Design and Development of an Antenna array system

[1]Md. Rakib Hossain ,[1]Mohammad Ali, [1]Runa Rukshana khan,[2]Md. Abdul Mazid

[1]Department of Electronics and Communication Engineering
Institute of Science and Technology, Under National University, Bangladesh
[2]Department of Computer Science and Engineering
Institute of Science and Technology, Under National University, Bangladesh
Corresponding author email- rakibhossainist@gmail.com

Abstract

In this paper discuss about the simulation of 2D and 3D radiation pattern of Broadside and end fire array antenna system. There are two types of antenna such as Broadside and end fire array. The weighting factor of each antenna element is governed by an adaptive algorithm based on input signal and desired signal components to achieve dynamic shaping of antenna beam. In this project work both single and two elements adaptive array antenna system is used to tune the gain in such a way that the gain is enhanced in the direction of desired signal and reduced in the direction of interference or jamming signals.

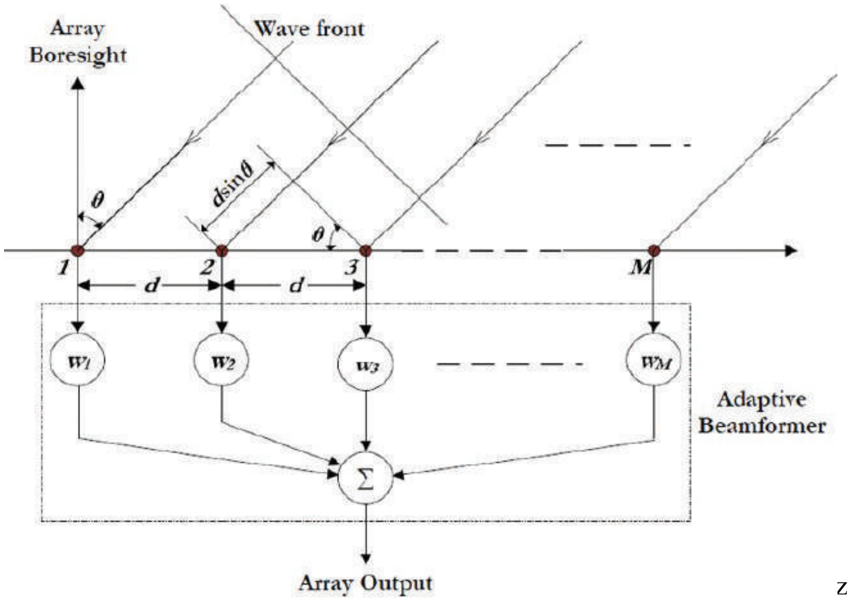
1. INTRODUCTION

In both mobile cellular and satellite communication, channel capacity could be extended using space division multiplexing (SDMA) on the existing access techniques like TDMA, FDMA or CDMA. Array antenna plays important role for SDMA technique to repeat the logical channel twice or more. Although single element antenna is prevalent now-a-days in both fixed and mobile communications but to get high directivity, narrow beams, low side lobe, steer able beams, particular patterns characteristics etc. commonly a group of antenna elements, called array antenna, or simply array is used. One of the major problems of wireless communication specially mobile cellular communication is co-channel interference, limits the carried traffic of network. To combat this interference dynamic cell formation in the direction of desired signal, at the same time reduction of radiation lobe in the direction of interference is necessary. Array antenna system has the ability to provide dynamic radiation pattern summarized in [1]-[6]. The radiation from individual elements will combine, resulting in reinforcement in some directions and cancellation in others to give greater gain and better directional characteristics which is impossible using individual antenna [7]-[11]. It could be used in various configurations for both mobile and satellite communications to provide Space Division Multiplexing (SDMA) specially base station of mobile cellular network or LEO satellite system to increase number of users within limited spectrum.

In array antenna several antennas are connected and arranged in a regular structure (linear, planer, circular) to form a single antenna. Antenna array produces radiation pattern, actually the combination of pattern of single elemental antenna. Single antenna elements are very popular but they are fixed for particular feed current and band of frequency.

