"Investigations of Adaptive Smart Antenna for mobile broadband network to increase BER Performance"

DISSERTATION-II

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SUBMITTED BY

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Transforming Education Transforming India

DISCIPLINE OF ELECTRONICS AND COMMUNICATION ENGINEERING
LOVELY FACULTY OF TECHNOLOGY AND SCIENCES
LOVELY PROFESSIOAL UNIVERSITY, PHAGWARA

(MAY, 2015)

ABSTRACT

In this research work, adaptive beamforming techniques are used for the design and implementation of the adaptive smart antenna. The beamforming techniques are based on the angle of arrival of the signal. The direction of arrival techniques used in this dissertation work is employed by using the MUSIC algorithm and the results are discussed and analysed. This performance of this beamforming technique is studied in accordance with the varying element spacing, the number of array antenna elements used and the type of the excitation used for the designing of antenna. All the techniques used are compared on the basis of the obtained radiation pattern, Gain and the Directivity of the array antenna with different number of elements of the antenna. From the results obtained for the MUSIC algorithm, it is observed that the maximum radiation pattern or array factor is present in the direction of the desired signals hence creating nulls in the direction of interfering signals.

CERTIFICATE

This is to certify that the Thesis titled "**Investigations of Adaptive Smart Antenna for Mobile Broadband Network to Increase BER Performance**" that is being submitted by "**Harpreet Kaur Saini**" is a record of bonafide work done for the submission and partial fulfilment of the conditions for the award of **Master of Technology in Electronics and Communication Engineering** from Lovely Professional University, Phagwara under my guidance. The contents in the report, in full or in parts, have neither been taken from any source nor have been submitted to any other institute or university for award or any degree or diploma and the same is certified.

Mrs. ISHA PURI

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Objective of this thesis is satisfactory / unsatisfactory

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Examiner I	Examiner II

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HARPREET KAUR SAINI **Signature**

(11000160) ________________________

DECLARATION

I **Harpreet Kaur Saini** of Lovely Professional University, Punjab, hereby declare that the work entitled "**Investigations of Adaptive Smart Antenna for Mobile Broadband Network to Increase BER Performance**", that contains all the information furnished in this thesis report carried as required for the award of degree of "**MASTER OF TECHNOLOGY in Electronics and Communication Engineering**", is based on my own intensive research and is genuine.

This thesis to the best of my knowledge does not contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

HARPREET KAUR SAINI **Signature**

11000160 **Date: ___________________**

It is certified that the above statement made by the student is correct to the best of my knowledge and belief. The Dissertation II is fit for submission for the award of degree on **Master of Technology in** Electronics and Communication Engineering.

ISHA PURI
Assistant Professor

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Date: _______________

Lovely Professional University
Phagwara, Punjab.

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LIST OF ABBREVATIONS

GPS	GLOBAL POSITIONING SYSTEM
WIMAX	WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS
UMTS	UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEM
W-CDMA	WIDEBAND CODE DIVISION MULTIPLE ACCESS
MIMO	MULTIPLE INPUT MULTIPLE OUTPUT
DOA	DIRECTION OF ARRIVAL
DSP	DIGITAL SIGNAL PROCESSING
BER	BIT ERROR RATE
SNR	SIGNAL TO NOISE RATIO
SIR	SIGNAL TO INTERFERENCE RATIO
MUSIC	MULTIPLE SIGNAL CLASSIFICATION
MATLAB	MATRIX LABORATORY
SLL	SIDE LOBE LEVEL
MMSE	MINIMUM MEAN SQUARE ERROR
FIR	FINITE INPULSE RESPONSE
DFT	DISCRETE FOURIER TRANSFORM
RF	RADIO FREQUENCY
IF	INTERMEDIATE FREQUENCY
LOS	LINE OF SIGHT

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO ANTENNA

In this emerging era of technology, communication through wireless medium has become a major part of everyday life that deals with the transfer of information signal between two or more points, that are not physically connected through any device. Wireless communication in the emerging technology has made the communication systems more fruitful and effective for the communication purpose at longer as well as shorter distances. For the communication through wireless medium, a signal may face multiple difficulties such as security and reliability. To improve the signal quality and to deal with all the problems of wireless communication, multiple technologies have been employed used. One of the most common wireless technologies is radio communication that is being made possible and reliable for larger and shorter distances using the Antenna theory or Aerial. Generally, the device known as antenna is a transducer designed to transmit and receive electromagnetic waves (EM). Antenna plays a vital role in Mobile communication, radio telescopes, television broadcasting, radio astronomy, satellite communication, radar, GPS, WIMAX, space vehicles navigation, mostly in cellular systems such as UMTS, W-CDMA and many more.

An antenna is a passive structure, which serves as a passage between a transmission line and air used for transmission or reception of the electromagnetic waves. An antenna is a device that is able to transmit and receive electromagnetic waves. On the other hand, this is a transformer between a transmission line and free space. According to its physical consummation, it is both a spatial filter and a frequency filter. The main parameters of antenna are operating frequency, bandwidth (from its geometry), and its ability of spatial filtering. In around 1830s, an experimental setup was done by Faraday that involved coupling of electricity and magnetism, which comes out to be the evolution of antennas or aerial. In 1888, based on this theory a German physicist Heinrich Hertz built the first antenna. In his pioneering experiments, he proves the existence of electromagnetic waves. He placed the dipole antennas at a focal point of parabolic reflectors for both transmitter and receiver. Typically, an antenna consists of the arrangement of metallic conductors that are electrically connected to transmitters and receivers. Antenna is a conductor or device that can transmit or receive signals such as satellite, microwave or radio signals. These days, we have a wide range of antennas present because of different need and requirement of parameters for different applications. The user may use various antennas according to its need such as wire antenna, loop antenna, micro strip antenna, array antenna, aperture antenna, reflector antenna, parabolic antenna, lens antenna, patch antenna, antenna array, smart antenna, mimo antenna and many more.

During a communication process from transmitter to receiver, a signal faces many type distortions due to multipath signalling, reflections or various noise components present in the environment. Moreover with increase in demand for the number of users, user may undergo a certain delay. A signal radiated from a single antenna reaches the receiver through multiple paths due to reflections causing the effect known as multipath. The reflection can occur due to the presence of the various obstacles in the environment such as trees, buildings, grounds, peoples etc. The strong signal obtained is mostly the Line of Sight (LOS) signal, which consists of the direct path from the transmitter antenna to the receiver antenna. The other arriving signals are the distorted signals (due to the reflections) known as multipath. Since there no direct line of sight (LOS) in some areas particularly in urban environments all received signals are from multipath. This multipath is the reason for the significant variation in the received signal, sometimes the received signal is reinforced by the multipath effect but it frequently subtracts the original signal. This phenomenon of subtraction of signal is known as fading. To overcome the effect of fading, a technique known as the antenna diversity is used, in which two or more antennas are used to improve the quality and reliability of the wireless link. To combat with all these problems of wireless communication, antennas diversity scheme has been developed that is mostly deployed these days. In this technique, multiple antennas are used to transmit or receive signal.

With development in technology and its use, there has been a rapid increase in number of users due to wide use. Bandwidth has to be the important factor in designing of a communication system as for more number is user, demand of bandwidth by cellular systems increased. To overcome the problem of bandwidth limitation, scientists and researchers are doing various researches and deploying various techniques on how to increase the channel capacity without compromising with the need of effective bandwidth utilization. As the frequency spectrum is limited and it is expensive to purchase carriers, there is an urge that within the same frequency spectrum, more users should be supported. Of all such techniques, one technique is use of antenna array. This technique includes use of multiple antennas either at transmitter/receiver or both.

1.2 ANTENNA PARAMETERS

Before the designing and study of antenna and its types, it is important to understand the antenna parameters. These are considered to be the fundamental parameters that are used to characterize an antenna are as following:

- Radiation pattern
- Beamwidth
- Directivity
- Antenna efficiency
- Field regions
- Gain

1.2.1 RADIATION PATTERN

Radiation pattern is defined as the strength of radiated field in the various directions from the antenna. This variation is observed in the direction of antenna's far field region as a function of the angle of arrival. The radiation pattern is generally three-dimensional, but it is difficult to display the this three dimensional radiation pattern in a meaningful manner, moreover it is also time consuming to measure a 3D radiation pattern while a two-dimensional radiation pattern can be easily displayed on a screen or a piece of paper. The representation of radiation pattern measurements is either in a rectangular or in a polar format.

If the radiation pattern is found to be same in all directions, then the pattern is said to be isotropic. These antennas are said to be ideal that are generally used for comparison. On the basis of the radiation pattern, the antenna can be classified as the Directional and the Omni- directional antennas. The omnidirectional antennas are those antennas which radiated power in single direction while in directional antennas power is radiated equally in all directions. The antenna which radiates as well as receives equally well in all the horizontal directions is said to be omnidirectional. To increase the gain of the omnidirectional antenna the beamwidth of the antenna in the vertical or elevation plane should be narrowed. The net effect hence is to focus the energy of antenna towards the horizon. The directional antennas are the antennas that focus the energy in a particular direction. These antennas are mostly used in some of the base station applications, where coverage by the separate antennas over a particular sector is desired. The pattern of an omnidirectional antenna is the special case of the directional pattern. Yagi-uda and panel antennas are directional antennas.

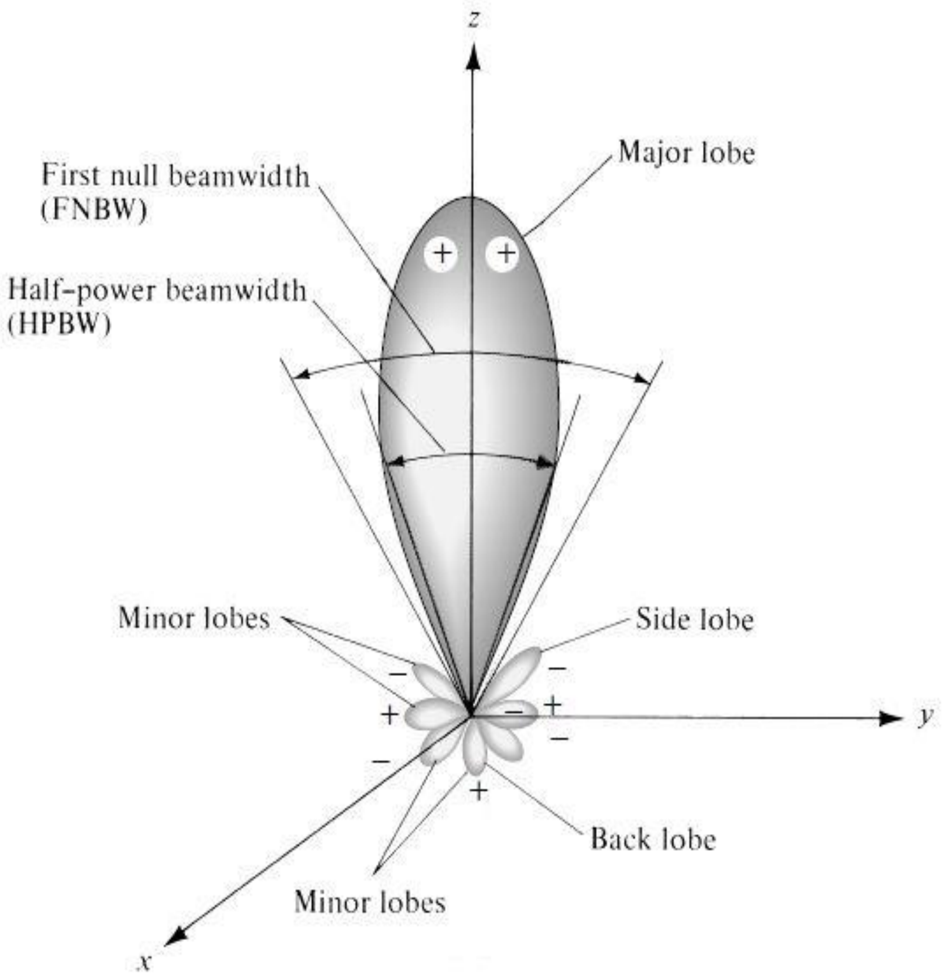

Fig 1.1: Antenna radiation pattern lobes and beamwidth

The radiation pattern of the antennas consists of various lobes. These lobes are classified as main lobe (major lobe), minor lobes, side lobes and back lobes. The main beam also known as major lobe is defined as the region around the direction in which the maximum radiation is obtained. The minor lobe constitutes of all the lobes obtained in the pattern except the main lobe. These are the beams that are smaller and are away from the main beam. These are usually radiations in the undesired directions that cannot be completely eliminated but rather they can be minimized. The side lobe is the type of minor lobe which defines the radiation lobe other than the intended lobe. These lobes are the largest among the minor lobes of the pattern. A back lobe is the lobe, which make approximately 180^o angle with respect to the main beam of the antenna radiation pattern. In most of the radar systems, it is very important to obtain low side lobe ratios so as to minimize the false target indications through the side lobes.

1.2.2 BEAMWIDTH

The beamwidth of a radiation pattern is defined as the angular separation measured between two identical points that are on opposite side where pattern maximum is obtained [1]. There are number of types of beamwidth used to define this angular separation. One of the mostly used beamwidth is HPBW (Half Power Beamwidth) which is used to calculate the strength of the radiation pattern and is calculated from the main beam of the antenna radiation pattern. The Half Power Beamwidth (HPBW) is defined as the angular separation at which the radiation pattern magnitude is decreased by 50% (-3 dB) from the peak of the main beam or where the radiation intensity is half that of the beam. The half-power (-3 dB) beamwidth is a measure of the directivity of the antenna.

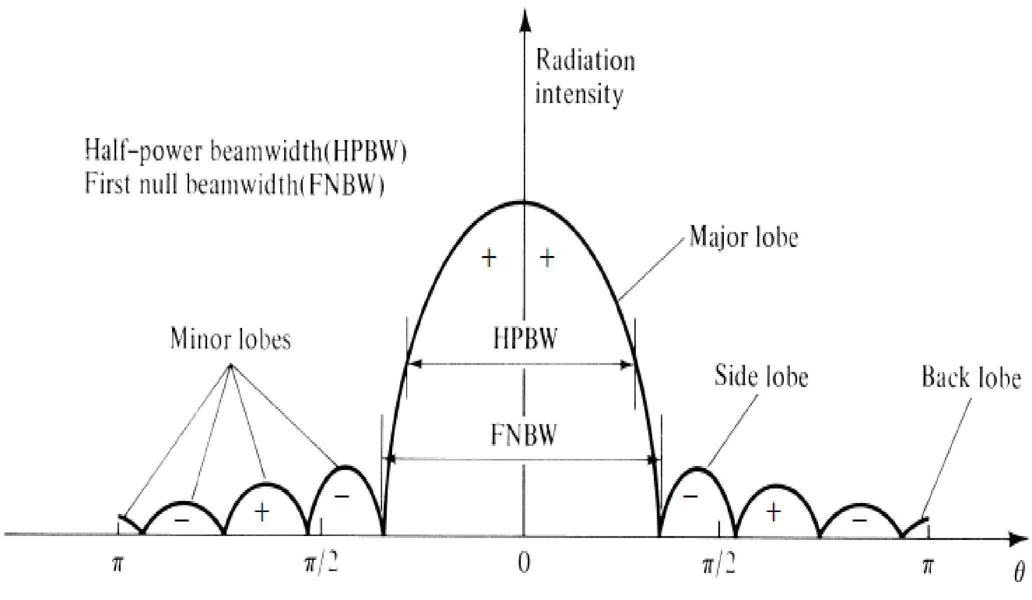

Fig1.2: 2D linear plot of the radiation pattern

Another important type of the beamwidth is the First-Null Beamwidth (FNBW). The First Null Beamwidth is defined as the angular separation obtained between the radiation pattern's first nulls. The beamwidth of an antenna an important parameter that is often used to balance trade-off between the radiation pattern and the side lobe level which is explained as if the beamwidth of the antenna decreases, then the side lobe gradually increases and vice versa.

1.2.3 DIRECTIVITY

Directivity is the ability of antenna to focus the energy in a particular direction when the transmitting or the received energy is better from a particular direction when receiving. Directivity is the measure of the directionality of the radiation pattern of the antenna. Any antenna that radiates power equally in all the directions would have zero directionality and it directivity would be 1 (or 0 dB).

