Performance comparison of different Array geometries for Adaptive beam forming algorithms LMS, NLMS and RLS in smart antenna systems

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Abstract—**Smart antenna system is used to maximize the output power of signal in desired direction and minimize the power in unwanted direction. Smart antenna system consists of multiple numbers of elements. Main concept in smart antenna technology is beam forming, it is used to improve signal to noise ratio. Beam forming technique is used for transmission of signal in direction of desired user. In smart antenna system we are using various algorithms to calculate the weights of smart antenna arrays to increase the output in desired direction and reduce the power in unwanted direction We are using different types of arrays i.e. linear array, circular array, planar array .LMS algorithm is widely used in adaptive filter. To improve the convergence rate NLMS algorithm is used. LMS algorithm having constant step size but in NLMS algorithm step size is depends on data at each iteration .Whereas RLS algorithm required more computations.**

Index Terms— ***Beamforming, smart antenna, complex weight, array geometry***

I.INTRODUCTION

From last some years, Wireless technology has grown-up at a challenging rate, thereby creating new and advanced services at minor cost. This resulted in an increase in demands of users. The most particular solution to this is to use spatial processing. Smart antenna system is based on Spatial processing [5].Due to increased Quantity of users and demands there is rise in Area of coverage and transmission quality, smart antenna helps to fulfill all these requirements. [1] Functionality of smart antenna system is properly understood when it is related to our human body system. [5] The brain is working as human signal processor, computes the direction of the speaker from time delays of the voice which is received by the two ears. The brain adds the Signal strength from each ear and focus on the sound of the particular direction. If additional speaker is participate in the conversation. The brain can tuned out unwanted interference and concentrate on one conversation at a time. And the listeners can response back to the same direction of the desired speaker by orienting the transmitter (mouth) toward the speaker. Electrically smart antenna systems work the same way using two antennas instead of ears. [5] And instead of brain digital signal processor is used. By using smart antenna architecture the weights of the antennas are adapted to point the main lobe in the particular direction and nulls are placed in the interference directions. Different algorithms are used for weight updating that is updating phase and amplitude.

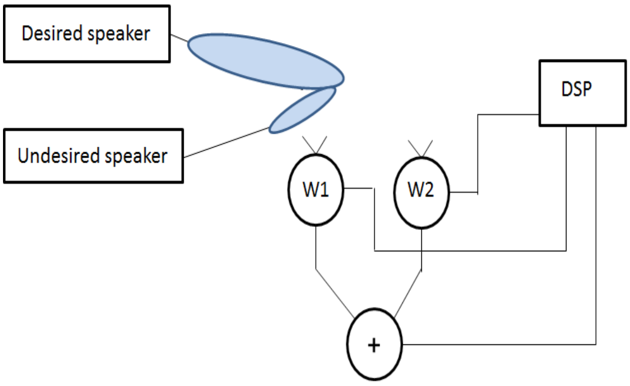


Fig.1Electrical equivalent of smart antenna system.

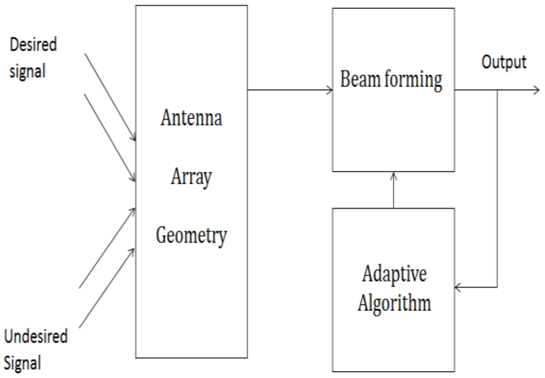
II. LITERATURE REVIEW

Capacity maintains is always a big challenge as the number of services and users increased.to fulfills the capacity demand required by multiple users smart antenna system is introduced. The brief history of the cellular radio system is presented as follows to explain the need of smart antenna system in recent cellular system structure.