Depending on relative phase, amplitude and separation among the antenna elements we can get beam of desired directivity and direction. Fig.1 shows the basic structure of a linear array antenna system.

1.1 Basics of linear array system

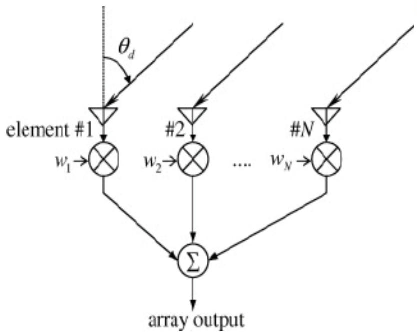


z

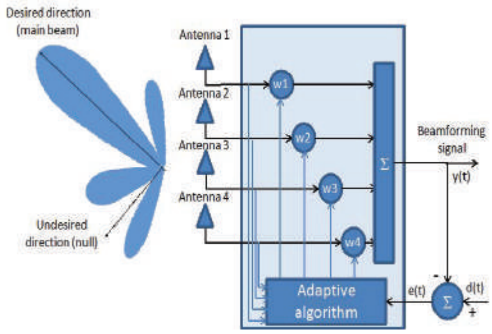
Figure :1 Linear array antenna with adaptive filter

Our desired signal often contaminated by unwanted signal. Normally we use filters to solve this problem. Conventional filters often can not solve the situation because we do not know the nature of input signal. At that time we need adaptive filters which can change its characteristics dynamically. Adaptive filters are such filters which can change its characteristic according to the input signal. It has digital filter with adjustable coefficients and an adaptive algorithm. To estimate the desired output, it first estimates an error then subtracts it from the received signal. The output is then used as feedback to the algorithm to update the filters coefficients.

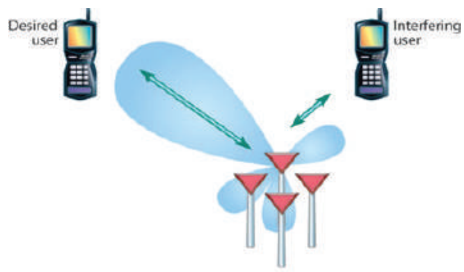
In most occasions we need to transmit or accept signal from particular direction. For this purpose we have to use adaptive beamforming technique. Adaptive beamforming is a special technique by which we can transmit or receive signal from any desired direction while denying the signal of same frequency from other directions. Such behaviors are found for relative phase, amplitude and separation among the antenna elements, but the adaptive filter do the same job by multiplying an weighting factor to a feed line like fig.2 explained explicitly in [11]-[13].



(a) Transmitting mode



(b) Receiving mode



(c) Desired signal and interference

Figure 2. Array antenna beam former including desired signal and interference

In communication field unwanted signal is a great problem. So we try to achieve our desired signal without unwanted noise. Jamming signal means a signal that introduces interference into a communication channel. The main objective of our project is to protect jamming signal which may come from any direction; on that direction we will tune the gain of antenna.

2. EQUATIONS NECESSARY FOR SIMULATION

2.1 Linear array

Now that the arraying of elements has been introduced and it was illustrated by the two element array,let us generalize the method to include N elements .

The array factor is given by

$$AF= 1 + e^{j(kdcos\theta+\beta)} + e^{2j(kdcos\theta+\beta)} + \ldots\ldots + e^{j(N-1)(kdcos\theta+\beta)} \quad (1)$$

Where d is separation between antenna elements ,k= $\frac{2\pi d}{\lambda}$,λ is a wavelength is the progressive phase and θ is the angle between array axis and the link between Tx and Rx .The AF is written in a convenient form like Which can also be written as

$$AF=\frac{e^{JN\psi}-1}{e^{j\psi}-1} \tag{2}$$

$$= e^{\frac{j(N-1)\psi}{2}}\frac{\sin\frac{N\psi}{2}}{\sin\frac{\psi}{2}}$$

If the reference point is the physical center of the array ,the array factor of reduces to

$$AF=\frac{\sin\frac{N\psi}{2}}{\sin\frac{\psi}{2}} \quad ;\text{Where } \psi = kd\cos\theta+\beta \tag{3}$$