Mathematically, directivity is given as:

$$D = \frac{1}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} |F(\theta,\phi)|^2 \sin\theta d\theta d\phi} \tag{1.1}$$

The directivity of antenna is defined as the ratio of the radiation intensity of antenna in a given direction to that of the radiation intensity averaged over all directions given as:

$$D = \frac{U}{U_o} = \frac{4\pi U}{P_{rad}} \tag{1.2}$$

Where, U =radiation Intensity measured in W per unit solid angle

U_o =radiation intensity of the isotropic source measured in W per unit solid angle

P_{rad} = total power radiated measured in W.

1.2.4 ANTENNA EFFICIENCY

To take the account of the losses occurring at the input terminals and present within the structure of the antenna the term known as total antenna efficiency e_o is defined. These losses occurred may be due to:

- Reflection mismatch between the antenna and the transmission line
- I^2R losses

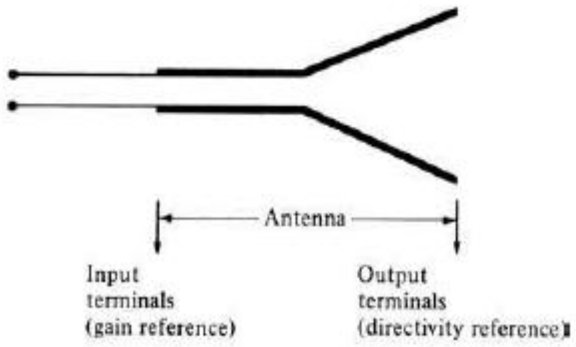

fig.1.3: Antenna reference terminals

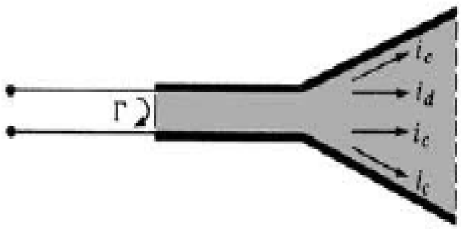

Fig. 1.4: Reflection, Conduction and Dielectric losses

By taking into account all the losses, the overall efficiency can be defined mathematically as:

$$e_o = e_r e_c e_d \tag{1.3}$$

Where, e_o = total efficiency

e_r = reflection mismatch efficiency

e_c = conduction efficiency

e_d = dielectric efficiency

1.2.5 FIELD REGIONS

The fields surrounding an antenna are divided into 3 principle regions:

- Reactive Near Field
- Radiating Near Field or Fresnel Region
- Far Field or Fraunhofer Region

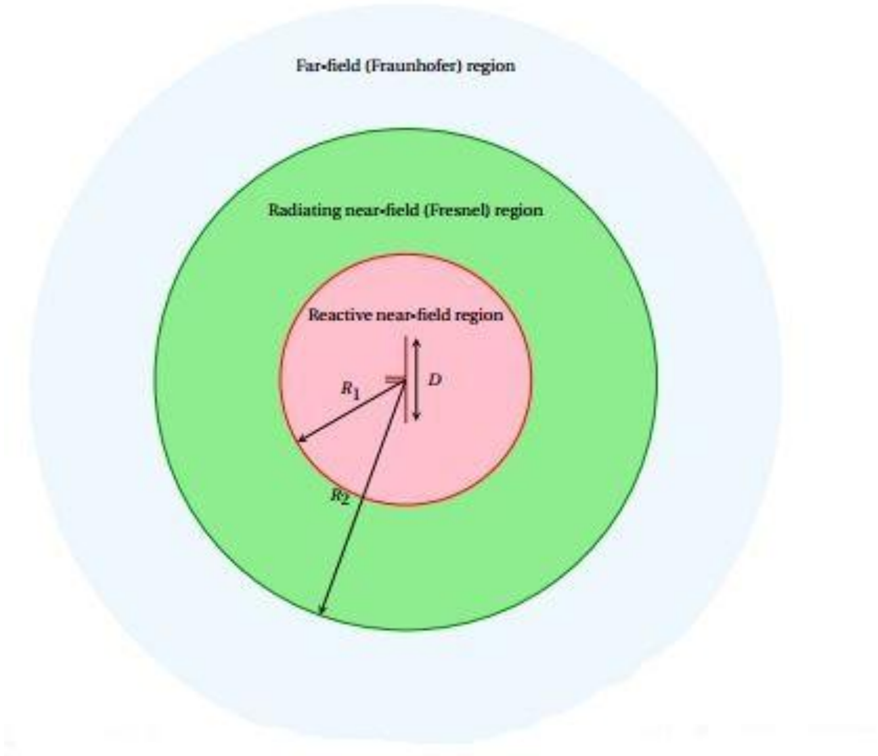

Fig. 1.5: Different Field regions

1. Reactive Near-Field Region: This region is defined as the portion of the near-field region immediately surrounding the antenna wherein the reactive field (non-radiating field) predominates. Here, $R < 0.62\sqrt{D^3/\lambda}$
2. Radiating Near-Field (Fresnel) Region: The region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation field is predominate and wherein the angular field distribution is dependent upon the distance from the antenna. If the antenna has a maximum dimension that is not large compared to the wavelength, this region may not exist. Here, $0.62\sqrt{D^3/\lambda} \le R < 2D^2/\lambda$
3. Far-Field (Fraunhofer) Region: The region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. Here, $2D^2/\lambda \ge R$.

1.2.6 GAIN

The antenna gain is defined as the measure of the ratio of the intensity in the given direction. The gain of antenna is related to directivity. It is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Gain does not account for losses arising from impedance mismatches (reflection losses) and polarization mismatches (losses). Mathematically, gain can be defined as the multiple of 4π times ratio of the intensity in a given direction to that of the power accepted by the antenna which was radiated isotropically that is th antenna which radiated equally in all the directions. Mathmatically, the value of the Gain is given as: :

$$gain, G = 4\pi \frac{U(\theta, \phi)}{p_{in}} \tag{1.4}$$

CHAPTER 2

REVIEW OF LITERATURE

S.F. Shaukat et.al [13] in 2009 proposed the sequential beamforming algorithm for smart antenna system designing. He simulated his work on training sequence algorithms such as LMS, RLS and CMA to perform the beamforming technique to form the main lobes toward the desired user. He simulated 8 element antenna arrays on MATLAB using input signal of desired user is obtained at zero degree while the interfering signals are at -60 degree, - 30 degree and 60 degree. The beamforming is obtained by calculating the array factor and amplitude response of the signal. RLS has the faster response than other while the BER performance is better in CMA algorithm. The BER is obtained by first demodulating the output signal to obtain the bits that were demodulated. CMA is a blind algorithm that does not require any training sequence while LMS algorithm is based on training sequence that requires a reference signal to be compared with the input signal so as to lessen the BER. The minimum error from the obtained simulations has been noticed for the RLS while maximum is for CMA technique.

M. Yasin et.al [16] in 2010 the proposed research works for analysing the performance of LMS and NLMS algorithms. These algorithms were compared for the array factor simulation based of number of antenna elements used, elements spacing and the angles of arrival of the desired users. For these techniques with elements spacing, d=0.5 of wavelength, the mean square error is less as compared to the spacing between them greater than or equal to 0.5. Also the results of array factors were compared for the number of elements used. With increase in number of antenna elements used, the optimized weight vectors are obtained and nulls are created in the direction of the interfering signals but at the same time, is we take a fixed spacing between the array elements and a fixed frequency, then narrow beam width is formed in accordance with the increase in number of elements which also happens to increase in the number of side lobes. However, LMS has good response towards the desired direction and has better capability to place nulls towards the direction of interfering signals. But convergence speed of NLMS is good as compared to the LMS as its convergence speed does not depend upon the Eigen value of input correlation matrix R.

Laleh Alley et.al [19] in 2010 proposed the beamforming algorithm which can be used for tracking the subscribers of a smart antenna. This experimental work was done to improve the weaker results obtained. And the responses of proposed algorithms were simulated. These results consists of plotting of the ‘s’ parameter values and the Eigen value of autocorrelation matrix. The ‘S’ parameters obtained were minimum for the input and output at same element. This simulation was done for the improvement of the convergence speed of the Eigen vectors. This work was done for the predictions about the relations between positions of the subscribers and the Eigen values and Eigen vectors of the autocorrelation matrix.

T.Nageswara Rao, V.Srinavasa Rao et.al [10] in 2011 explained the detailed working and implementation of MUSIC algorithm. They have theoretically explained the difference between the mathematical explanations of the LMS i.e. the adaptive beamforming algorithm and the MUSIC i.e. the direction of arrival estimation theorem. The desired signal takes form of sharper peaks in case of the MUSIC algorithm angular spectrum while deep nulls in LMS array beam pattern. In LMS, the correlation matrix is the expected value of the array signal vector and its hermitian transpose. However in practical world, the exact value of the expected value is not available so we need to replace it by its estimated value using music algorithm. Moreover, beam formers are used to gather information while direction of arrival estimation methods extracts the information from the incoming signals. Implementing music algorithm, sharper peaks are obtained in case of desired users.

Anindya Kundu et.al [11] in 2012 conducted a research work on the smart antenna using DOA estimation method with RAKE receivers. They did this research work to improve the results of antenna performance and decrease the co-channel interference. MUSIC algorithm pseudo spectrum for varying SNR was implemented and plotted which shows that greater the SNR more is the spectrum. If taken more number of antenna elements, greater spectrum is obtained. Along with the advantages of MUSIC algorithm, the BER Vs SNR performance for beamforming along with RAKE is implemented. A signal with MUSIC algorithm, beamforming and RAKE has the greater BER Vs SNR performance. The number of antenna elements is increased, sharper spectrum and hence higher resolution is obtained.

Bo Han et.al [12] in 2013 along with the other authors proposed the beamforming technique for the designing of the smart antenna system. They basically compared the beamforming technique for 2-D and 3-D. The conventional structure is drawn in two different angles i.e. the horizontal angle ϕ and the vertical angle θ. The 2-D structure only has its horizontal angle while its vertical angle is being neglected. And in 3-D structure both the angles are considered. In 2-D beamforming, we cannot distinguish between two users and nodes that have same direction of horizontal angles because they do not have any vertical angles to differentiate. Taking into account the diversity technique, if the MISO is used, then data rate of the signal is not increased or improved. While he use of SIMO or MIMO diversity scheme, we can have the better data rates, SNR and increased coverage capacity.

Chintan S. Jethva et.al [14] in 2013 proposed five of the adaptive beamforming algorithms namely LMS, NLMS, RLS, CGM and SMI for the computation of array weights. These adaptive techniques used have the high rate of convergence and reduced mean square error. He has compared the weight equations for the types of algorithms and has proposed the error performance for the LMS and NLMS algorithms. Their weight computations and comparisons are done on the basis of the step size and the correlation matrix formed. LMS, NLMS, RLS and SMI are all the steepest descent methods in which the convergence speed is comparatively slow as required. While the CGM method has the accelerated rate of convergence where value of step size does not depends upon the input signal. When the error signals for LMS and NLMS algorithms were performed, NLMS shows the quick convergence of the error signal as compared to the LMS algorithm. RLS also has the high speed of convergence but the side lobes are not completely cancelled while the SMI algorithm consists of computation block by block and hence reducing the computational complexity.

Rupal Sahu et.al [15] in 2013 simulated the adaptive beamforming techniques for the smart antenna systems. She proposed the LMS and MUSIC algorithms. The LMS array factor was plotted at different interference signals and source signals and their respective signal to noise ratio and signal to interference ratios were used for the plotting of error magnitude. And the results obtained shows that the sharper beams were directed towards the direction of desired users. Along with the error performance plotting for LMS algorithm, she also displayed the direction of arrival estimation for MUSIC algorithms, with 8 numbers of elements and SNR = 60db was used for the plotting of pseudo spectrum for the MUSIC algorithm. The spectrums were obtained at different angles of arrival and for each arrival of signals, the angles having maximum spectrum is selected.

Vishal V. Sawant et.al [17] in 2013 proposed the traditional LMS algorithm technique for beamforming technique in the smart antennas. The performance of LMS for different parameters is analysed. The performance analysis was based on the antenna arrays used and the spacing between the array elements to determine the error rate and the radiation pattern of the signal where, maximum radiation pattern is obtained in the direction of desired signal while creating nulls. These nulls obtained has very less radiation spectrum as compared to the main lobe and hence obtaining sharper beams in the direction of desired signals and the antenna arrays having more number of elements has better error performance that is the error for them is less.

V. Krishnaveni et.al [18] in 2013 proposed the various beamforming techniques for the estimation of direction of arrival (DOA) of the signal at the array antennas. Since DOA is the most prominent technique, the estimation survey done here is based on the nyquist sampling rate and its compressive sensing alternative is done. The detailed survey on various DOA estimation beamforming algorithms existing, were made. Based on the literature survey made, it was concluded that beamforming based on Compressive Sensing for DOA estimation is more advantageous. Compressive sensing based beamforming called Compressive Beamforming for DOA estimation was found to be more beneficial over Nyquist sampling. This survey was done for various beamforming techniques such as MVDR, MUSIC and ESPRIT and their respective merits and demerits were discussed.

D.B Salunke, R.S. Kawitkar et.al [8] in 2013 explained the algorithms and techniques for the direction of arrival (DOA) estimation and bending of main lobe in the direction of desired signal. MUSIC algorithm is a DOA based algorithm in which sharper peaks are obtained indicating locations of desired users. While LMS and NLMS algorithms are the adaptive beamforming algorithms used for directing the main beam towards the direction of desired source signals and generating the deep nulls in the direction of other undesired, interfering signals. LMS algorithms being used here has good response towards the direction of desired signal and it also has better capability to place null vectors towards the direction of interfering signal as compared to NLMS algorithm. But NLMS has an advantage of convergence capability over LMS that is the convergence speed of NLMS algorithm is good than LMS as the convergence speed for NLMS does not depends upon the Eigen value of the input correlation matrix while it plays an important role in calculation of optimum solution in case on LMS.

Nihad A.A.Elhag et.al [9] in 2013 had undergone the work for designing of the smart antenna system for wideband wireless communication system for the estimation for angle of arrival in case of beamforming of the signal using MUSIC algorithm in MATALB. In this type of adaptive algorithm, sharper peaks are obtained in the angle or direction of the desired signals. They took three different cases as- 18 elements and 6 different angles, 30 elements and 9 angles, 10 elements and 4 angles. Here, covariance matrices have an 'n' repeated minimum Eigen value that represents the variance of noise, where n is the number of angles. And hence the numbers of incident angles are given by 'm-n' where m represents the number of elements. And hence in all the cases plotting the eigenvectors and the signals, a signal with maximum pseudo spectrum is chosen.

Prerna Saxena, A.G.Kothari et.al [7] in 2014 compared a research work here for various adaptive beamforming techniques for the designing of smart antennas by varying the spacing of elements and the number of antenna array element for each of the algorithm. The first parameter the considered of comparing adaptive technique is distance (d) between two antenna elements, is spacing here is less than $\lambda/2$ then the side lobe level (SLL) is very high however it decreases if d is above $\lambda/2$ thus increasing the directivity of antenna array. When d= $\lambda/2$, the SLL is low and null depth is highest resulting in greater suppression capability thus it is the optimum separation distance between two antenna elements. The second parameter is the number antenna elements M, with increase in number of elements, the SLL decreases thus resulting in greater directivity. RLS algorithm has a narrow beam width with higher SLL and compared to SMI, LMS and CGM with decreased SLL.

Otilia Popescu et.al [6] in 2014 proposed the antenna spatial diversity scheme for 4G technologies for LTE and WIMAX systems. The use of 4G technology involves high data rates and high speeds. The performed the BER simulations to evaluate the effect of BER with respect to SNR with or without diversity schemes. The use of the spatial diversity scheme does not affect the amount of bandwidth available for the transmission of information as it is in case of the frequency diversity. It also does not affect the actual information data rate as it is in case of time diversity. They used the two different combining schemes such as SC (selection combining) and MRC (maximum ratio combining). MRC has the better BER performance than the SC diversity technique. Moreover, the use of more number of antenna elements of antennas at the receiver also improves the performance of BER. Wimax has better performance rate than the LTE system.

