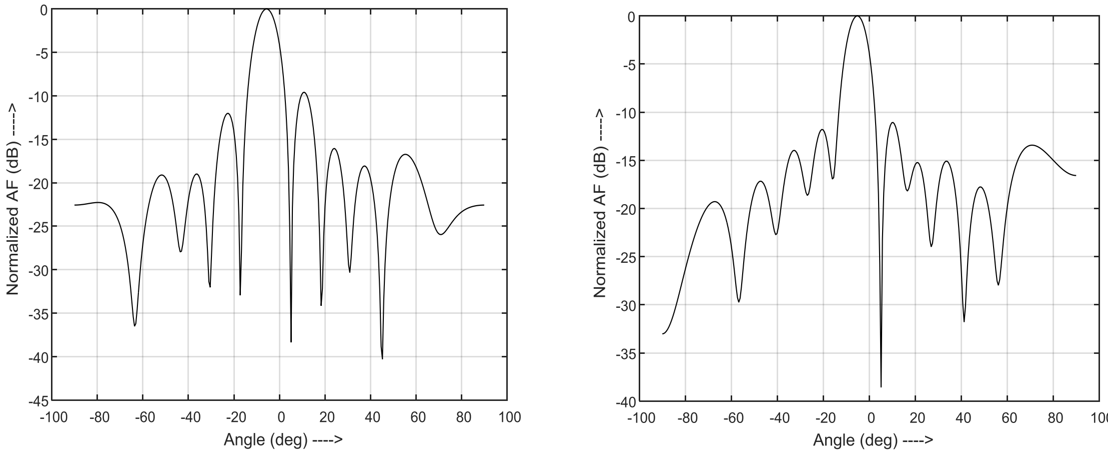
$$AF_{max} = \frac{AF}{AF_{max}} \quad (9)$$

SMI algorithm is used for beam generation of smart antenna of periodic and aperiodic arrays at different angles. Simulated results for periodic and aperiodic arrays for 10 element (N=10) antenna arrays for beam direction (BD) at $0^0$ and null direction (ND) at $-10^0$ are shown in Fig. 2 and for BD= $-5^0$ and ND=$5^0$ are shown in Fig. 3. For aperiodic array of 10 elements, inter-element spacing is d=0.3λ, 0.33λ, 0.36λ, ......... 0.54λ. For periodic array d=0.5λ.




(a)Periodic array (b) Aperiodic array

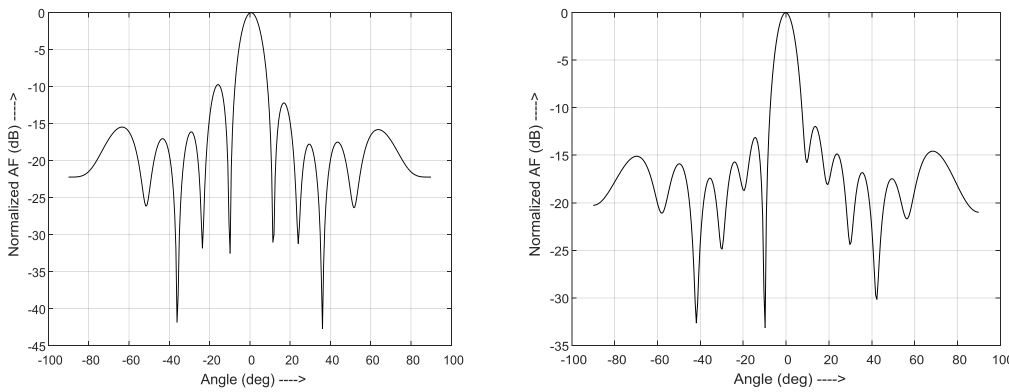
**Fig. 2.** Array factor for smart antenna of periodic and aperiodic arrays




(a)Periodic array (b) Aperiodic array

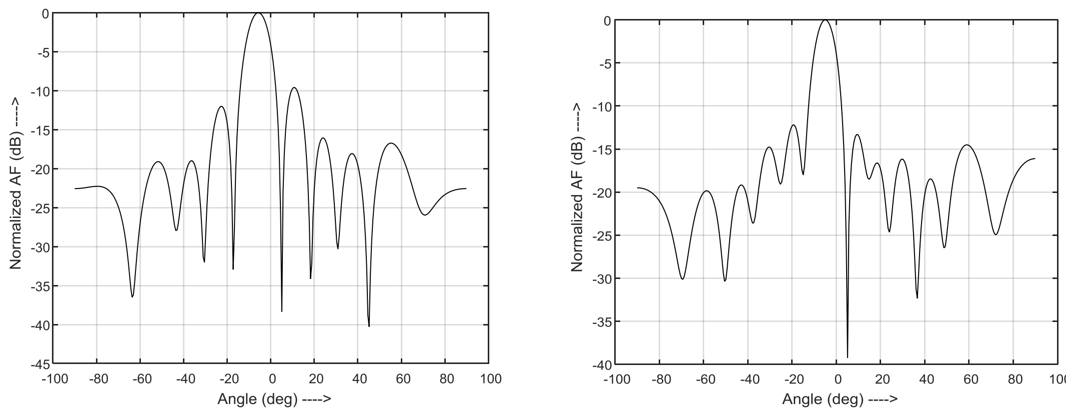
**Fig. 3.** Array factor for smart antenna of periodic and aperiodic arrays

Simulated results for periodic and aperiodic arrays for 10 element (N=10) antenna arrays for beam direction (BD) at $0^0$ and null direction (ND) at $-10^0$ are shown in Fig. 4, for BD= $-5^0$ and ND=$5^0$ are shown in Fig. 5 and for BD=$15^0$ and ND=$25^0$ are shown in Fig. 6. For aperiodic array inter-element spacing is d=0.35λ, 0.38λ, 0.41λ, ......... 0.59λ. For periodic array d=0.5λ.



