Smart Antenna: DOA Estimation and Beamforming using MUSIC & LMS Algorithms

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Abstract: This paper presents simulation results for a smart antenna system based on direction of arrival estimation and null steering. Direction of arrival (DOA) estimation is based on the MUSIC algorithm for identifying the directions of the desired signals and the null steering beamformer adapts the antenna pattern to steer the main beam towards the desired user and nullify all other interference. This system can be used to reduce multipath and co-channel interference. These benefits include the enhancement of coverage and the channel capacity, lower transmitted power, better signal quality, higher data rate and providing value-added services such as users position location (PL) and at the same time to minimize interference arising from other user by introducing nulls in their direction.

Indexed Terms – Smart Antenna Technology, Beamforming, Direction-of-Arrival (DOA) Estimation, Multiple Single Classification (MUSIC), Signal Nulling.

I. INTRODUCTION

There is an ever increasing demand on mobile wireless operators to provide voice and high speed data services. At the same time, these operators want to support more users per base station to reduce overall network cost and make the services affordable to subscribers. As a result, wireless systems that enable higher data rates and higher capabilities are pressing need. Unfortunately because the available broadcast spectrum is limited, attempts to increase traffic within a fixed bandwidth create more interference in the system and degrade the signal quality. When omni-directional antennas are used at the base station, the transmission and reception of each users signal becomes a source of interference to other users located in the same cell, making the overall system interference limited.

The demand for wireless services has risen dramatically from few years. Wireless communication systems are evolving from the second generation systems to the third and fourth generation systems, which will provide high data rate multimedia services as video transmission. New value added services such as the position location (PL) services for emerging calls, the fraud detection, intelligent transportation systems, and so fourth are also coming in to reality[1,2,3].
Smart antenna technology offers a significantly improved solution to reduce interference levels and improve the system capacity. With this technology, each users signal is transmitted and received by the base station only in the direction of that particular user.

Smart antenna technology may be the solution to satisfying the requirements of next generation wireless network [4]. The smart antenna or adaptive array allows the system to manipulate received signal not only in the time and frequency dimensions but in the spatial domain as well to achieve optimized system goals. The unique ability of the smart antenna to perform spatial filtering on both the receive and transmit signals is the major advantage of smart antenna over existing conventional transceiver techniques [6].

A smart antenna technology can achieve a number benefits like increase the system capacity, greatly reduce interference, increase power efficiency [4,5]. In the following section we review on the smart antenna technology with the help of simulation by using MATLAB.

II. BASICS OF DOA ESTIMATION & NULL STEERING

Since most RF antennas amplifiers, mixers, filters and ADC technologies have reached a mature state, accurate estimation of the angle of arrival of signals impinging an array of antennas becomes the most important parameter regarding the performance of an adaptive array. Assuming a linear and isotropic transmission medium, multiple impinging wave fronts can be modeled as the superposition of these wave fronts impinging on the array. It is therefore necessary for the DOA estimation algorithm to be able to resolve impinging and often fully coherent wave fronts into their respective DOA's. Many DOA estimation algorithms exist, but only a few have found use in smart antennas i.e. conventional methods, linear prediction methods, eigenstructure methods and estimation of signal parameters via Rotational invariance techniques (ESPRIT) [6]. All these methods are based on the digital beamforming (DBF) antenna array. Signals received by individual antenna elements, are down converted to base band signal then they are digitized and fed into a digital signal processing (DSP) chip where the DOA estimation algorithm is executed. In this paper we take a brief review on the DOA estimation using MUSIC algorithm for finding the PL and rejected all other interfering signals using null steering.

The delay and sum beamformer is attractive because of its simplicity and ease of implementation. The limiting factor method is that though it can steer its main beam it has no control over its side lobes. The solution to this problem is the null steering beamformer.

The null steering beamformer adopts the antenna pattern to steer the main beam towards the desired user and place nulls in the direction of interfering users. This method in theory should minimize the signal to interference ratio.

If the m is the steering vector matrix with the desired signal of interest, k are the wave numbers, d is the spacing between antenna elements, M element array, L total number of users, then the desired weight vector w and e_i (k) is the excitation phase vector in degree then the solution of the null steering becomes,

e_i (k) = 1 ; if user signal direction.
e_i (k) = 0 ; if interferer

i = 1,2…m

Therefore the weights can be calculated as the first column of the matrix whose i^{th} column is the i^{th} steering vector, multiplied by M.

III. SIMULATION STUDY AND RESULTS

The simulation is developed in MATLAB the following parameters are used for the DOA estimation. First set the noise properties SNR=20, antenna properties, M=9 number of elements in antenna array, N=100 number of times steps, dt and t are the length of time step and time vector. Then set the incoming signal properties, L=5 number of incoming signals, $f_0 = 1x10^9$ incoming signal frequency, set amplitude and phase then round up the data noise. Calculate the matrix that content the antenna outputs

X(:,i)=A*s + n

Where A=steering vector, s=signal received at first antenna. Then initialization of covariance matrix Rxx, then the MUSIC spectrum are shown in fig. 1 & 2, these spectrums are randomly taken.