Harpreet Kaur Saini et.al [20] in 2015 proposed her research work to design the smart antenna and to draw the variations in the radiation pattern of the array antenna with different antenna elements. The first case considered was to choose the distance between the two consecutive antenna elements and the conclusion drawn states that if the distance between the antenna elements is equal to $\lambda/2$ then the antenna has better radiation pattern as compared to the array antenna structures having antenna spacing less than or equal to $\lambda/2$. The second case considered was the number of antenna elements to be used for the designing and the conclusion is drawn that more will be the number of elements in the array antenna, better will be the radiation pattern of the pattern maxima obtained will be better. The third case considered was the use of the adaptive algorithm in order to reduce the noise component from the receiver. The results drawn shows that LMS algorithm used has better efficiency to remove the noise from the signal as compared to that of the RLS and SMI algorithms but that slower convergence speed.

CHAPTER 3

SCOPE AND OBJECTIVE OF STUDY

3.1 SCOPE OF STUDY

In the world of science and technology, transfer of a signals or information from one point to another point or from source to destination through wireless communication has been of tremendous use these days. Technology is finding ways to make wireless communication easy, flexible, error free, cheaper and low profile system. One the most important part of wireless communication is the antenna designing. Antenna or an Arial is a device which is used for the transmission and reception of signals. Designing of antenna consists of various factors such as higher capacity, low BER, high efficiency, small antenna size and many more. In order to meet all these specifications, a use of antenna arrays with a simple micro strip structure is considered. Antenna array are basically a set of two or more antenna elements which is used for the purpose of getting higher gain, high efficiency and maximum signal to noise ratio (SNR). It has various applications in wireless communication such as satellite systems, indoor radio system, land mobile communication systems, broadband networks etc. Antenna array are optimized with certain weights of the adaptive algorithms so as to remove the effect of noise from the signal received at the receiver and to get high SNR for low BER.

3.2 OBJECTIVE OF STUDY

The objective of my research work constitute of the following parameter:

- To study the variations in the radiation pattern of the antenna array based on the number of elements of the array used.
- To study the effect MUSIC algorithm on the radiation pattern of signal at the receiver.
- To improve the performance of BER vs. SNR on the account of the number of elements used in the array structure.

CHAPTER 4

SMART ANTENNA

4.1 ANTENNA ARRAY

Antenna array, which is also known as phased array includes a set of two or more antennas. Moreover we can say that for the purpose of having high data rate, we need more number of antennas on the transmission side. The phased array is array of antenna elements, in which the respective signals feeding the multiple antenna elements is considered and their relative phases are varied in such a way that the strong effective radiation pattern of the array is obtained in the desired direction and is suppressed in the undesired directions. Antenna array is a set of N similar antenna elements or radiators being spatially separated. The signals coming from all of these antennas are combined or processed at the receiver so as to achieve improved performance and characteristics of the signal obtained using single antenna.

Generally, performance of array of antennas increases with number of antennas or antenna elements (M) in an array structure that is the more are the number of elements of antenna, the more is the directivity of the signal received at the receiver. Array of antennas are used to direct radiated power towards a desired angular sector. Antenna arrays can be widely used for the diversity reception of antennas. This method is considered to be one of the most straightforward uses of antenna arrays. Because of the fact that the power level of a received signal may vary significantly with small changes in the distance, a diversity array technique simply uses a set of N antennas (elements) and combines all the signals to obtain the maximum signal. The first experimental setup on antenna arrays was done by Brown. In his experimental setup, he separated the two vertical antennas by half of their wavelength then fed them both out of phase and found that there was increase in the directivity.

In a phased array structure, the exciting currents phases in each element of antenna array are adjusted so as to change the pattern of the array structure, typically for considering a pattern with maximum spectrum or null in the desired direction. The polar radiation pattern of single element is known as the element pattern. The array structures could also be build recursively. That is, the element being used in an array structure can be an array itself. The origin and coordinate system of position N elements in phased array structure is given by-

$$\mathbf{d}_n = [x_n \ \ y_n \ \ z_n] \tag{4.1}$$

These elements need not to be spaced on to a regular grid, neither they need to have the same terminal voltages but it is generally assumed that all of them are fed with same frequencies and the fixed amplitude levels and the phase angle for the derived voltage of each element.

Let $X_1, X_2, \ldots\ldots\ldots, X_n$ represents the outputs of antennas 1 to N respectively. The output obtained from these antenna elements are most frequently multiplied by a set of 'N' weights and are added together as shown in Figure-

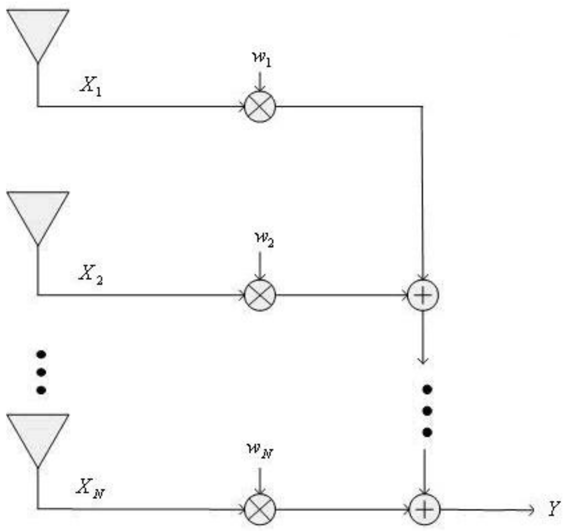

Fig.4.1: Weighting and summing of the signals of the antennas to get the output of a Phased Array.

By choosing the certain value of weights and geometry of an antenna array structure properly, the phased array can be designed that cancel out energy from undesirable directions and receive energy most sensitively from the desired direction. The output of an antenna array is given as-

$$Y = \sum_{n=1}^{N} w_n X_n \tag{4.2}$$

Pattern multiplication, AF (array factor) is given as-

$$AF_N = \left[\frac{\sin\frac{N\psi}{2}}{N\sin\frac{\psi}{2}} \right] \tag{4.3}$$

There are basically two types of antenna array:

- Parasitic array- it is a type of antenna array, which is used to control radar and various narrow beams such as the microwave communication system.
- Driven array- In this array structure, the radiating elements are connected to an energy source and have a small amount of loss when compared to parasitic array, but still maintain the narrow beam characteristics. These arrays are used as radar antennas where narrow beams are less critical when compared to low losses.

But, Now-a-days with increase in coverage and capacity of a system a new set of antenna arrays has been derived that uses multiple antennas known as smart antennas or many antenna and recently designated MIMO antennas. The demand for increased capacity in wireless communications networks has motivated recent research activities toward wireless systems that exploit the concept of smart antenna and the space selectivity. Smart antennas and the associated technologies play a significant role in enabling the broadband wireless communication system. Smart antennas are the antenna arrays being used along with the smart signal processing algorithms that are used for the identification of the spatial signal signature such as estimation of DOA (direction of arrival) of the signal. It is also be used for calculating the vectors of beamforming so as to track and locate the beam of antenna on the mobile system. This smart antenna used in mobile systems can be a type of sensor. Smart antenna technology undergoes the aim of diversity very effectively.

4.2 INTRODUCTION TO SMART ANTENNA

The first smart antenna was developed for military communications and intelligence gathering. The growth of the cellular mobile communication system in early 1980s has upgraded the digital radio technology used in mobile phones, indoor radio networks and satellite communications. In 1990s, satellite broadcasting industries have developed opportunities for smart antennas for creating the MIMO (multiple-input-multiple output) technologies used in 4G wireless networks.

Smart antenna techniques are used in various acoustic processing, to track and scan radar that are mostly used in mobile telecommunication cellular systems like CDMA, UMTS. It works by taking into account the advantage of the diversity effect of the wireless system at the transceiver. The term diversity refers to the transmission and receiving of the multiple radio frequencies, which during data communication are used to decrease the error and are also used to increase the data speed from the source to the destination. A Smart Antenna system is a system, which provides better signals and frequency usage by reacting dynamically to its environment to for wireless communications. A smart antenna is a system that involves multiple antenna elements and a digital signal processor to adjust the radiation and elements of antenna. Smart antennas use the arrays of antennas elements usually, which are linked together to control a unit or a digital signal processor.

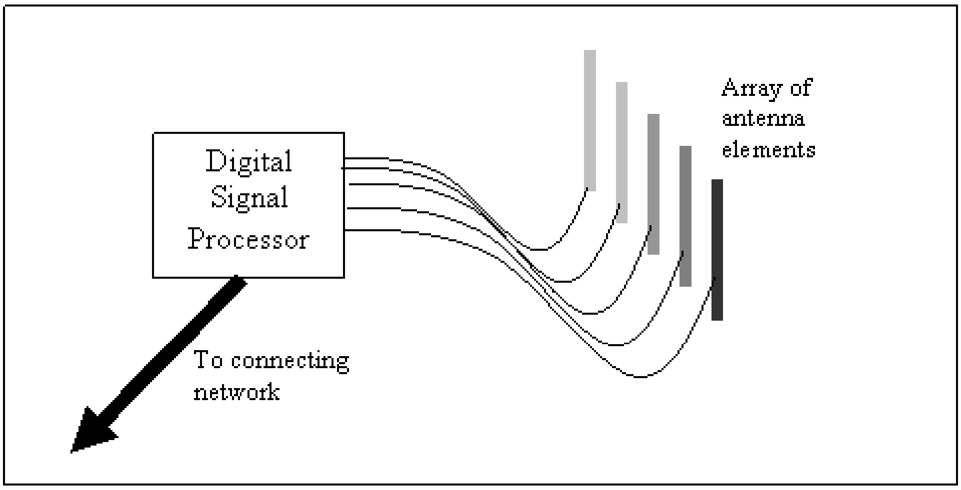

Fig.4.2: Smart Antenna System

The smart antenna technology uses various adaptive and smart algorithm techniques that are widely used to remove the noise present in the message signal that is being received at the receiver. Smart antenna technologies are caused to transform the wireless communication industry with the enormous potential of this technology to enable the development of more powerful, efficient and cost-effective systems. While some of the alternative techniques such as wider bandwidth and low noise amplifiers can be used for the improvement in the performance of the wireless systems. But use of these techniques cannot compared with the smart antenna technologies, which essentially combine and put together an array of antenna elements along with a technique of digital signal processing (DSP) due to its capability of enhancing range, speed, and capacity. Smart antenna system is an intelligent system, which is an antenna array that integrates the simultaneous operation of diversity schemes along with the digital signal processing capabilities to transmit and receive data.

Currently the smart antenna developments are done for the use in the wireless digital networks, which are used for the mobile telephone systems and the computer networks. The development of smart antennas for the mobile telephone networks mainly focus on replacing the standard base station antennas so as to communicate with standard mobile phone antennas. However, the mobile phone handsets being made for the future may consists of the smart antennas and hence known as the smart antenna systems. The smart antenna theory has been around for some time. If we have two signals being received at the receiver at the same time causes jamming and eavesdropping. However for large digital networks, the smart antennas have become a successive option as computer processors to process wireless signals in real time, now have sufficient computational power. Smart antennas works on the statement which states that the interference (caused by the devices transmitting on the same frequency) is caused rarely in the same physical location as that of another device. This can be exploited by smart antennas by targeting the gain of antenna or sensitivity of antenna in the direction of individual devices. This means that signals are not received from interferers or much weaker than the desired device signal which is transmitted and received. Destination devices may also reduce the interference which is radiated to other devices. So, it can be inferred that the other devices can use the same frequency. The capacity of the frequency space can effectively be increased by using the same set of frequencies for more than one set of devices. The function of smart antenna is to switch on to a traditional wired computer network for the purpose of sending signals only to the intended recipients or the desired destinations.

There are many efforts for the designing of smart antenna arrays. For example, antenna design research has mainly focused in the selection of attractive radiating elements and architecture of antenna that can accommodate the physical and electrical requirements of the system. Signal processing problems of the smart antenna systems has concentrated on the development of efficient algorithms for DOA estimation and adaptive beamforming.

The classification of Smart Antennas is determined by the type of environment and the system requirements. There are basically two types of Smart Antennas.

1. Switched beam antenna
2. Adaptive array antenna

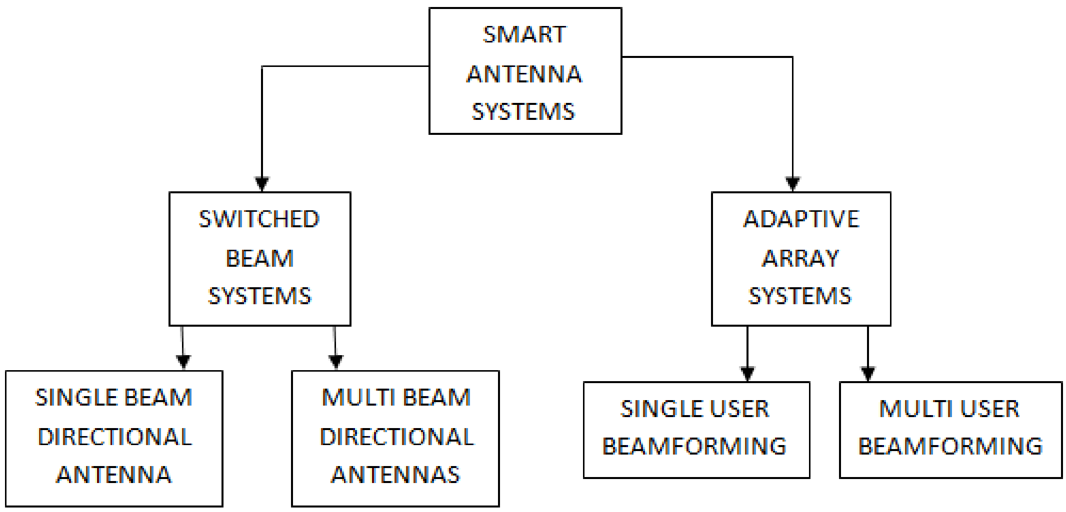

Fig.4.3: Classification of smart antenna

4.2.1 SWITCHED BEAM ANTENNA

It is also known as Beam Smart or Multi-beam Antenna. It consists of a finite number of fixed and the predefined patterns. This system forms multiple heightened sensitive fixed beams in particular directions. In this type of array antenna structure, there will be a large amount of fixed beams present from which only one beam will turned on or will be steered or directed towards the desired signal. This can be done only by adjusting the phase. When incoming signals detected it determines the beam which is best aligned based on SOI (signal of interest) and switches that beam to communicate with the user. Or it can be concluded that as the desired target moves, the main beam will also be steered. The antenna structure, which gives the best performance, generally in terms of received power, is considered. Some gain is achieved due to the higher directivity as compared to the conventional antennas. The antenna of this type will be easier to implement than the more complex adaptive arrays in existing cell structures, which also includes the low cost. The signal strength may reduce quickly during the switching of the beam. In addition to this, if the user is away from the centre and the interferer is present at the centre of the selected beam, the strength of the interfering signal can be decreased than the desired signal. The Phased array antenna figure is shown below.

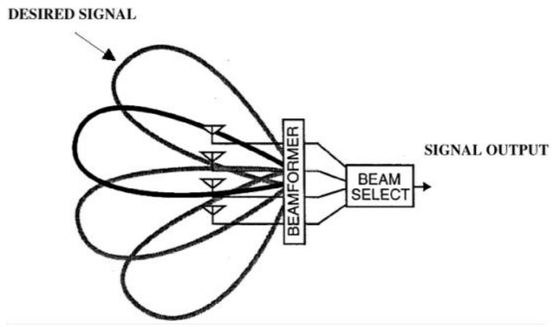

Fig4.4: Switched beam antenna

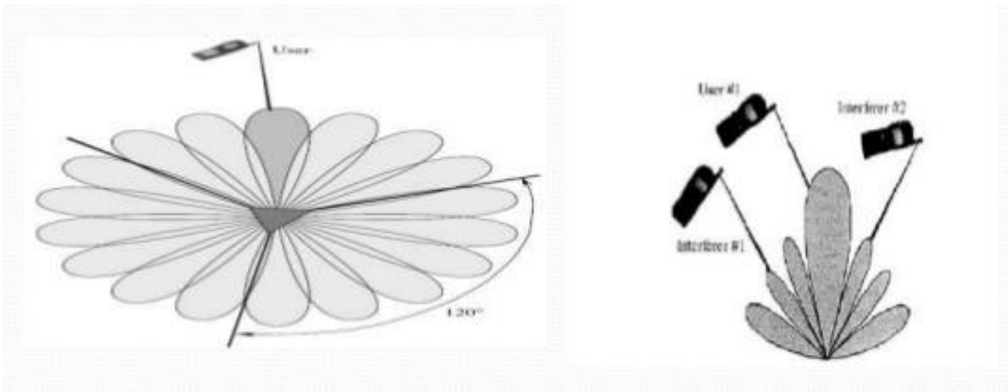

Fig.4.5: Switched beam coverage pattern

This technique subdivides the sector into a number of narrow beams, and then each beam is considered as individual sector serving as single user or a group of users.