For small values of ψ ,the above expression can be approximated by

$$AF\cong \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$

The maximum value of is equal to N.To normalize the array factors so that the maximum value is equal to unity are written in normalized form as

$$AF= \frac{1}{N}\frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$

To Find the nulls of the array is set equal to zero that is

$$\sin\frac{N\psi}{2}=0 \Rightarrow \frac{N\psi}{2}=\pm n\pi \Rightarrow \theta = \cos^{-1}\left[\frac{\lambda}{2\Pi d}\left(-\beta \pm \frac{2n}{N}\pi\right)\right] \tag{4}$$

n=1,2,3....

The maximum values of occur when

$$\frac{\psi}{2}=\frac{kd\cos\theta+\beta}{2}=\pm m\pi \Rightarrow \theta=\cos^{-1}\left[\frac{\lambda(-\beta\pm 2m\pi)}{2\pi d}\right] \tag{5}$$

m=0,1,2...

To control the null and maxima the excitation coefficients of the array is selected by Binomial array or Dolph-Tschebyscheff array.

2.1 Broadside array

In many applications, it is desirable to have the maximum radiation of an array directed normal to the axis of the array. To optimize the design the maxima of the single element and of the array factor should be directed toward $\theta = 90^{\circ}$. The requirements of the single elements can be accomplished by the judicious choice of the radiators and those of the array factor by the proper separation and excitation of the individual radiators. The first maximum of the array factor occurs when

$$\psi = kd\cos\theta + \beta = 0 \tag{6}$$

Since it is desired to have the first maximum desired growth toward θ=90 degrees

$$\psi = kd\cos\theta + \beta = \beta = 0$$

Thus to have the maximum of the array factor of a uniform linear array directed broadside to the axis of the array,it is necessary that all the elements have the same phase excitation. The separation between the elements should not be equal to multiple of a wavelength whenβ=0 degree If d=nλ,n=1,2,3,…… and β=0 degree

$$\psi = kd\cos\theta + \beta = 2\pi n\cos\theta = \pm 2n\pi \tag{7}$$

2.2 End fire array

Instead of having the maximum radiation broadside to the axis of the array, it may be desirable to direct it along the axis of the array . As matter of fact, it may be necessary that it radiates toward only one direction

To direct the first maximum toward θ=0 degree

$$\psi = kd\cos\theta + \beta = kd + \beta \Rightarrow \beta = -kd \tag{8}$$

If the first maximum is desired toward θ=180 degree, then

$$\psi = kd\cos\theta + \beta = -kd + \beta = 0 \Rightarrow \beta = kd \tag{9}$$

3. RESULT

The radiation pattern is obtained using MATLAB simulation Software. The radiation pattern is obtained using polar plots. If the radiation of main beam is directed along the axis of the array in called endfire array again if the axis of the beam is perpendicular to the direction of axis of the array called broadside antenna array.Three dimensional and Two dimensional radiation of Broadside and End fire array are shown in fig 3. It is visualized that the phase angle of the broadside array is maximum radiation in the direction of the line of array 90 degree and the phase angle of the end fire array is maximum radiation in the direction of the line of array 0 and 180 degree. Similar results also made by Md. Imdadul Islam et.al.