A. Omnidirectional system

Cell is represented as small geographic shaded area with radius R. Base station is present at the Centre of each cell and which is equipped with an omnidirectional antenna with a given band of frequencies. Base station in adjacent cells is assigned frequency bands that contain different
frequencies.

Fig.2 Typical cellular structure



With 7 cells reuse pattern

B. Cell splitting

In Cell splitting cells are subdivided in to small cells. In cell splitting capacity is increased by decreasing the Radius of the cell R.

C. Sectorized system

In sectorization the cell is sectorized into three sectors of 120^0 each.in sectorization capacityis increased but by keeping the radius unchanged [5] [1]

D. Smart antenna system

Working principal of Smart antenna system is based on cell sectorization in which the sector coverage is composed of multiple beams. By using antenna array this aim is archived [5],[1].Beam forming or spatial filtering is to make response of the vector sensitive to SOI and provide null to SNOI depending upon the array geometry.Array system increases the cost and complexity of the hardware implementation, as well as increases the convergence time. The linear structure is used primarily for beam forming in the horizontal plane (azimuth) only. This will normally be sufficient for outdoor environments, Portable devices required to scan the main beam in any direction of ϴ (Azimuth) And Ø(Elevation) so planer arrays are more attractive for these mobile devices. Circular array system provides azimuthal symmetry. But because of space limitations circular geometry is practically not used. [5]

E. Switched-Beam Systems

In switched beam system one pattern is chosen from many patterns to increase gain of the received signal.

F. Adaptive Array Systems

Adaptive array system provides more flexibility. Maximum energy is concentrated in particular direction.

III. MATHEMATICAL MODEL

Smart antenna elements are arranged in different geometries. We are using linear, circular and planar array geometry. Various algorithms are used to update amplitude and phase; fig 3 shows the block diagram of the smart antenna system. Different Array Geometries are used in smart antenna system: Linear array geometry, circular array geometry and planar array geometry. All are having different array factor.

Fig 3 Block diagram of smart antenna system

Different Array Geometries are used in smart antenna system: Linear array geometry, circular array geometry and planar array geometry. All are having different array factor.

A. Linear Array Geometry

Linear array are not suitable for scan in 3D space in linear array geometry all elements are arranged linearly. And array factor AF (ϴ)s calculated by using eq^n.

$$\mathrm{AF}(\Theta)= \sum_{n=0}^{N-1} \omega_n \, e^{jnkd\cos(\theta)} \qquad (1)$$

ω_n =Complex array weight at element n,
ϴ =angle of incidence of electromagnetic plane wave from array axis.
K =Wave number (2π/λ).
λ = Wavelength.
d = Inter-element spacing.

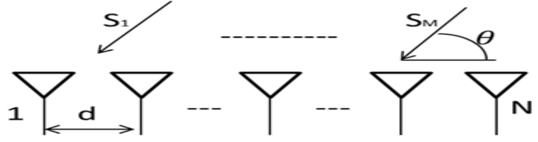


Fig 4 Linear array geometry

B. Circular Array Geometry

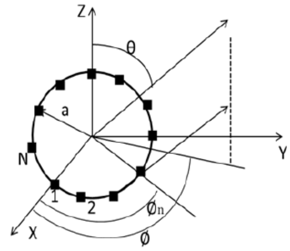


Fig 5 Circular array geometry

$$\mathrm{AF}(\Theta, \varnothing) = \sum_{n=1}^{N} w_n \, e^{-jka\,[\sin(\Theta)\cos(\varnothing-\varnothing n)-\sin(\Theta)\cos(\varnothing 0-\varnothing n)]} \quad (2)$$

Where
Wn =excitation coefficients (amplitude and phase) of n^{th} element.
$\varnothing_n$=2π (n/N) = angular position of n^{th} element on x-y plane.

C. Planar Array geometry

Portable devices required to scan the main beam in any direction of ϴ (Azimuth) And Ø (Elevation) so planer arrays are more attractive for these mobile devices.