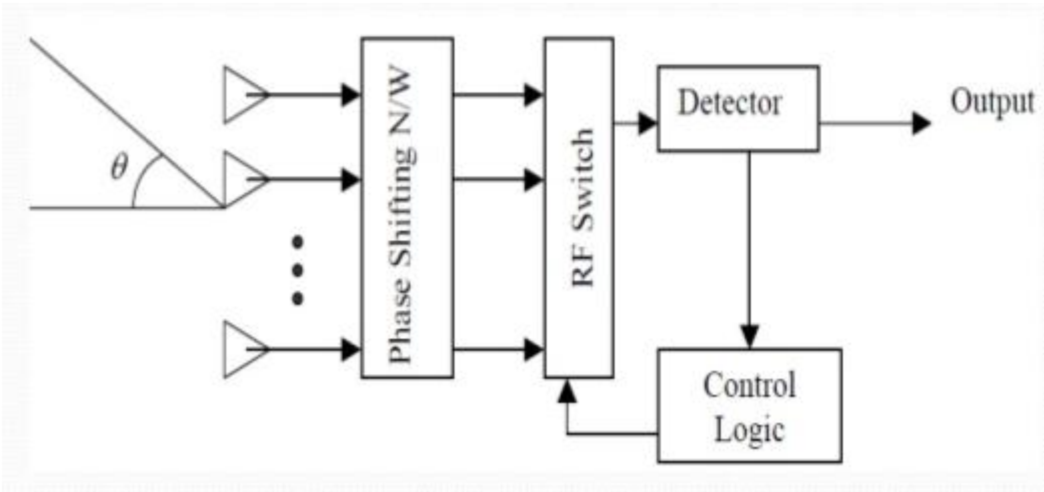

Fig.4.6: Block diagram of switched beam antenna

It this diagram, phase shifting network (PSN) forms multiple beams looking in certain direction. The right beam is actuated by RF switch in the desired direction. The selection of right beam is done by control logic governed by an algorithm. This algorithm, which considers all the beams, selects the strongest receiving signal. This selection is based on measurement made by the detector. The overall goal is to increase the gain according to the user location.

4.2.2 ADAPTIVE ARRAY ANTENNA

It is a type of antenna, in which the beam pattern will change according to the movement of the user and the interference. It consists of a finite number of patterns based on scenarios that are adjusted in real time. The main beam is directed toward the SOI (signal of interest) by the adaptive array antennas and suppresses the antenna pattern in the direction of interference. For each individual user, it can customise an appropriate radiation pattern. The adaptive approach utilizes knowledgeable signal processing algorithms so as to continuously distinguish between the desired signals, multipath components and the interfering signals as well as to calculate their directions of arrivals. The adaptive approach used here updates its beam pattern continuously. This updating technique is based on changes that occur in both the locations of the desired signal and the interfering signal. The adaptive array antenna smoothly tracks users with main lobes that is with highest BER performance rate and interferers with nulls ensures that the link budget is constantly maximized and maximum performance of bit error rate (BER) Vs signal to interference ratio (SIR) is achieved. The signals received will be weighted and are combined later to increase the signal to noise ratio (SNR). Thus, the interference direction will be balanced as the desired signal will be obtained in the direction of the main beam. The antenna can easily control the direction of the main beam to any direction and at the same time nullifying the effect of the interfering signal. The DOA method is used for calculating the direction of the beam.

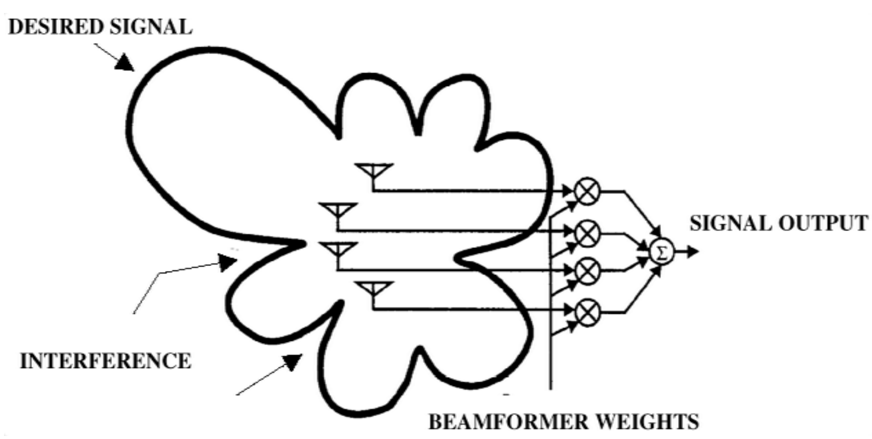

Fig.4.7: Adaptive array antenna

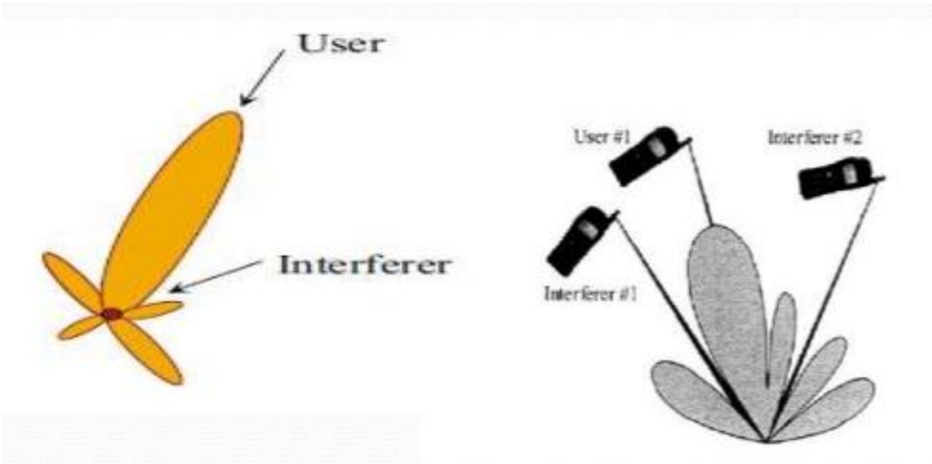

Fig.4.8: Adaptive array system coverage pattern

By simultaneously identifying, minimizing and tracking interfering signals they can provides optical gain.

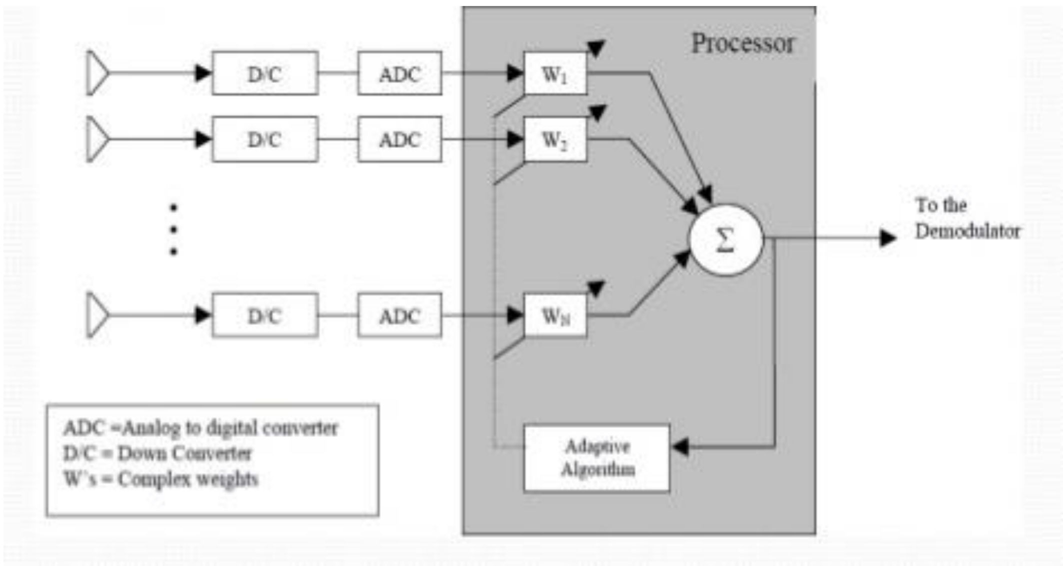

Fig.4.9: Block diagram of adaptive array system

In this block diagram, D/C converts IF signal to RF signal. ADC is an analog to digital converter that converts the signal for further processing. W's contains amplification and phase information.

The following functions can be performed by the smart antenna system:

- The direction of arrival (DOA) estimation of all the incoming signals including the desired signals, interfering signals and the multipath signals can be estimated using the various Direction of Arrival algorithms.

- The desired user signal from all the incoming signals is identified and separated from the all of the unwanted incoming signals.
- A beam is steered or directed in the direction of the desired signal and creating nulls in the direction of interfering signal direction and hence a user can be tracked as he moves by constantly updating the applied algorithm complex weights.

There is another way to categorize the smart antennas based on the number of inputs and outputs used for the device. They can be classified as:

1. SISO (Single Input – Single Output) – In this category, there is a use of a single antenna elements at the source as well at the receiver for the data transmission.
2. SIMO (Single Input – Multiple Output) - In this method of array structures, one antenna will be used at the source and the multiple antennas will be used at the destination.
3. MISO (Multiple Input – Single Output) - In this technique, source uses multiple antennas and only one antenna is used at the receiver.
4. MIMO (Multiple Input – Multiple Output) - In this category, the source and the destination both make use of multiple antennas. This is the most efficient method amongst all.

4.2.3 BEAMFORMING

The technique used for the designing and estimation of adaptive smart antennas is the beamforming technique. It is an adaptive technique, in which beam is bend towards the desired signal direction and the nulls are created in the direction of the interfering signals. The mobiles or receiver devices at which the signals are to be sent are first look after and then the signal phases are added to create a radiation pattern of the antenna array. The mobiles which will not need the signal will be out of pattern. This method seems a little too complicated, but it can easily be done with the help of a FIR tapped delay line filter. The weight of the FIR filter can be changed accordingly by the signal parameters. The filters used will also be helpful in providing the optical beamforming in order to decrease the MMSE (Minimum Mean Square Error) between the message signal and the desired beam pattern formed. One method for the beamforming technique is DOA estimation.

Direction of arrival (DOA) estimation – In this technique, a signal with maximum spectrum is selected. It consists of techniques such as MUSIC (Multiple Signal

Classification) algorithm and signal parameters estimation by the rotational invariance technique algorithms for finding the DOA of the signal. This technique requires many computations and algorithms, making it a complex technique. The antenna acts like a sensor in which a spatial spectrum of the array is selected and the sharper peaks are obtained. DOA is found out from the peaks of this spectrum.

CHAPTER 5

RESEARCH METHODOLOGY

An antenna designing on the software has various products such as HFSS (High frequency structure simulator), ADS (Advanced design system), CST (Computer simulation technology), and many more. For the designing of the smart antennas, I have used HFSS v12.1. A brief description of this software is given below. Designing of antenna structure include various parameters.

5.1 HFSS (HIGH FREQUENCY STRUCTURE SIMULATOR)

HFSS is an interactive software package for the designing of antenna to calculate the electromagnetic behaviour of a structure designed by Ansys. The software includes post-processing commands for analyzing this behaviour in detail.

Using HFSS, we can compute:

- Basic electromagnetic field quantities and, for open boundary problems, radiated near and far fields.
- Characteristic port impedances and propagation constants.
- Generalized S-parameters and S-parameters renormalized to specific port impedances.
- Radiation pattern and Gain in Rectangular, 2D and Polar plots.
- The Eigen modes, or resonances, of a structure.

HFSS is the industry-standard simulation tool for 3D full wave electromagnetic field simulation. HFSS provides E-Fields, H-Fields, currents, S- parameters and near and far field radiation field results. Intrinsic to the success of HFSS as an engineering designing tool is its automated solution process where users are only required to specify geometry, material properties and desired output. From here HFSS will automatically generate an appropriate, efficient and accurate mesh for solving the problem using the proven finite element method.

The core of HFSS is based on the finite element method (FEM) where it is numerical technique that is being used for finding approximate solutions to the partial differential equations (PDE) and the integral equations. FEM is the special case of Galerkin method which has the polynomial approximation functions. The approach of the solution is based on the point of eliminating the spatial derivatives from PDE. This approximates the PDE with the following conditions:

1. A system of algebraic equations for steady state problems.
2. A system of ordinary differential equations for transient problems.

These equation systems are linear if the PDE is linear, and vice-versa. Algebraic equations systems are then solved using numerical linear algebraic methods.

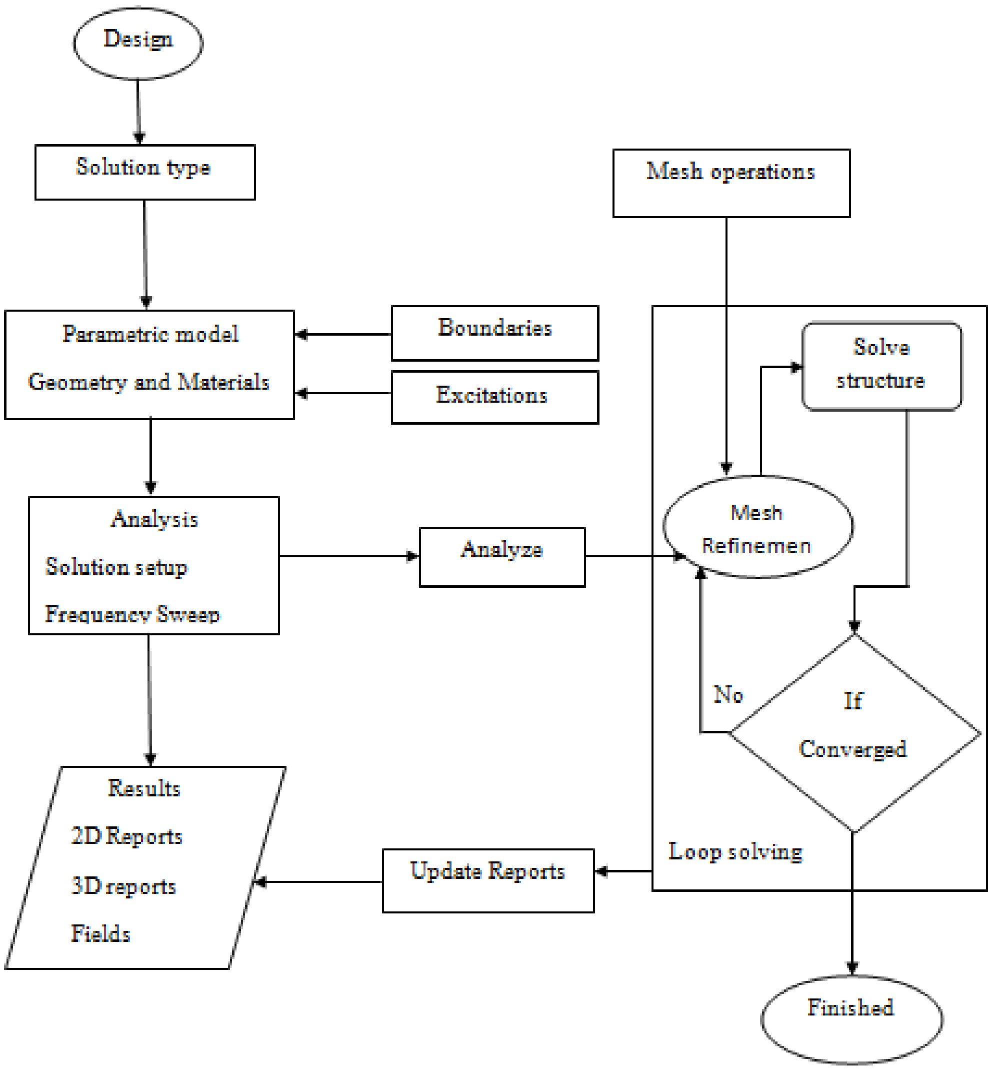

Fig. 5.1: HFSS procedural overview to find solution

The multiple antenna elements also known as array antennas are constructed using this software to introduce the diversity scheme at the receiver to deploy the SIMO (single input multiple output) technique.