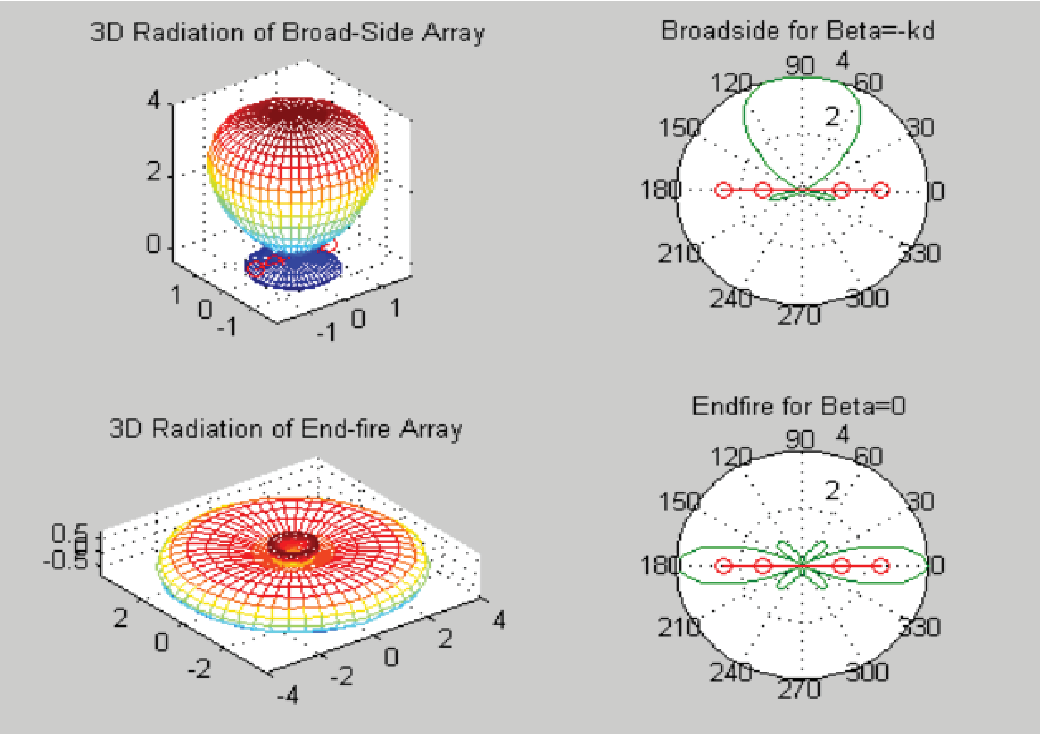


Figure 3: Simulation of 3D& 2D Radiation pattern of Broadside and End fire array

3.1 Effect of radiation pattern of Broadside and End fire array

Broadside array Directivity is more than end fire array. The radiation of the Broadside array is maximum tend fire array. End fire array is unidirectional and spacing is constant. The Broadside array is bidirectional.The Radiation pattern in polar coordinate Broadside and End fier array are shown in fig 4

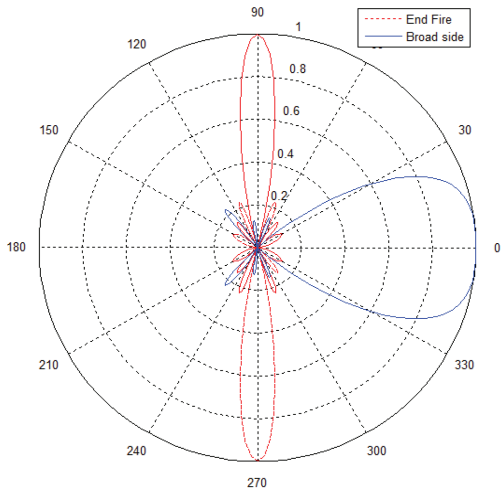


Figure:4 Radiation pattern in polar co ordinate

4.CONCLUSION

The radiation patterns of Broadside and End fire has found perfectly. To take more accorate majo lobs and to reduced minor lobs. A tiny changing matlabs coding should be performed. Increasing of antenna element will give the better performance but at the expense of mathematical complexity. Whereas incorporation of Least Mean Square (LMS), Recursive Least Square (RLS), Mean Squared Error (MSE) algorithm can be used to observe the performance of the system.