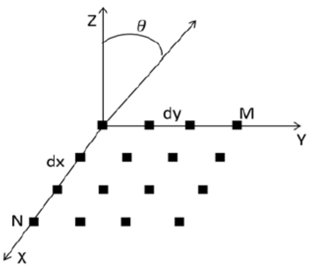


Fig 6 Planar array geometry

$$\mathrm{AF}=\mathrm{AF}_x\mathrm{AF}_y= \sum_{m=1}^{M}\sum_{n=1}^{N} w_{mn}\; e^{j\,[(m-1)(\Psi x+\beta x)+(n-1)(\psi y+\beta y)]} \qquad (3)$$

Where
$\psi_{x=}\mathrm{kd}_x \sin_{\Theta}\cos_{\psi 0}$
$\psi_{y=}\mathrm{kd}_y \sin_{\Theta}\sin_{\psi 0}$
$\beta_{x=}-\mathrm{kd}_x \sin_{\Theta}\cos_{\psi 0}$
$\beta_{y=}-\mathrm{kd}_y \sin_{\Theta}\cos_{\psi 0}$
Are phase delays, which are used to steer the beam in desired direction.

IV. ALGORITHMS

A. LMS Algorithm

To compute the LMS algorithm some initial calculations are required and these are the received signal at the nth element can be given as:

$$x_n(t) = \sum_{i}^{M} S_i(t) e^{-j(i-1)nkdsin(\theta} + n_n(t) \qquad (4)$$

Here S1 (t) is the desired signal, S2; M (t) is the interference signal and n_n (t) is the noise signal received at the nth element.

The total array output is expressed as:

$$Y(t) = W^H.X(t) \qquad (5)$$

Where

W^H= [w0, w1, w2 ……………………wn-1] ^{T} is matrix of weights.

X (t) =(x_1(t), x_2(t) …………………x_n (t)) ^{T} is matrix of signal vector.

The least mean squares algorithm is a gradient based optimization technique. The reference signal used to update the weights at each iteration is given by

$$W(n+1) = w(n) + \mu x(n) e^*(n) \qquad (6)$$

The constant μ is called the step size. It determines how close the weights are moving to optimum value. The convergence of the algorithm depends on the step size. Typical values for the step size are $0 < \mu < \lambda$max.

B. NLMS Algorithm

The normalized LMS algorithm is a modified form of the standard LMS algorithm. It uses a time varying adaptive step size μ (n).

$$\mu(n)=\propto/(\square+X^H(n)X(n)) \qquad (7)$$

C. RLS Algorithm

Recursive Least Squares (RLS). At every iteration the LMS algorithm minimizing the estimation error, whereas the RLS algorithm minimizing the errors up to and including the current iteration. The auto correlation matrix (Rss) and the cross-correlation (Pss) vectors of the desired signals are updated and then used to compute weight vector (Wk). The following steps are involved to compute optimal weights

1).Update Rss through

$$R_{ss,k+1} = R_{ss,k} + X(k)X^T(k) \qquad (8)$$

2). Update Pss through

$$P_{ss,k+1} = P_{ss,k} + d(k)X(k) \qquad (9)$$

3). $Invert R_{ss,k+1}$ (10)