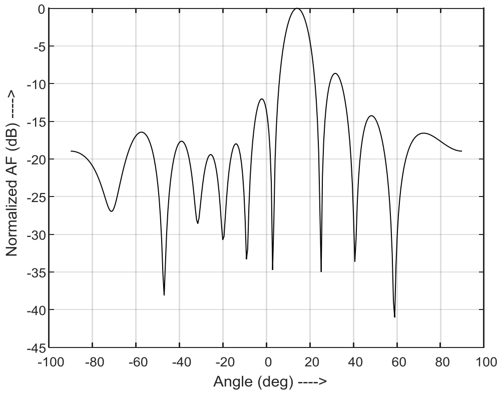

(a)Periodic array (b) Aperiodic array

**Fig. 4.** Array factor for smart antenna of periodic and aperiodic arrays

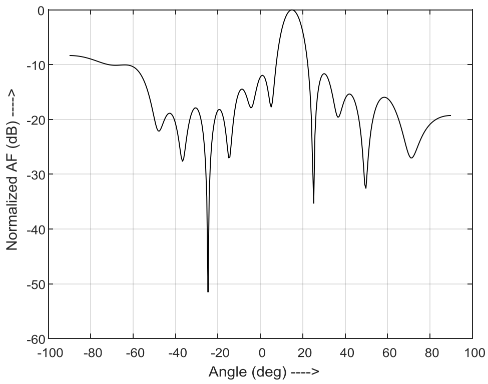



(a)Periodic array (b) Aperiodic array

**Fig. 5.** Array factor for smart antenna of periodic and aperiodic arrays




(a)Periodic array




(b) Aperiodic array

**Fig. 6.** Array factor for smart antenna of periodic and aperiodic arrays

Simulated results, presented in above figures, are compared in Table 1.

**Table 1** Comparison of results between periodic and aperiodic arrays

| Figure | Specifications | Type of Array | BD | ND | HPBW | $SLL_{max}$ |
|---|---|---|---|---|---|---|
| Fig. 2 | Desired BD= $0^0$ and ND= $-10^0$ | Periodic (d=0.5λ) | $0.5^0$ | $-9.8^0$ | $9.5^0$ | -9.7 dB |
| | | Aperiodic (d=0.3λ, 0.33λ, 0.36λ, ......... 0.54λ) | $-0.05^0$ | $-9.8^0$ | $9.35^0$ | -11 dB |
| Fig. 3 | Desired BD= $-5^0$ and ND= $5^0$ | Periodic(d=0.5λ) | $-5.7^0$ | $5.1^0$ | $10.03^0$ | -9.5 dB |
| | | Aperiodic (d=0.3λ, 0.33λ, 0.36λ, ......... 0.54λ) | $-5.2^0$ | $5.1^0$ | $9.45^0$ | -11.1dB |
| Fig. 4 | Desired BD= $0^0$ and ND= $-10^0$ | Periodic(d=0.5λ) | $0.5^0$ | $-9.8^0$ | $9.5^0$ | -9.7 dB |
| | | Aperiodic(d=0.35λ, 0.38λ, 0.41λ, ......... 0.59λ) | $-0.05^0$ | $-9.8^0$ | $6.8^0$ | -10.5 dB |
| Fig. 5 | Desired BD= $-5^0$ and ND= $5^0$ | Periodic(d=0.5λ) | $-5.7^0$ | $5.1^0$ | $10.03^0$ | -9.5 dB |
| | | Aperiodic (d=0.35λ, 0.38λ, 0.41λ, ......... 0.59λ) | $-5.2^0$ | $4.6^0$ | $7.2^0$ | -11 dB |
| Fig. 6 | Desired BD= $15^0$ and ND= $25^0$ | Periodic(d=0.5λ) | $14.3^0$ | $25.2^0$ | $9.8^0$ | -8.7 dB |
| | | Aperiodic (d=0.35λ, 0.38λ, 0.41λ, ......... 0.59λ) | $14.9^0$ | $25.2^0$ | $8.9^0$ | -11.7dB |

In Table 1, in all the cases, half power beamwidth (HPBW) for periodic array is more than the HPBW of aperiodic array. Therefore, directivity of smart antenna of aperiodic array is higher than the directivity of periodic array.

## III. CONCLUSION

Beamforming of smart antenna using isotropic aperiodic arrays is presented here. MATLAB simulated results for aperiodic arrays are compared with the results for smart antenna of periodic array. Number of iteration (block length) in all the cases is 1000. Directivity of aperiodic array is found to be more than the smart antenna of periodic array. Lower side lobe level is achieved for smart antenna of aperiodic array which is desired in mobile network for interference suppression. Possibility of appearance of grating lobe in aperiodic array is more and for aperiodic array feed network design is more complicated than periodic array. Mutual coupling between antenna elements is not considered in this work. Performances of adaptive smart antenna of aperiodic arrays with different types of non-uniform spacing may be the direction of future work.

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Pooja Raj ."Smart Antenna of Aperiodic Array in Mobile Network." IOSR Journal of Engineering (IOSRJEN), vol. 08, no. 4, 2018, pp. 66-70.