REFERENCES

[1]Yaccoub, M., Jaoujal, A., Younssi, M., El Moussaoui, A. and Aknin, N. (2018). *Rectangular Ring Microstrip Patch Antenna for Ultra-wide Band Applications*. [online] Issr-journals.org. Available at: http://www.issr-journals.org/ijias/es/abstract.php?article=IJIAS-13-211-13 [Accessed 15 Oct. 2018].

[2].Chand, A. and Kumar, D. (2016). Design & Parameters Analysis of Microstrip Patch Antenna for Ultra wide band Application. *International Journal of Electronics and Communication Engineering*, 3(7), pp.26-30.

[3]abdennaceur, k. (2018). *Novel method for planar microstrip antenna matching impedance*. [online] Academia.edu.Availableat:http://www.academia.edu/2484187/Novel_method_for_planar_microstrip_antenna_matching_impedance [Accessed 15 Oct. 2018].

[4]Akhter, J. (2018). *Array Antenna System of Frequency Independent Antennas Based on RWG Elements*.
[online]Academia.edu.Availableat:http://www.academia.edu/12179091/Array_Antenna_System_of_Frequency_Independent_Antennas_Based_on_RWG_Elements [Accessed 15 Oct. 2018].

[5] Godara, L. C., "Application of antenna arrays to mobile communication, pasr I: Performance improvement, feasibility and system considerations," Proceedings of the IEEE, vol. 85, no. 8, July 1997

[6] Rappaport, T. (1991). Wireless personal communications: trends and challenges. *IEEE Antennas and Propagation Magazine*, 33(5), pp.19-29.

[7] J. E. Padgett, C. G. Gunther, and T. Hattori, "Overview of Wireless personal communications," IEEE Commun. Mag., vol.33 pp. 28-41, Jan 1995

[8].Van Veen, B. and Buckley, K. (1988). Beamforming: a versatile approach to spatial filtering. *IEEE ASSP Magazine*, 5(2), pp.4-24.

[9] Ghavami, M. and Kohno, R. (2000). Recursive fan filters for a broad-band partially adaptive antenna. *IEEE Transactions on Communications*, 48(2), pp.185-188.

[10]Sekiguchi, T., Miura, R. and Karasawa, Y. (1997). Beamspace adaptive array antenna for broadband signals. *Electronics and Communications in Japan (Part I: Communications)*, 80(10), pp.38-48.

[11] Lozano, A., Farrokhi, F. and Valenzuela, R. (2001). Lifting the limits on high speed wireless data access using antenna arrays. *IEEE Communications Magazine*, 39(9), pp.156-162.

[12]Tuan Do-Hong, Demmel, F. and Russer, P. (2004). Wideband direction-of-arrival estimation using frequency-domain frequency-invariant beamformers: an analysis of performance. *IEEE Microwave and Wireless Components Letters*, 14(8), pp.383-385.

[13]T. Do-Hong and P. Russer, "Frequency-invariant beam-pattern and spatial interpolation for wideband beamforming in smart antenna system," Proc. MICRO.tec 2003 Conf., pp. 626–631.

[14]Bernard Widrow and Samuel D. Stearns, 'Adaptive signal processing,' LPE, Pearson Education, 2005 [15]L.C. Godara, 'Applications of antenna arrays to mobile communication, part I: Performance improvement, feasibility and system considerations,' Proceedings of the IEEE, vol. 85, no.7, pp. 1031-1063, July 1997.

[15]L.C. Godara, 'Application of antenna arrays to mobile communication, part II: Beamforming and direction of arrival consideration,' Proceedings of the IEEE, vol. 85, no.8, pp. 1195-1245, Aug. 1997.

[16]M. R. A. Khandaker, Md. Imdadul Islam and M. R. Amin, 'Adaptive beamforming of linear array antenna system.

[17]C.A. Balanis ,'Antenna Theory : Analysis and Design, 2 nd ed, Wiley, New York, 1997.