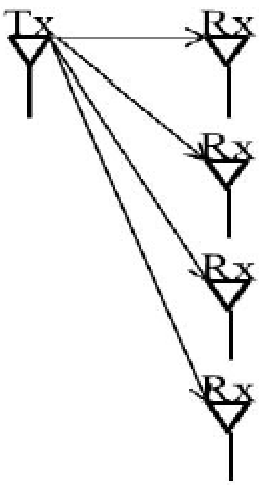

Fig. 5.2: Antenna configuration for space diversity with 1x4 antenna elements

For the designing of smart antenna system, this array antenna is implemented with various adaptive techniques using various algorithms using MATLAB.

5.2 MATLAB (MATRIX LABORATORY)

This software is developed by MathWorks. It allows matrix manipulations, functions and data plotting, implementation of various algorithms, creation of the user interfaces, and interfacing with programs written in other languages. This software is used to build up vectors and matrices. The MATLAB application is built around the MATLAB language, and most use of it involves typing a MATLAB code into the Command Window or executing text files containing MATLAB code, including scripts and/or functions. It can also be used for reading/ writing of text files, wave files (speech signalling), image processing, spread sheets and many more. MATLAB uses various variables and commands for the calculations of mathematical expressions.

During the smart antenna system designing to increase the BER performance, I have used this MATLAB software for the coding purpose. This coding is done so as to remove the noise component present in the signal received through the multipath fading effects. A signal received at the receiver undergoes various adaptive algorithms designed using MATLAB to remove or decrease the effect of noise.

5.3 BEAMFORMING

Also known as spatial filtering is a signal processing technique used in sensor arrays for directional signal transmission or reception. Beamforming is a type of RF (radio frequency) management in which an access point uses multiple antennas to send out the same signal. It is used for tracking the subscribers in a wide angle spread environment of a smart antenna system. In this technique, the mobiles or the device at which the signals are supposed to be sent are first seek and then the radiation pattern of the array of antenna is created by adding the phases of the signal. At the same time the mobiles or the devices that are not in the requirement of the signal will be considered out of pattern. As if this method seems a little too complicated but it can easily be done with the help of a tapped FIR filter. According to the signal used, the FIR filter weight can also be changed accordingly. These filters will be helpful in providing optical beamforming so that the MMSE between the message and the desired signal should be decreased. In this technique, from all the signals obtained by multiple antennas through multipath effect at the receiver, the main beam is directed towards the direction of the desired signal direction while in the other direction or the remaining interference directions, nulls are created i.e. rest all the signals are neglected. In the beamforming technique, the correlation matrix obtained has the expected value of the input signal vector and its hermitian transposed signal.

In the beamforming technique, the various algorithms when applied to the multiple signals at the receiver, the signal with lowest BER at higher SNR obtained is selected and the main beam is bend the same desired signal direction while creating nulls in the other signal directions and hence decreasing the level of side lobes. There are various algorithms used in the beamforming technique of the smart antenna designing such as LMS, NLMA, RLS, CMA and many more.

5.4 DIRECTION OF ARRIVAL (DOA)

The direction of arrival estimation technique is another technique used the signal reception at the receiver. In this technique, multiple antenna elements receive the signal and the signal with maximum pseudo spectrum is selected. In comparison with the beamforming technique, the correlation matrix is the estimated values of the input signal vector while in beamforming it as the expected value. As in practice, the exact expected value cannot be obtained so, instead of using the expected values, the estimation technique is used. The DOA estimation theory explains that the signals obtained at the receiver array undergo various DOA algorithms so as to obtain the sharper peaks in the direction of certain angles of the pseudo spectrum and the signal with maximum spectrum is selected. There are various algorithms for the DOA estimation such as MUSIC, ESPRIT and many more. Of all the algorithms used, MUSIC is the most widely used algorithm with high resolution subspace DOA algorithms.

5.4.1 MUSIC (MULTIPLE SIGNAL CLASSIFICATION) ALGORITHM

MUSIC stands for the Multiple Signal Classification which gives the estimation of the number of signals arrived and hence their directions of arrival. This type of algorithm deals with the decomposition of the covariance matrix into two orthogonal matrices that is – the signal-subspace and the noise-subspace. DOA estimation from one of these two subspaces is performed by assuming that the noise present the in channel is highly correlated.

The output of the array is given as:

$$Y(k) = \vec{W}^H * \vec{X}(k) \tag{5.1}$$

Here, $$\vec{X}(k) = \vec{A}.\vec{s}(k) + \vec{n}(k) \tag{5.2}$$

Where $\vec{X}(k)$ is array signal vector.

$\vec{s}(k)$ is the incoming complex signals vector at time k.

$\vec{n}(k)$ is the noise vector at each array element m, with mean= zero and variance= σ^2.

$\vec{A}$ is the M x D matrix of steering vectors $\vec{a}(\phi_i)$

Where, $\vec{a}(\phi_i) = e^{-jkd(m-1)\cos(\phi_i)}$

In this algorithm, the autocorrelation matrix R_{xx} is given as:

$$\vec{R}_{xx} = \vec{A}\vec{R}_{ss}\vec{A}^H + \vec{R}_{nn} \tag{5.3}$$

Where, $\vec{R}_{ss}$ is the D x D source correlation matrix.

$\vec{R}_{nn} = \sigma^2 \vec{I}$ is the M x M noise correlation matrix

$\vec{I}$ is N x N identity matrix.

Therefore, $$\vec{R}_{xx} = \vec{A}\vec{R}_{ss}\vec{A}^H + \sigma^2 \vec{I} \tag{5.4}$$

$$\vec{R}_{xx} = E[X(t)X^H(t)] \tag{5.5}$$

$$\vec{R}_{xx} = \frac{1}{N}\sum_{n=0}^{N-1}[X(t)X^H(t)]$$

The pseudo spectrum of the MUSIC algorithm is given by

$$P(\phi) = \frac{1}{\vec{a}^H(\phi)\vec{E}_N\vec{E}_N{}^H\vec{a}(\phi)} \tag{5.6}$$

Where, $\vec{E}_N = [\vec{e}_1\vec{e}_2 \ldots \vec{e}_{M-D}]$ is the M x (M-D) dimensional subspace spanned by the noise eigenvectors.

MUSIC algorithm works well for the simple methods such as picking up the peaks of DFT spectrum that too in the presence of the noise component, when the number of components is already known in the advance, because knowledge of this number is being exploited here so as to ignore the noise in its final simulation report. Because of its estimation function can be evaluated for any frequency, it is able to estimate the frequencies with the higher accuracy not just those of DFT bins. It is a form of super resolution. The main disadvantage of the using MUSIC technique is that the number of components is required to be known in advance, so generally cannot be used in more cases.

5.5 BER (BIT ERROR RATE)

In the transmission of the digital signal, BER is the key parameter used to access the digital data being transmitted from a one location to another. BER is the percentage of bits with errors divided by the total number of bits that have been transmitted, received or processed over a given time period. The rate is typically expressed as 10 to the negative power. BER is the digital equivalent to signal-to-noise ratio in an analog system. When data is transmitted over a data link, there is a possibility of errors being introduced into the system. If errors are introduced into the data, then the integrity of the system may be compromised. As a result, it is necessary to assess the performance of the system, and bit error rate, BER, provides an ideal way in which this can be achieved. Mathematically, BER is defined as the ratio of the number or errors to that of the total number of bits being transmitted.

5.5.1 FACTORS AFFECTING BER

There are number of factors that affect the performance of BER. In order to optimise a system the variables that can be controlled can be manipulated so as to provide the required performance levels. This consideration is taken in the stages of the designing of a data transmission system so as to adjust the performance parameters at the initial design concept stages. Some of the factors affecting the BER performance are as follows:

- Interference: The interference levels present in a system are generally set by the external factors that cannot be changed by the design of the system. However it is possible to set the bandwidth of the system. By reducing the bandwidth the level of interference can be reduced. However reducing the bandwidth limits the data throughput that can be achieved.
- Increase transmitter power: It is also possible to increase the power level of the system so that the power per bit is increased. This has to be balanced against factors including the interference levels to other users and the impact of increasing the power output on the size of the power amplifier and overall power consumption and battery life, etc.
- Lower order modulation: Lower order modulation schemes can be used, but this is at the expense of data throughput.
- Reduce bandwidth: Another approach that can be adopted to reduce the bit error rate is to reduce the bandwidth. Lower levels of noise will be received and therefore the signal to noise ratio will improve. Again this results in a reduction of the data throughput attainable.

It is necessary to balance all the available factors to achieve a satisfactory bit error rate.

CHAPTER 6

EXPERIMENTAL WORK

The experimental work consists of the designing of the smart antenna based on the all the studied facts and parameters. The array antenna is designed at a frequency of 10GHz for the purpose of getting the maximum radiation pattern at the receiver. The comparison is done based on the flowing parameters:

- Number of antenna elements used
- Spacing between the two elements
- Array fed with number of inputs
- Type of algorithm used
- BER calculation

The designing of array antenna is done on HFSS while the coding being done so as to remove the effect of noise is done using MATLAB. The results being obtained for the radiation pattern at HFSS are exported to MATLAB where firstly at array factor is being calculated then the channel transmission and coding at the receiver is done.

6.1 SINGLE ELEMENT PATCH ANTENNA

The first step for the designing of the array antenna is to design a single patch antenna.

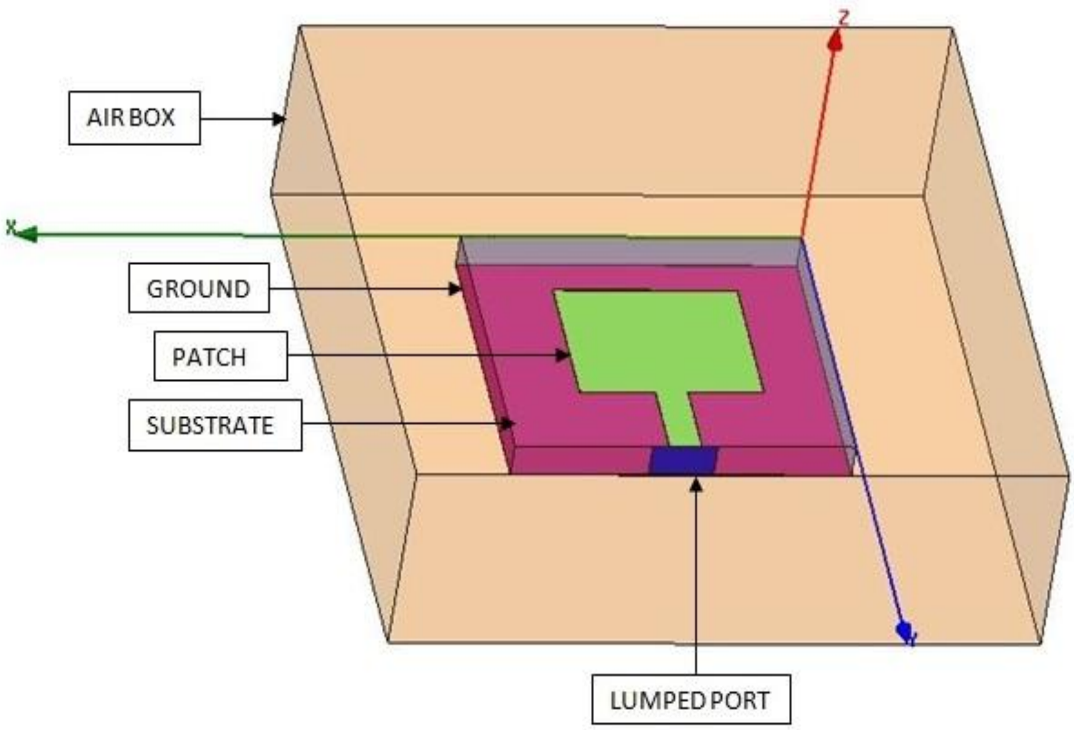

Fig. 6.1 Patch Antenna

The single patch antenna designed at 10GHz frequency using Rogers Ultralam 1250 (tm) which has relative permittivity of 2.5, relative permeability of 1 and dielectric loss tangent of 0.0015.

By using all the formulas discussed in chapter 4 for a single patch antenna, the dimensions obtained are as follows:

- Patch= 11.3 x 9.08 x 0.05
- Substrate= 20.9 x 18.68 x 2
- Ground= 20.9 x 18.68 x 0.05

The structure with the above mentioned dimensions is shown below:

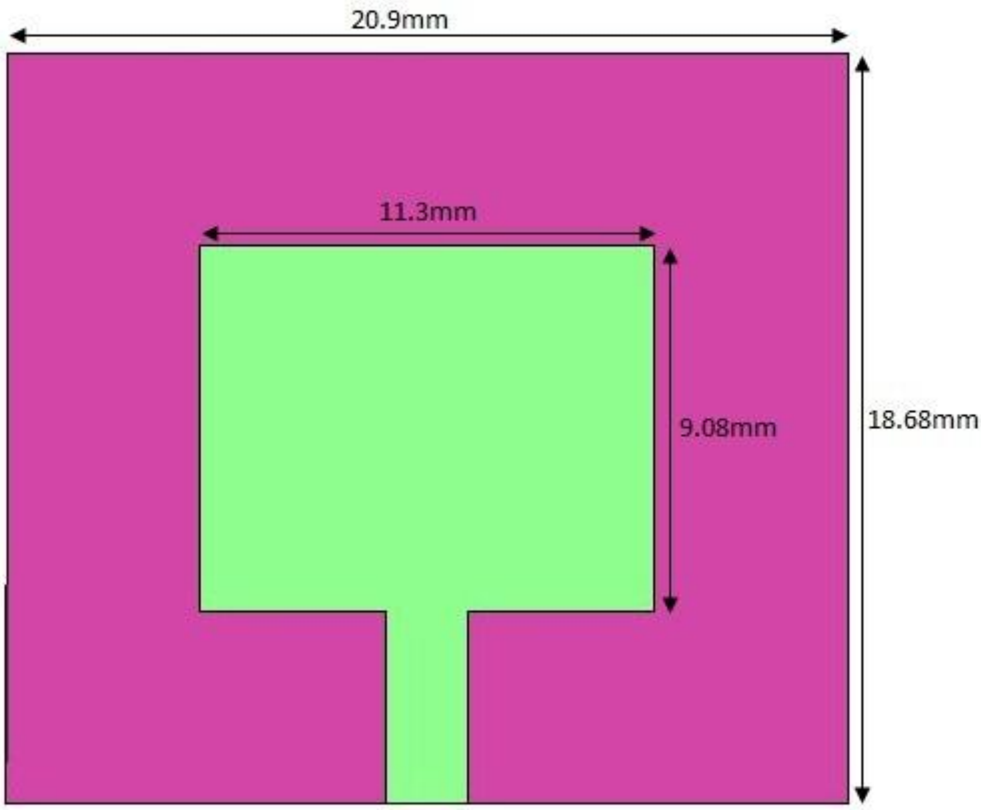

Fig. 6.2 Dimensions of single patch antenna

The material used for the design of patch and the ground is copper which has relative permittivity of 1 , relative permeability of 0.999991 and dielectric loss tangent of 0.

