Implementation of Digital Beamforming Technique for Linear Antenna Arrays

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Abstract—A digital Beamforming technique used for increased channel capacity and also increased signal to noise and interference ratio. In smart antenna, different type of radiation pattern of an antenna can be changed either by selecting appropriate weights or by changing the array geometry. This paper presented based on auxiliary phase algorithm by using this algorithm in linear antenna array determine the array pattern approximating the auxiliary function in both amplitude and phase. Cost function involving auxiliary function and array pattern is minimized by modifying the pattern.

Keywords - Linear Antenna arrays, multibeam pattern, Beamforming

I. INTRODUCTION

Beamforming is a signal processing technique used with arrays of transmitting or receiving transducers that control the directionality of, or sensitivity to, a radiation pattern. When receiving a signal, Beamforming can increase the receiver sensitivity in the direction of wanted signals and decrease the sensitivity in the direction of interference and noise. When transmitting a signal, Beamforming can increase the power in the direction the signal is to be sent.

Beamforming takes advantage of interference to change the directionality of the array. When transmitting. a beamformer controls the phase and relative amplitude of the signal at each transmitter, in order to create a pattern of constructive and destructive interference in the wavefront. When the number of users increase, same frequency will be used by using Beamforming technique and overall capacity also increase and suppressed the interference signal. Several technique uses to generate radiation patterns approximating a given desired pattern, with nulls aimed to reject undesired sources. Genetic algorithm change some of the least significant bits of the beam steering phase shifters to minimize the total output power. By using small value of adaptive phase in minor deviation in the beam steering direction and small perturbation in the sidelobe level in addition to constraining the search space of the genetic algorithm. Genetic algorithm approach is proposed to form nulls in the radiation pattern of a linear array by phase only control[1].

II. BEAMFORMING CONFIGURATION

Basically there are two major configurations of Beamforming.

A. Switched–Beam : a finite number of fixed, predefined patterns or combining strategies.(sectors).

B. Adaptive array : a theoretically infinite number of patterns(scenario-based) that are real time according to the spatial changes of SOIs and SNOIs.

A. Switched beam antenna

A switched-beam system is the simplest smart antenna technique. It forms multiple fixed beams with heightened sensitivity in particular directions. Such an antenna system detects signal strength, chooses from one of several predetermined fixed beams, and switches from one beam to another as the cellular phone moves throughout the sector.

B. Adaptive antenna approach

The adaptive antenna systems approach communication between a user and a base station in a different way by adding the dimension of space. By adjusting to the RF environment as it changes (or the spatial origin of signals), adaptive antenna technology can dynamically alter the signal patterns to optimize the performance of the wireless system. Adaptive array systems provide more degrees of freedom since they have the ability to adapt in real time the radiation pattern to the RF signal environment; in other words, they can direct the main beam toward the pilot signal or SOI while suppressing the antenna pattern in the direction of the interferers or SNOIs[5].

III. AUXILIARY PHASE ALGORITHM (APA)

Here we propose a new iterative method of power synthesis for antenna arrays of arbitrary geometry. The method, here called auxiliary phase algorithm (APA), enables to generate patterns with single or multiple main lobes and low pattern amplitude in large angular regions. A considerable advantage of the presented approach is the low CPU time necessary to perform the synthesis, which is due to the simple closed form expressions employed to perform each iteration step and to the use of a proper weight function[2].

The field pattern of an antenna array of N element in x-y plane, equation can be written as

$$F(\mathbf{a};\ \ ) = \sum_{n=0}^{N-1} a_n p_n(\ \ ) e^{j\frac{2}{\ }r_n \cos(\ \ -\ \ _n)}$$

$$= \sum_{n=0}^{N-1} a_n f_n(\ \ ) \qquad (1)$$

Where φ is the azimuth angle, $\mathbf{a}=[a_1, a_2, \dots, a_N]^T$ is the column vector of the complex excitation voltages, $p_n(\varphi)$ is the radiation pattern of the n^{th} array element, r_n and φ_n are the polar coordinates of the position of the n^{th} array element, and λ is the wavelength.