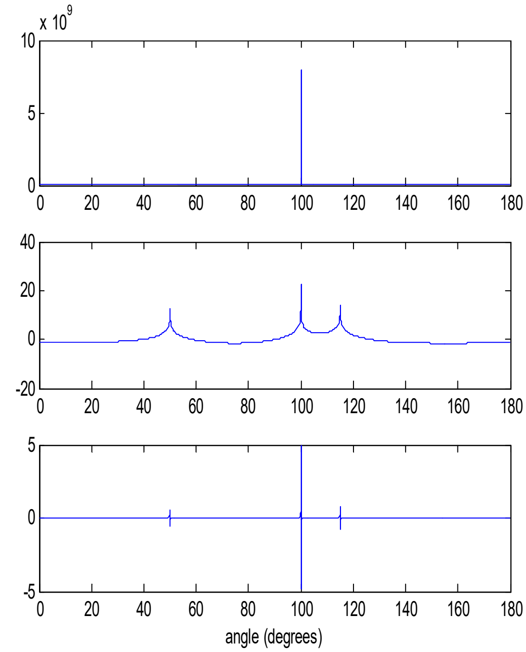

Fig. 1 MUSIC spectrum for DOA estimation

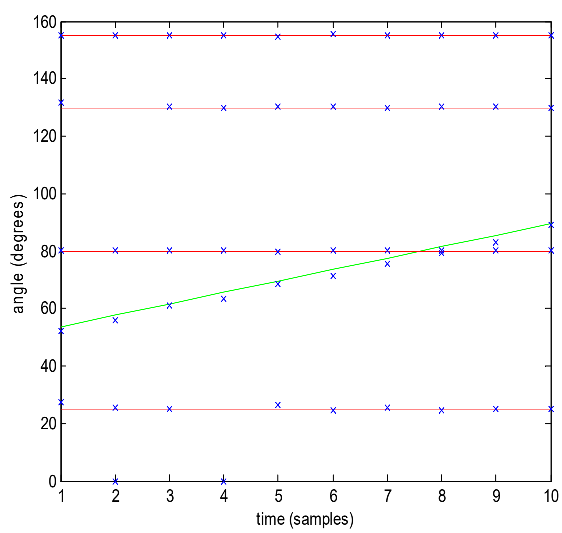

Fig. 2 MUSIC spectrum for DOA estimation

And for the null steering beamformer simulation, set f_0, and d=0.5 distance between antenna element, M=5 number of array elements, L=5 total number of users, theta is (90, 10, 80, 120 and 160), set the additional variable like c- speed of light lambda-wavelength, k-wave number, then generate the normalized array factor and plot the radiation pattern, and user position, in fig.3 where a side lobe allows the interfering signal although attenuated to reach the receiver after the weights are applied and the solution is null steering. Fig. 4, here the desired user at the 100^0 and the respective NAF amplitude is shown here the user at 65^0, 30^0 & 130^0 is the interferer.

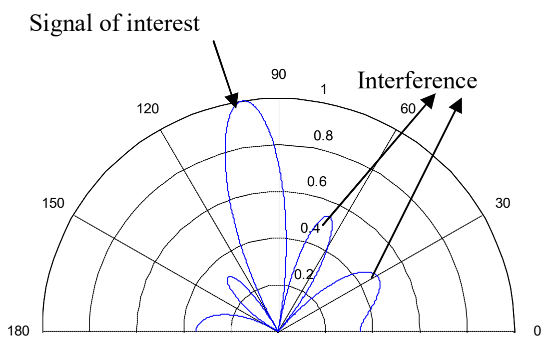

Fig. 3 Null steering beamformer

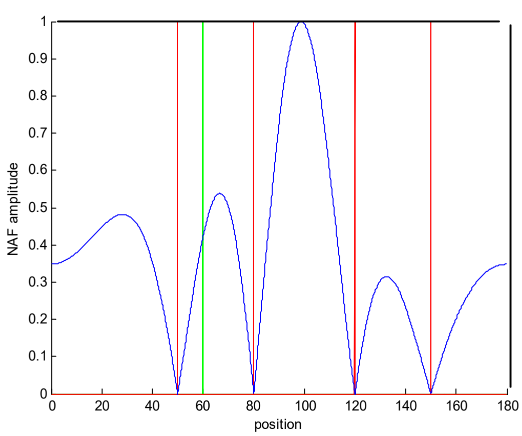

Fig. 4 PL and NAF amplitude.

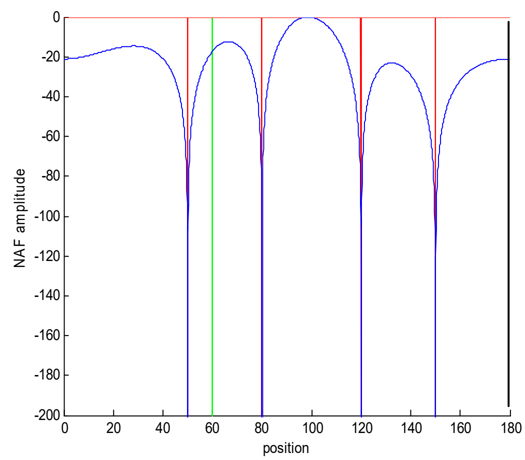

Fig. 5 PL and NAF amplitude

IV. CONCLUSION

Here the simulation for the DOA estimation, compute a spatial spectrum then estimate DOA's. These methods apply weights to each element in the array so as to steer the antenna pattern towards a known look direction. Once a DOA is estimated, the null steering beamformer adapts the antenna pattern to steer the main beam towards the desired user and place nulls in the unwanted direction.

It has advantage of analyzing the signals of arriving antenna array, using beams flexibly and optimistically reducing the probability of interfering and being interfered, enhancing frequency utilization efficiency, and improving system performance.

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