6.2 ARRAY ANTENNA USING 8 ELEMENTS OF RADIATING PATCH

All the array structures being used for the designing of smart antenna consists of designing of array elements with each antenna separated by the distance $= \lambda/2$. This condition is considered because if the spacing is greater than $\lambda/2$ or less than $\lambda/2$ then both of the cases generates less amount of radiation pattern and hence gain as compared to when the spacing between the elements is taken be to equals to $\lambda/2$. This condition has been studied and implemented in the dissertation-I work. So, for the designing of the smart antenna which uses array elements, it is efficient and effective to use the antenna spacing of $\lambda/2$ between the two consecutive elements of the array. The structure with similar requirements is drawn with 2 x 4 elements and antenna spacing, $\lambda/2$ =15mm as shown below:

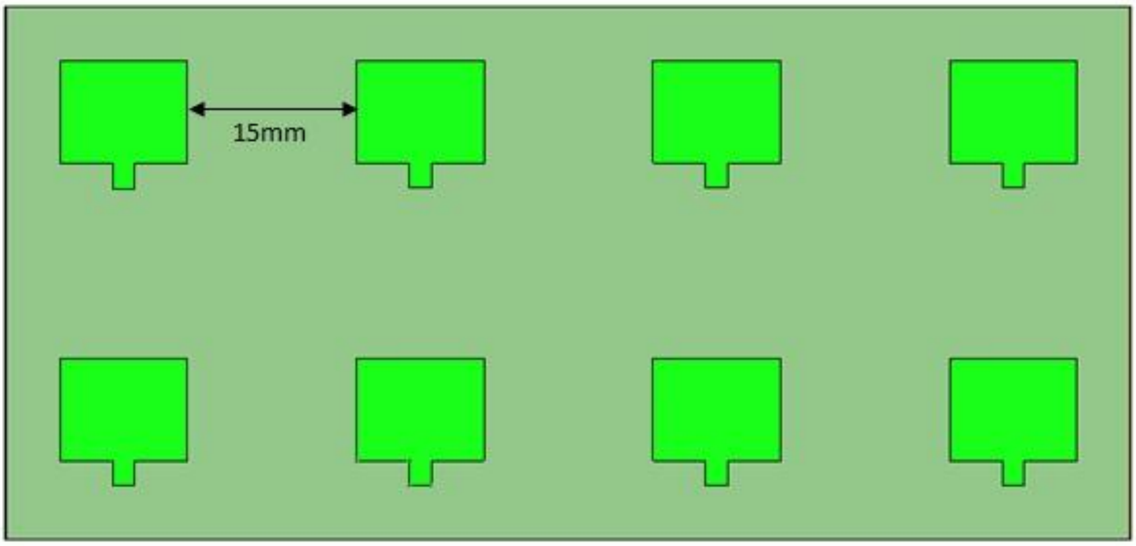

Fig.6.3: 8 elements antenna array

6.3 ARRAY ANTENNA USING 16 ELEMENTS OF RADIATING PATCH

The sixteen elements antenna array is designed with antenna spacing $\lambda/2$ between the two consecutive elements of array. The structure drawn consists of the structure having 5 x 4 elements and the results are compared with the 8 element structure of 2 x 4 elements design of the array structure on the basis of the directivity, gain and radiation patterns obtained in both of the cases. The 16 elements antenna ha two considerations for assigning the input excitations:

- All elements fed with same input
- Every element fed with different input

6.3.1 ANTENNA ARRAY WITH 16 ELEMENTS HAVING SAME FEED

In the designing of the 20 element antenna array, if all of the elements fabricated and drawn with similar structure are fed with the same excitations or the input, then number of inputs required will be less and hence less power will be required as compared to the array structure of the antenna that uses different excitations. The structure with similar characteristics is shown below:

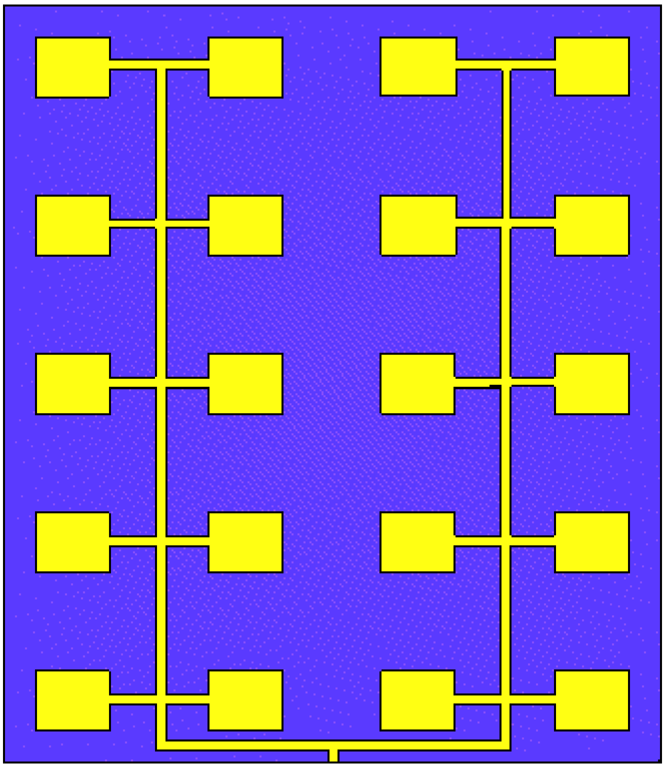

Fig 6.4: 5 x 4 array antenna with same excitation

6.3.2 ANTENNA ARRAY WITH 20 ELEMENTS HAVING DIFFERENT FEED

When all the 20 elements of the array structure of the antenna being designed for the purpose of designing smart antenna is used all being fed with the different excitations, then the structure will use more inputs but the results in both of the cases are comparable. The usage of more number of the excitations for the designed elements of the array antenna consumes more power and hence more input as compared to the input power used by the single structure. The antenna with the similar characteristics as described here is shown in the figure 6.5

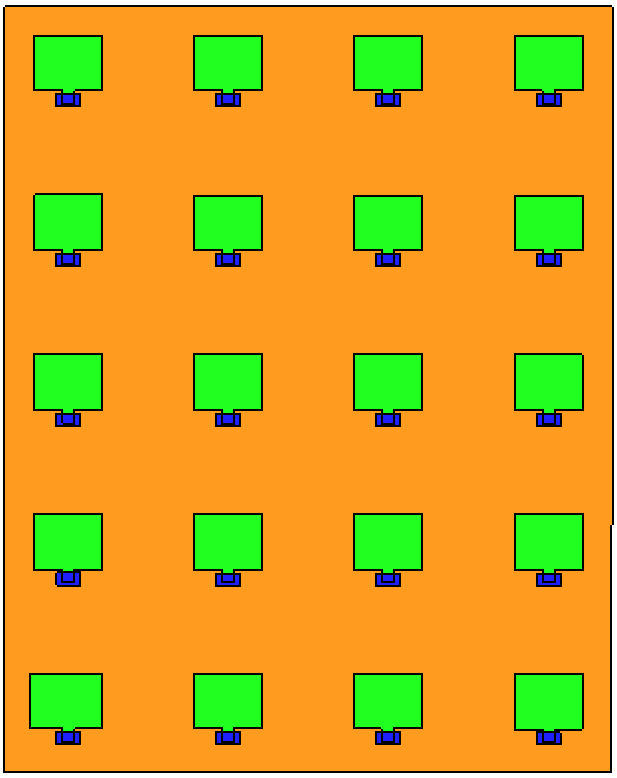

Fig 6.5: 5 x 4 array antenna with total of 20 elements having different excitations

CHAPTER 7

RESULTS AND DISCUSSIONS

In the previous chapter, the designing of the various antennas was done based on the number of antenna elements used and were discussed in detail. After the structures are validated and are stimulated, the results are obtained which are discussed in detail in the below sections. The concept and validation of the smart antenna is based on how the antenna radiates and behaves even in worst conditions. For the purpose of same, the smart antenna study consists of stimulation and improvements made in the radiation pattern of the antenna only. That is smart antennas can be compared on the basis of their radiation pattern and antenna Gain only. As discussed, all the results include how the radiation takes place in various antenna structures and the amount of gain obtained in context to the radiation pattern and the result obtained are shown below:

7.1 SINGLE ELEMENT PATCH ANTENNA

7.1.1 RADIATION PATTERN

The far field radiation pattern of the single element patch antenna at 10 GHz at 180^o phi is shown in the figure 7.1:

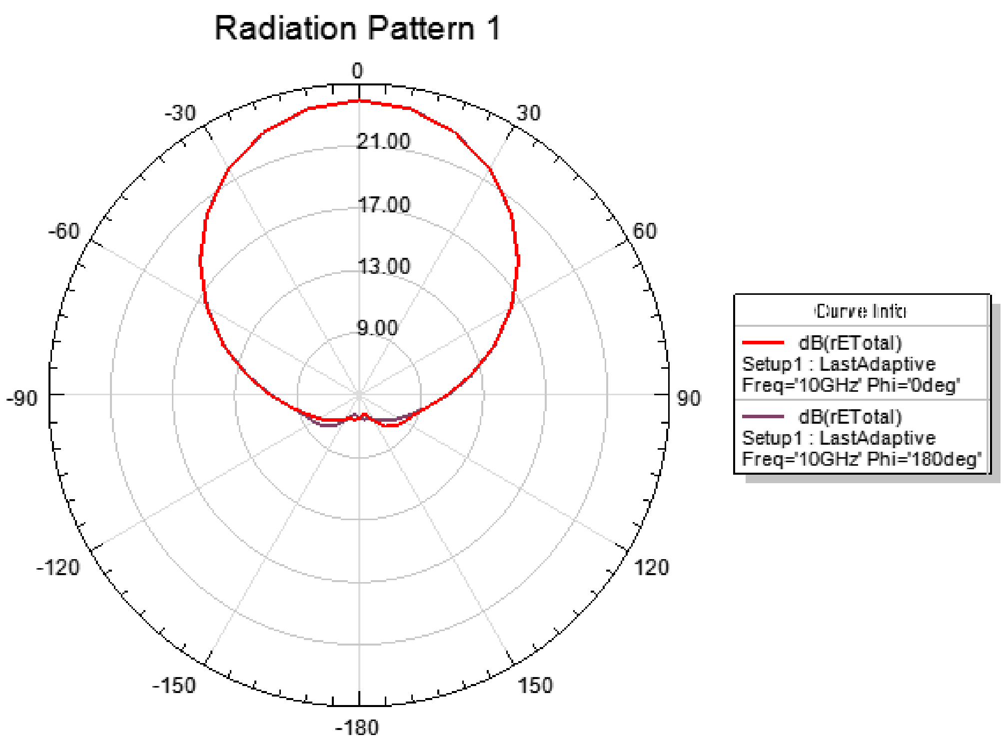

Fig. 7.1: 3D rectangular plot for Radiation pattern of single element using HFSS

The figure shown above, figure 7.1 gives the 3D rectangular plot to define the radiation pattern of the single element patch antenna. Here, we can conclude that the maximum radiation pattern of antenna is about 24.09 dB.

7.1.2 RADIATED EMISSIONS

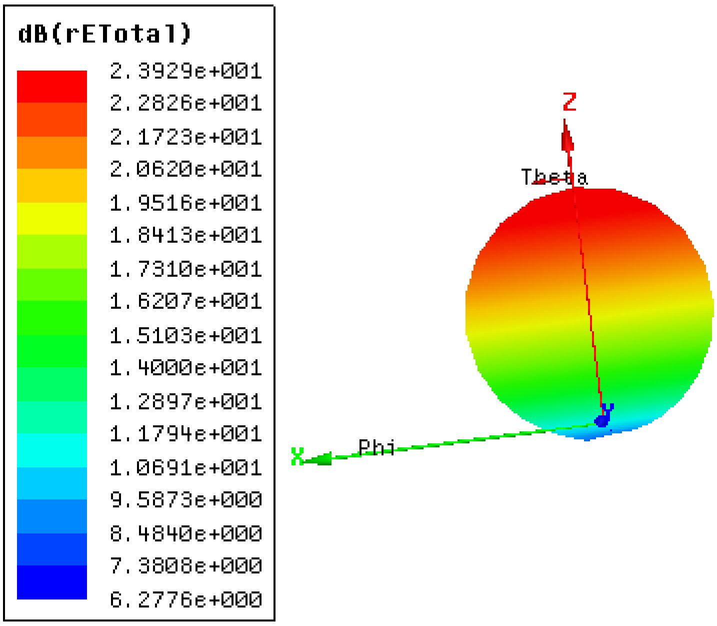

Fig. 7.2: 3D plot for Radiation pattern of single element using HFSS

The figure shown above figure 7.2 gives the 3D polar plot which defines the radiated emissions of the single element patch antenna. Here, we can conclude that the maximum radiation pattern of antenna is about 23.929 dB.

7.1.3 GAIN

The 3D Gain plot is represented at value of phi equals to 0^o and 180^o as shown in the figure 7.3. From the figure below, it can be concluded that the gain has the maximum value of 7.3455 dB for the designed single element patch antenna. Gain is a measure which takes into account the directional capabilities of the antenna as the gain of antenna is related to the directivity of antenna. Hence the directivity of the designed antenna is also explained in the next session. Gain of the single element antenna is shown in the figure 7.3.

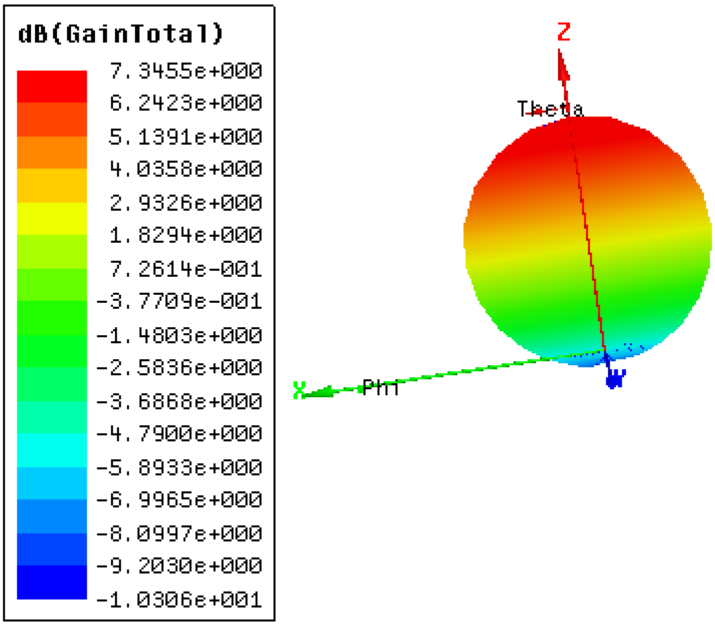

Fig. 7.3: 3D Polar plot for Gain using HFSS

7.1.4 DIRECTIVITY

The 3D Directivity plot is represented at phi equals to 0^o and 180^o as shown in figure 7.4 which has the maximum value of 7.3402 dB for the designed single element patch antenna.

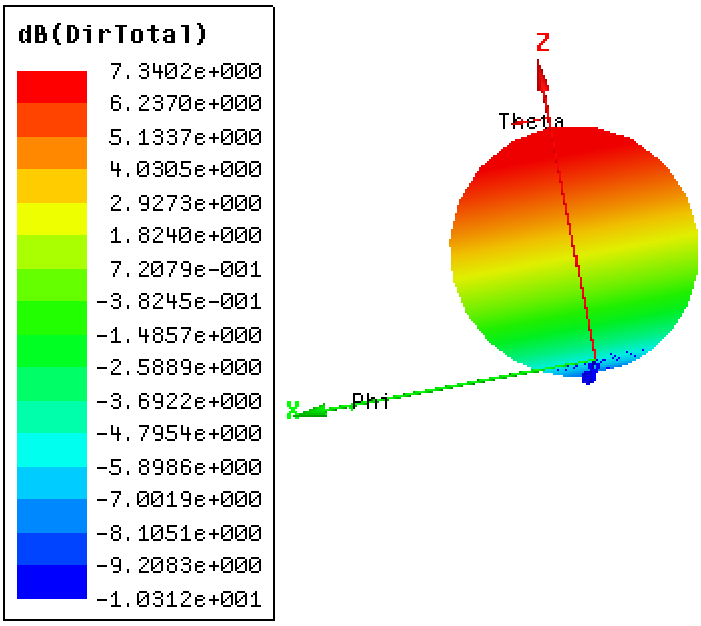

Fig. 7.4: 3D Polar plot for Directivity using HFSS

7.2 EIGHT ELEMENTS ARRAY ANTENNA

7.2.1 RADIATION PATTERN

The far field radiation pattern of the single element patch antenna at 10 GHz at 0^o and 180^o phi is shown in the figure 7.5:

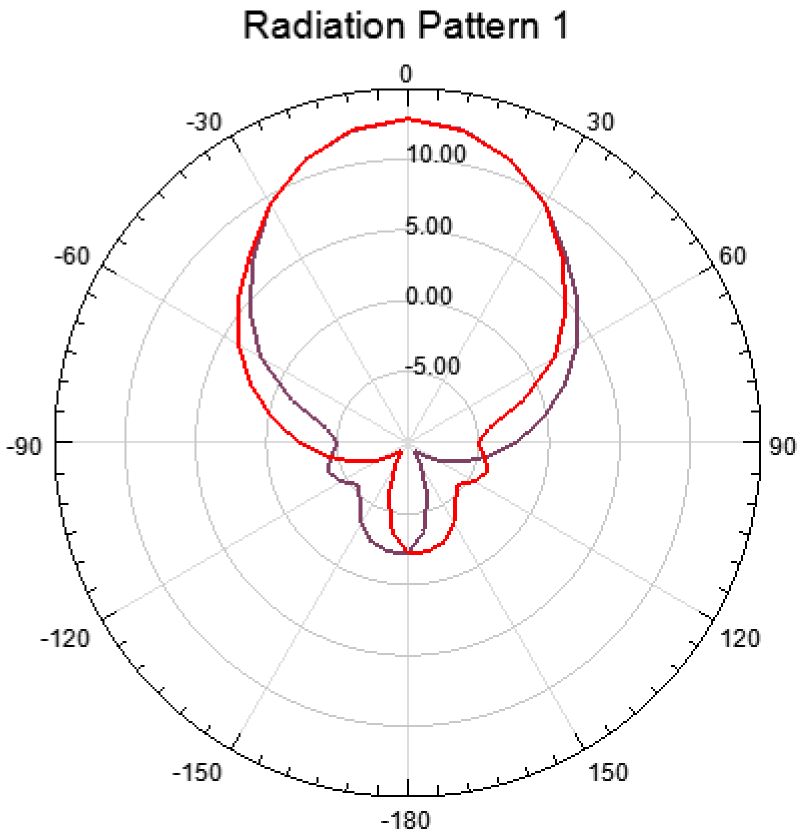

Fig. 7.5: 3D rectangular plot for Radiation pattern of 8 element antenna array using HFSS

The far field region shown in the above figure has the maximum radiation pattern at 0^o and 180^o phi of about 13.15dB. This is the radiation pattern for the structure but to calculate to overall value of the radiation pattern spectrum, it is mandatory to calculate the array factor of the antenna array. The concept of array factor has been already discussed in chapter 3.