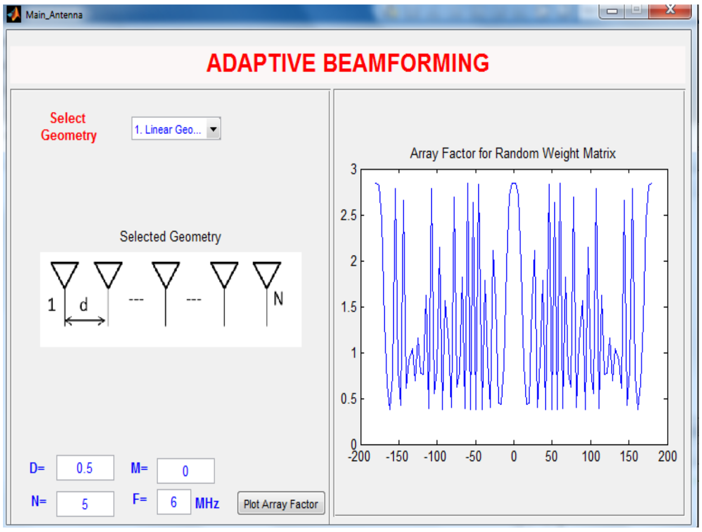
4). Compute WK+1 through

$$W_{k+1} = (R_{ss,k+1})^{-1} P_{ss,k+1} \qquad (11)$$

V. RESULTS

Different array geometries show different values of array factors. From all of them planar array gives good results

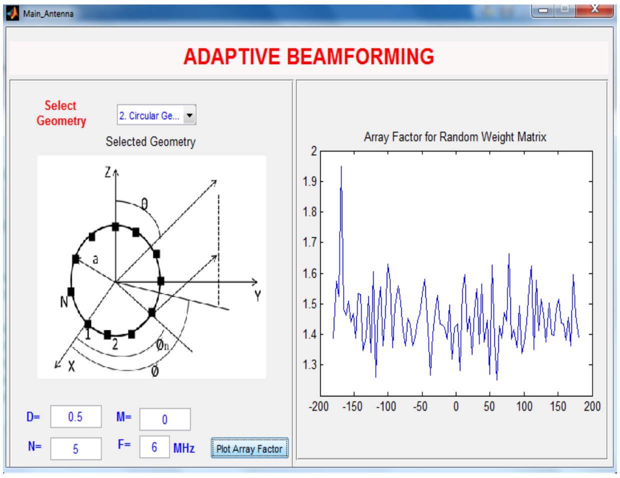
A. Array factor for linear geometry



D= 0.5 M= 0
N= 5 F= 6 MHz

Linear array are not suitable for scan in 3D space in linear array geometry all elements are arranged linearly. And array factor AF (θis calculated by using eq^n. (1)

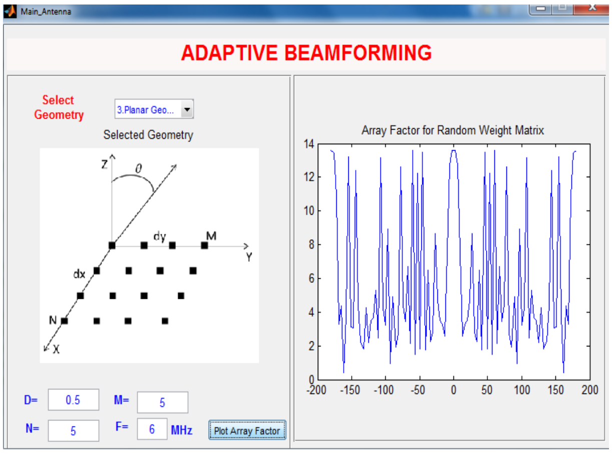
B. Array factor for Circular geometry



D= 0.5 M= 0
N= 5 F= 6 MHz

Circular array system provides azimuthal symmetry. But because of space limitations circular geometry is practically not used.[5] The nth array elementsare arranged in circular manner with radius 'a' and phase angle is $Ø_n$ .Array factor is given by eq^n(2).

C. Array factor for planar geometry



Main_Antenna

ADAPTIVE BEAMFORMING

Select Geometry: 3.Planar Geo...

D= 0.5

M= 5

N= 5

F= 6 MHz

Portable devices required to scan the main beam in any direction of ϴ(Azimuth) And Ø(Elevation) so planer arrays are more attractive for these mobile devices.

CONCLUSION

Aim of this paper is to compare the Array factor for different geometries: Linear, circular and planar. Out of them planar geometry gives better results of array factor compared to linear and circular. Because of space symmetry problem circular array is practically not used.

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