Consider now a real positive function $F_0(\varphi)$, representing the desired radiation pattern amplitude. This function is assumed to be normalized with respect to unity. We want to generate an array pattern whose modulus approximates $F_0(\varphi)$. To this purpose, we search for an array pattern $F(\mathbf{a};\varphi)$ whose amplitude minimizes the functional

$$\boldsymbol{\mathcal{F}}[|F(\mathbf{a};\ )|, F_0(\varphi)]$$

$$= \int_{-\ L}^{\ L} \left| |F(\mathbf{a};\ )| - \frac{F_0(\varphi)}{w(\varphi)} \right|^2 w(\varphi) d \qquad (2)$$

Where $w(\varphi)$ is a real positive weight function and φ_L is a constant depending on the array geometry ($\varphi_L = \frac{\pi}{2}$ for a linear array, φ_L=π for a circular array).

Let us consider the auxiliary function $F_0(\varphi)e^{j\Phi(\varphi)}$, having assigned amplitude pattern $F_0(\varphi)$ and generic phase pattern $\Phi(\varphi)$. The problem of minimizing (2) is equivalent to that of finding **a** and phase function $\Phi(\varphi)$ minimizing the functional [2].

$$d^2[a,\ (\ )] = \mathcal{F}[F(a;\ ), F_0(\ )e^{j\ (\ )}]$$

$$= \int_{-\ L}^{\ L} \left| |F(a;\ )| - \frac{F_0(\ )}{w(\ )} \right|^2 w(\ )d \qquad (3)$$

Which depends on **a** and phase function $\Phi(\varphi)$. Substituting (1) into (3) Minimizing difference between the array pattern and desired pattern by using auxiliary phase algorithm which flow chart is given below.

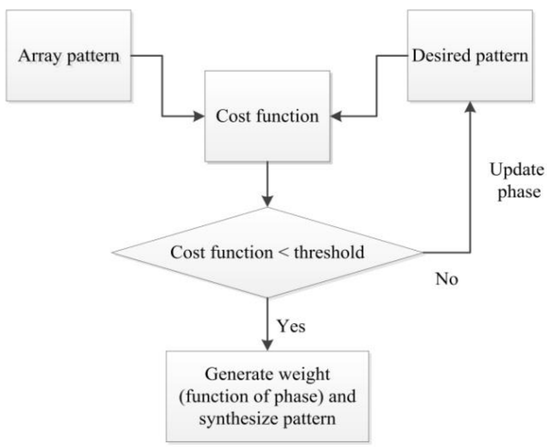

Fig. 1 auxiliary phase algorithm (APA) flow chart.

A. Linear array synthesis

In linear array synthesis, synthesis is performed with auxiliary phase algorithm with 10 array elements. All array elements are spaced half wavelength apart and lying along positive y-axis. All array elements are considered to be isotropic radiators and desired pattern is generated with mainbeam and interferer with Gaussian shape.

Number of samples K=15.

$\mu 1 = 2.5$

Fig. 2 shows array geometry, the synthesized pattern and excitation values for that pattern.