7.2.2 ARRAY FACTOR FOR 8 ELEMENTS ANTENNA ARRAY

The figure 7.6 shown below shows the spectrum of radiation pattern of the 8 elements of the antenna array depicting the array factor in decibels. The figure below shows that the maximum value of the array factor is about 323 dB.

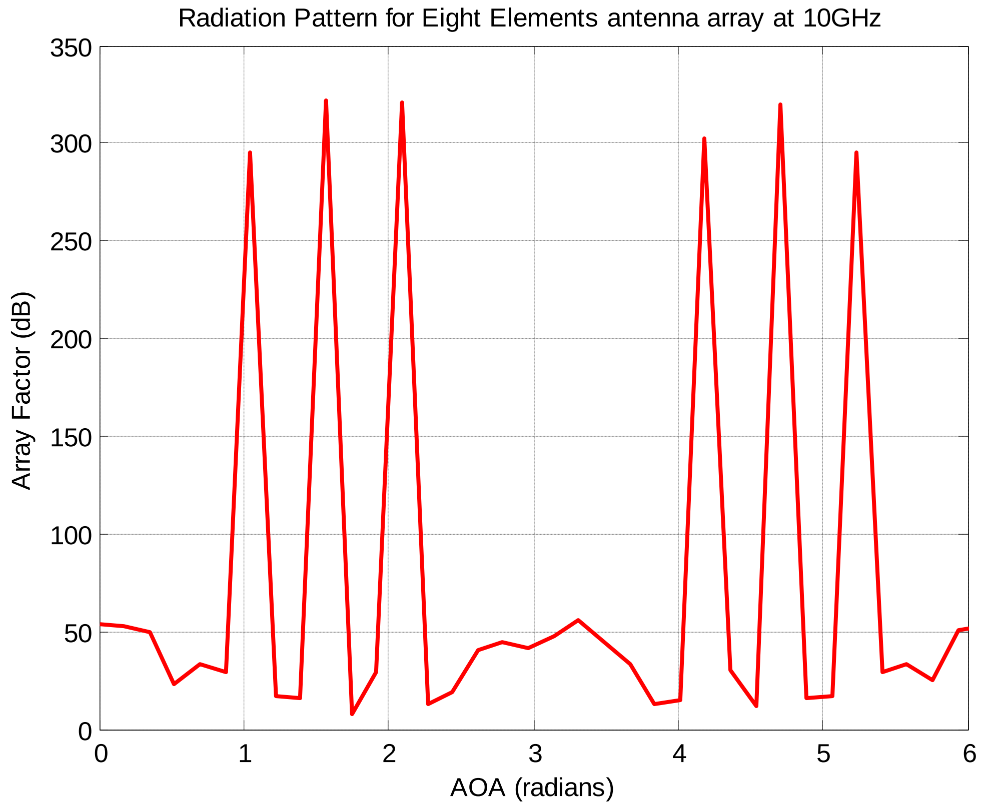

Fig. 7.6: Array factor for 8 element antenna array using MATLAB

7.2.3 GAIN

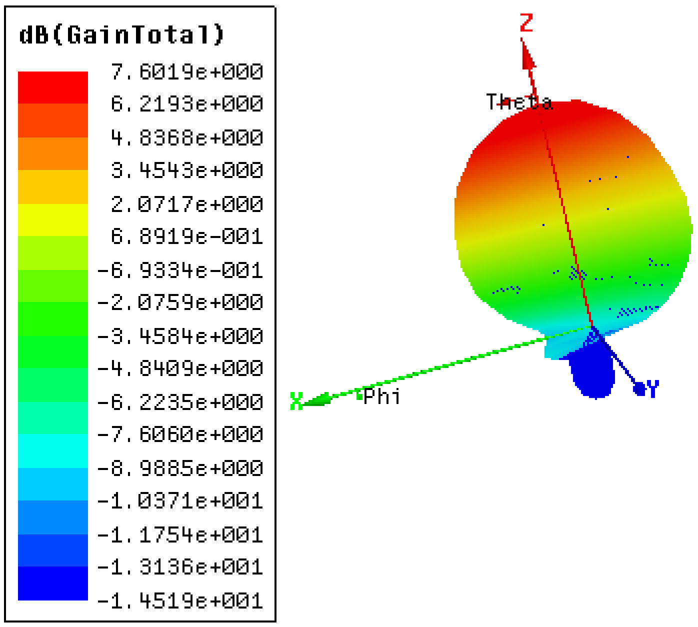

Fig. 7.7: 3D Polar plot for Gain using HFSS

The 3D Gain plot is represented at value of phi equals to 0^o and 180^o as shown in the figure 7.7. From the figure shown above, it can be concluded that the gain has the maximum value of 7.6019 dB for the designed antenna array using 8 elements at the desired values o phi.

7.2.4 DIRECTIVITY

The 3D Directivity plot is represented at phi equals to 0^o and 180^o as shown in figure 7.8 which has the maximum value of 7.5776 dB for the designed antenna array having 8 elements at the desired values of phi.

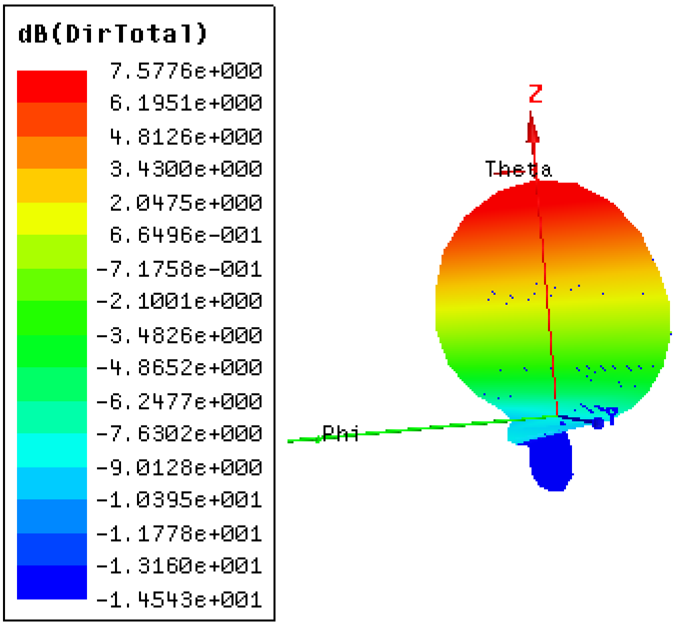

Fig. 7.8: 3D Polar plot for Directivity using HFSS

7.3 TWENTY ELEMENTS ANTENNA ARRAY WITH SAME EXCITATION

The results for the antenna array having twenty elements with structure having designing of elements as 5 x 4 as shown in section 5.3 are shown in this section. The results for the antenna array having 20 elements are validated on the basis of the type and the number of excitations provided to the array structure. In this section, all the 20 elements of antenna array are fed with the same excitations hence reducing the power consumption. That is the results are based on whether they all are fed with the same excitation or with the different excitations and the results drawn are shown in the below sub-sections.

7.3.1 RADIATION PATTERN

The far field radiation pattern of the single element patch antenna at 10 GHz at 0^o and 180^o phi is shown in the figure 7.9:

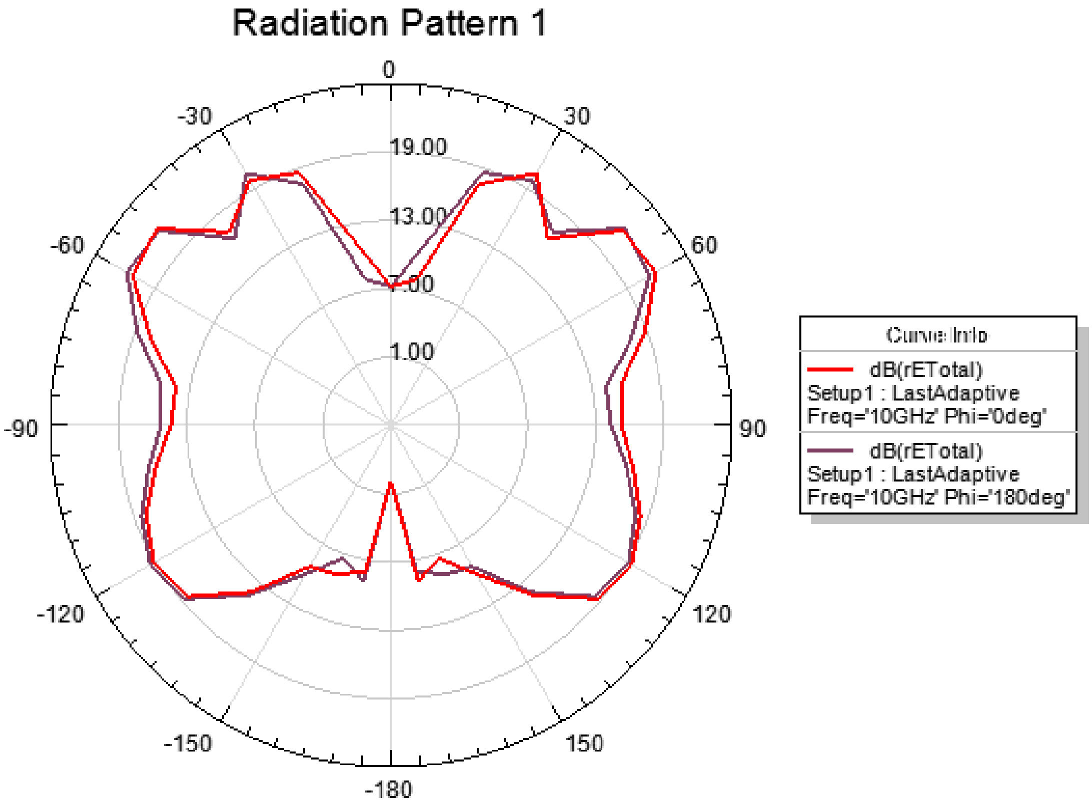

Fig. 7.9: 3D rectangular plot for Radiation pattern of 20 element antenna array having same excitation using HFSS

The far field region shown in the above figure has the maximum radiation pattern at 0^o and 180^o phi of about 20.74dB.

7.3.2 ARRAY FACTOR FOR 20 ELEMENTS ANTENNA ARRAY

The is the radiation pattern for the structure is shown in the fig 7.9 but in order to find the total radiation pattern of the array antenna, we need to find the overall value of the radiation pattern spectrum and for that we need the array factor of the antenna array. The figure 7.10 shown below depicts the spectrum of radiation pattern of the 8 elements of the antenna array depicting the array factor in decibels. The figure below shows that the maximum value of the array factor is about 305 dB.

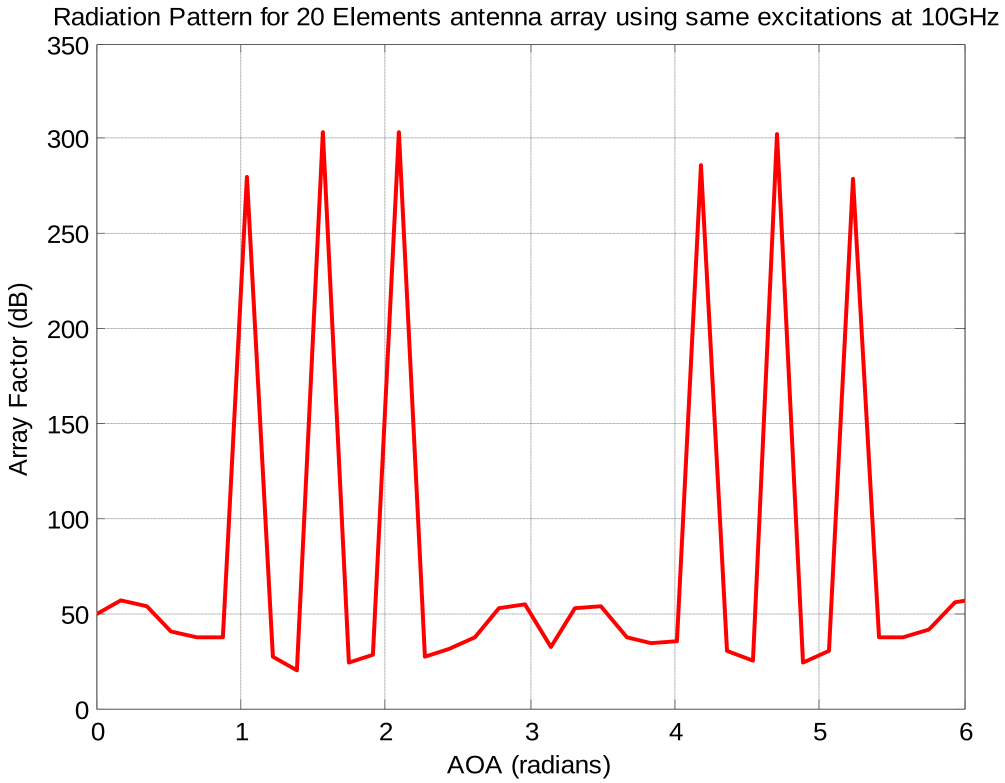

Fig. 7.10: Array factor for 20 element array with same excitation using MATLAB

7.3.3 GAIN

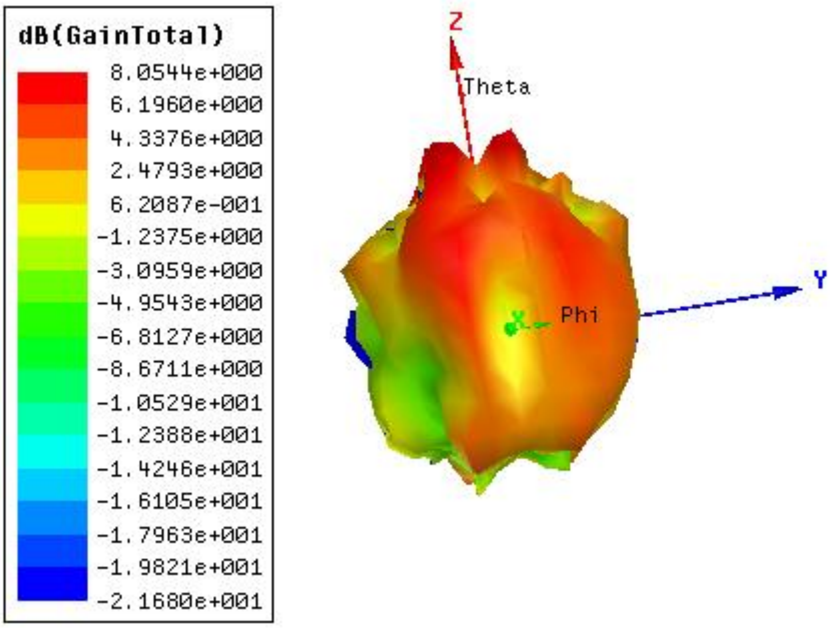

Fig. 7.11: 3D Polar plot for Gain using HFSS

The 3D Gain plot is represented at value of phi equals to 0^o and 180^o as shown in the figure 7.11. From the figure shown above, it can be concluded that the gain has the maximum value of 8.0544 dB for the designed antenna array using 8 elements at the desired values o phi.