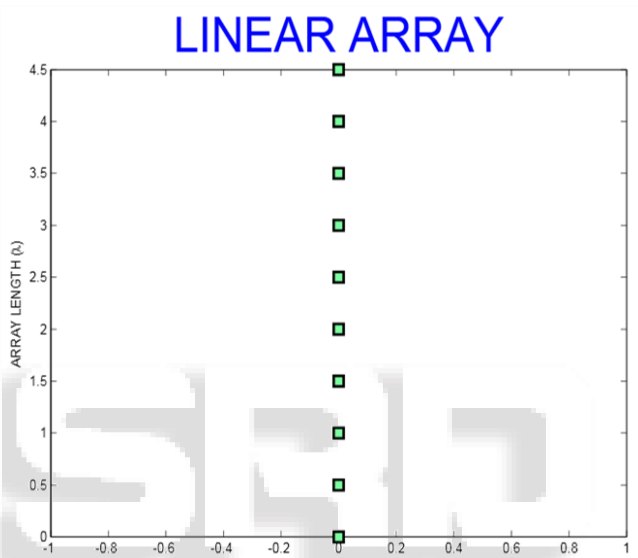

Fig. 2 Uniform linear array with N=10 lying along positive y-axis

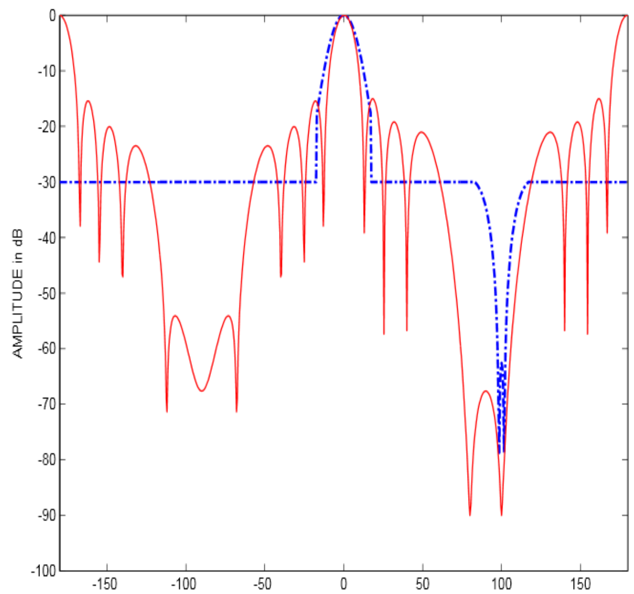

Fig. 3 pattern synthesized for SOI = 0 and SNOI = 100

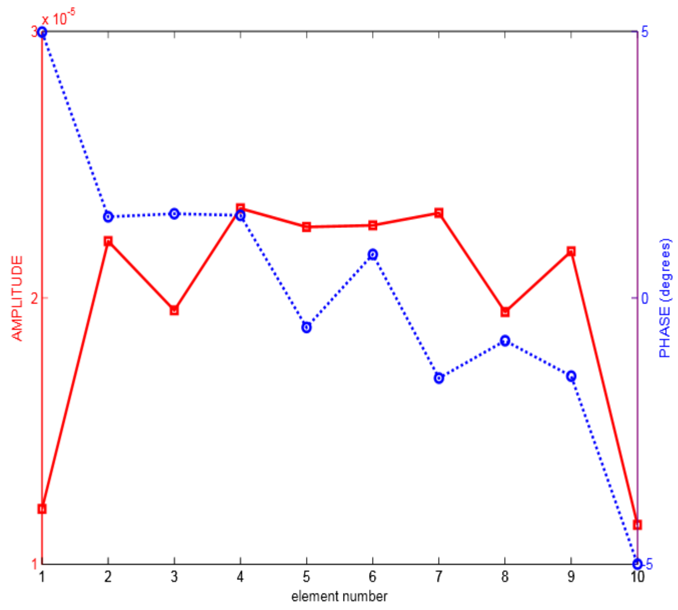

Fig.. 4 corresponding excitation to each antenna element.

Thus APA develops as follows. At first we select the weight function as

$$w(\ ) = F_0(\varphi)^{\mu_1}$$

Where $\mu_1(\leq 1)$ is a constant. This choice guarantees larger values of w( )in the angular regions where the desired pattern $F_0(\varphi)$ amplitude is lower, and the weight values can be increased by increasing μ_1[2].

IV. CONCLUSION

From this paper we can conclude that radiation pattern of an antenna can be changed either by selecting appropriate weights or by changing the array geometry. In this paper we have considered only a linear arrays. Each combination of weight creates a constructive and destructive interference pattern in the space and results in a radiation pattern. Phase-tapered weight makes it possible to steer the beam in any desired direction in elevation plane. Finally by using this algorithm generate multiple main beam in direction of SOIs and multiple null beam in direction of SNOIs.

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