7.3.4 DIRECTIVITY

The 3D Directivity plot is represented at phi equals to 0^o and 180^o as shown in figure 7.12 which has the maximum value of 8.2973 dB for the designed antenna array having 8 elements at the desired values of phi.

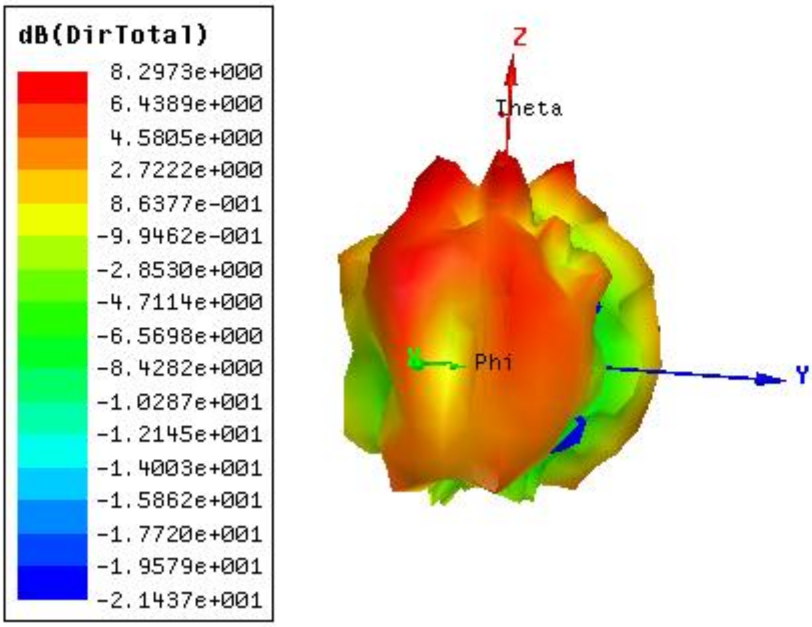

Fig. 7.12: 3D Polar plot for Directivity using HFSS

7.4 TWENTY ELEMENTS ANTENNA ARRAY WITH DIFFERENT EXCITATIONS

The results for the antenna array having twenty elements with structure having designing of elements as 5 x 4 as shown in section 5.3 are shown in this section. The results for the antenna array having 20 elements are validated by considering that all the elements of the array structure are fed with the different excitations. That is the results are based on whether they all are fed with the same excitation or with the different excitations and the results drawn are shown in the below sub-sections.

7.4.1 RADIATION PATTERN

The far field radiation pattern of the single element patch antenna at 10 GHz at 0^o and 180^o phi is shown in the figure 7.13:

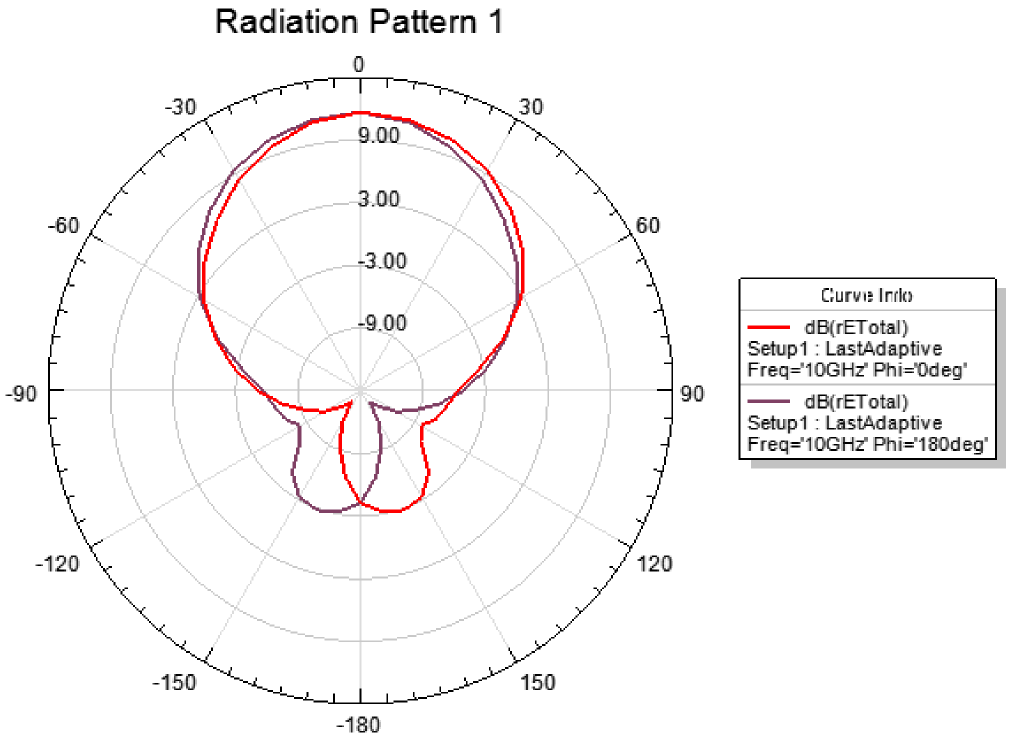

Fig. 7.13: 3D rectangular plot for Radiation pattern of 20 element antenna array having different excitation using HFSS

The far field region shown in the above figure has the maximum radiation pattern at 0^o and 180^o phi of about 10.2dB.

7.4.2 ARRAY FACTOR FOR 16 ELEMENTS ANTENNA ARRAY

The is the radiation pattern for the structure is shown in the fig 7.13 but in order to find the total radiation pattern of the array antenna, we need to find the overall value of the radiation pattern spectrum and for that we need the array factor of the antenna array. The figure 7.14 shown below depicts the spectrum of radiation pattern of the 8 elements of the antenna array depicting the array factor in decibels. The figure below shows that the maximum value of the array factor is about 330 dB.

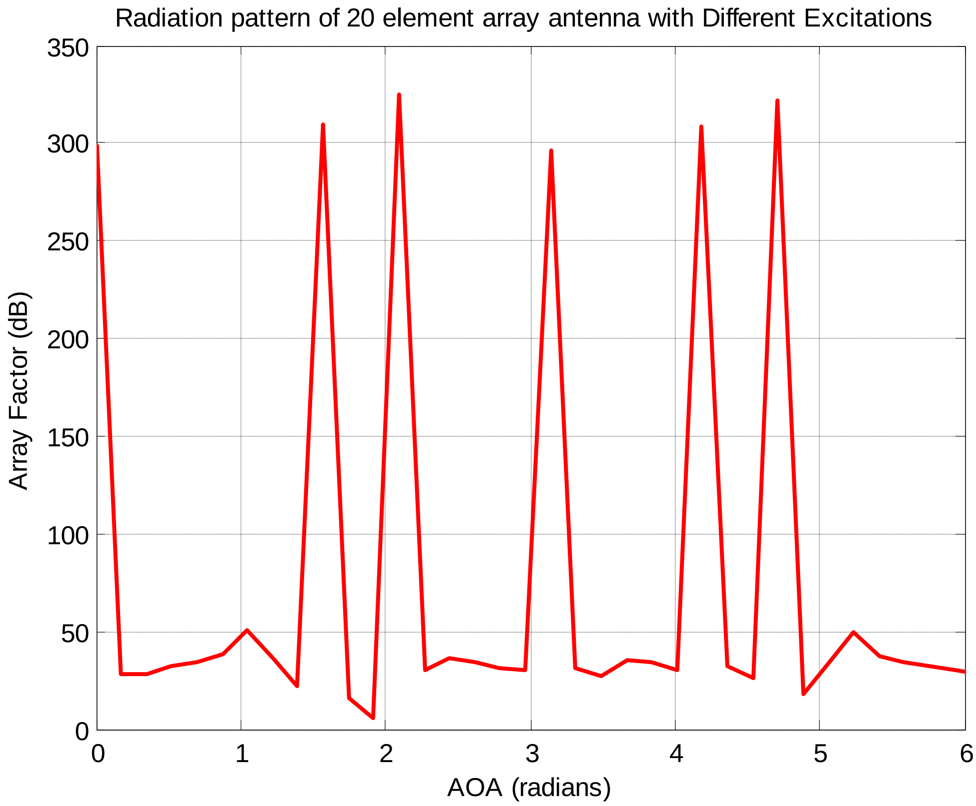

Fig. 7.14: Array factor for 20 element array with same excitation using MATLAB

7.4.3 GAIN

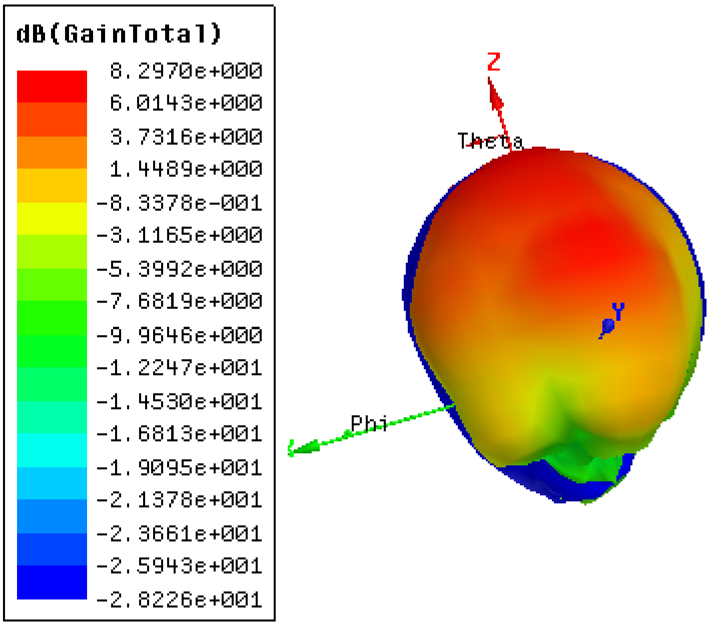

Fig. 7.15: 3D Polar plot for Gain using HFSS

The 3D Gain plot is represented at value of phi equals to 0^o and 180^o as shown in the figure 7.15. From the figure shown above, it can be concluded that the gain has the maximum value of 8.2970 dB for the designed antenna array using 8 elements at the desired values o phi.

7.4.4 DIRECTIVITY

The 3D Directivity plot is represented at phi equals to 0^o and 180^o as shown in figure 7.16 which has the maximum value of 8.3145 dB for the designed antenna array having 8 elements at the desired values of phi.

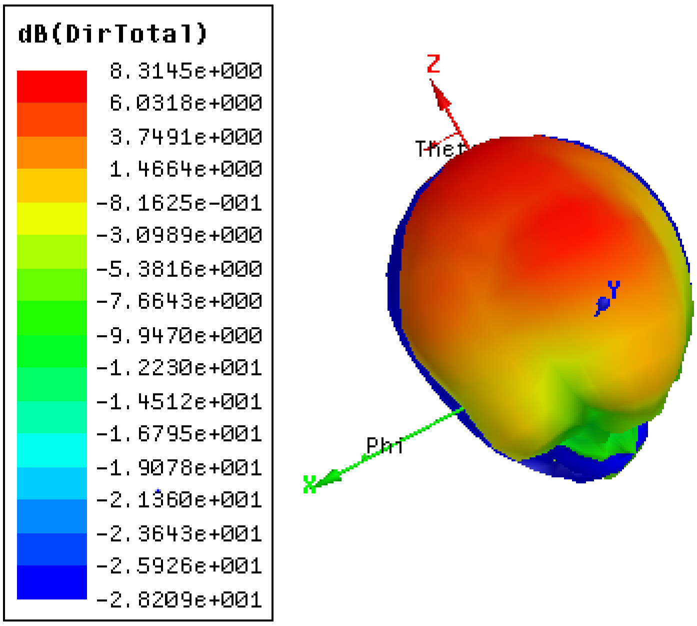

Fig. 7.16: 3D Polar plot for Directivity using HFSS

7.5 RADIATION SPECTRUM AT RECEIVER USING MUSIC ALGORITHM

The applicability of the MUSIC algorithm is checked and analysed on the basis of the type of the feeding input provided to the 5 x 4 structure of antenna array having a total of 20 elements of the array. The result for the antenna array for the elements with same excitations and elements with different excitations are compared after the MUSIC algorithm is applied to both of the array structures in order to get the signals in the desired direction and to remove the noise from the signal received at the receiver.

When the source signal is transmitted from the transmitter, the signal may suffer many distortions and multipath effects hence introducing noise in the signal and distorting the signal strength at the receiver. These multipath effects may be reduced at the receiver by using MUSIC algorithm which stands for Multiple Signal Classification. This algorithm calculates the spectrum of the antenna array by taking into account the estimation of the autocorrelation matrix of the received signal. The pseudo spectrum plotted using the algorithm used i.e. MUSIC is obtained in the desired directions or are obtained in the desired angles only.

In the designed smart antenna which has a total of 20 elements with the structural designing of 5 x 4 elements and the results are obtained are in the direction of the angles at 0^o , 30^o and 60^o . The plots of the MUSIC pseudo spectrum for the array antenna having different excitations and same excitation are shown in the below diagrams.

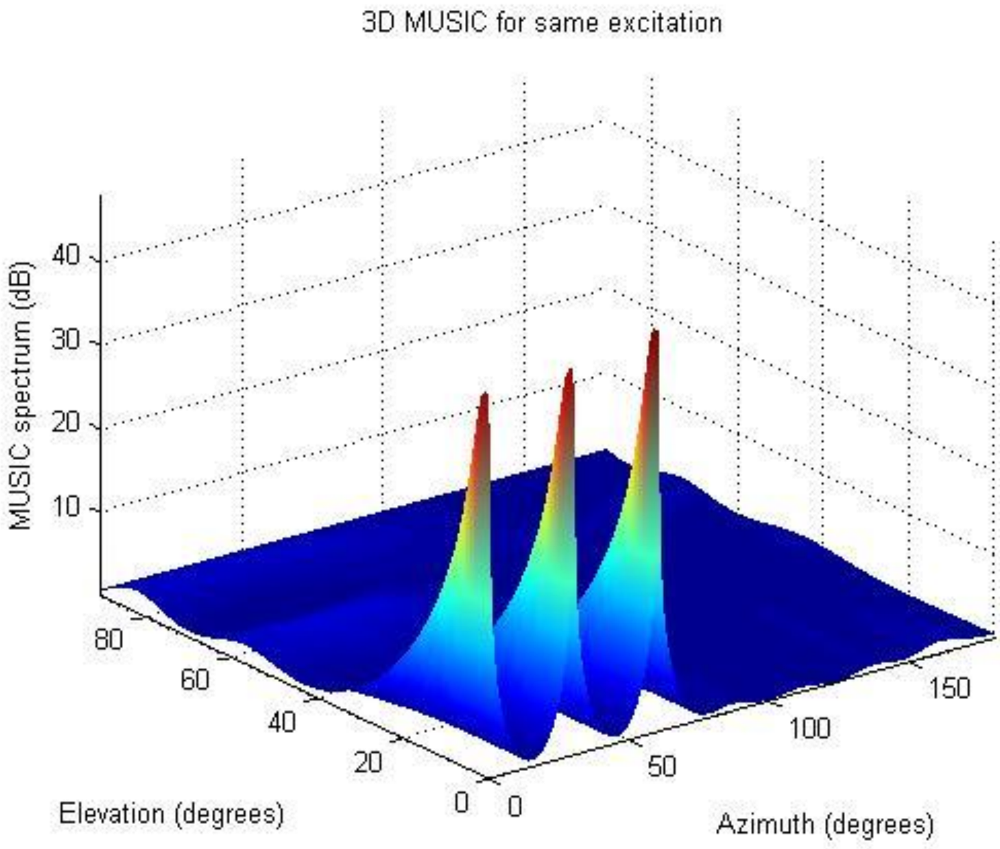

Fig. 7.17: 3D plot for the radiation pattern by using MUSIC algorithm at the receiver for antenna array with same excitation.

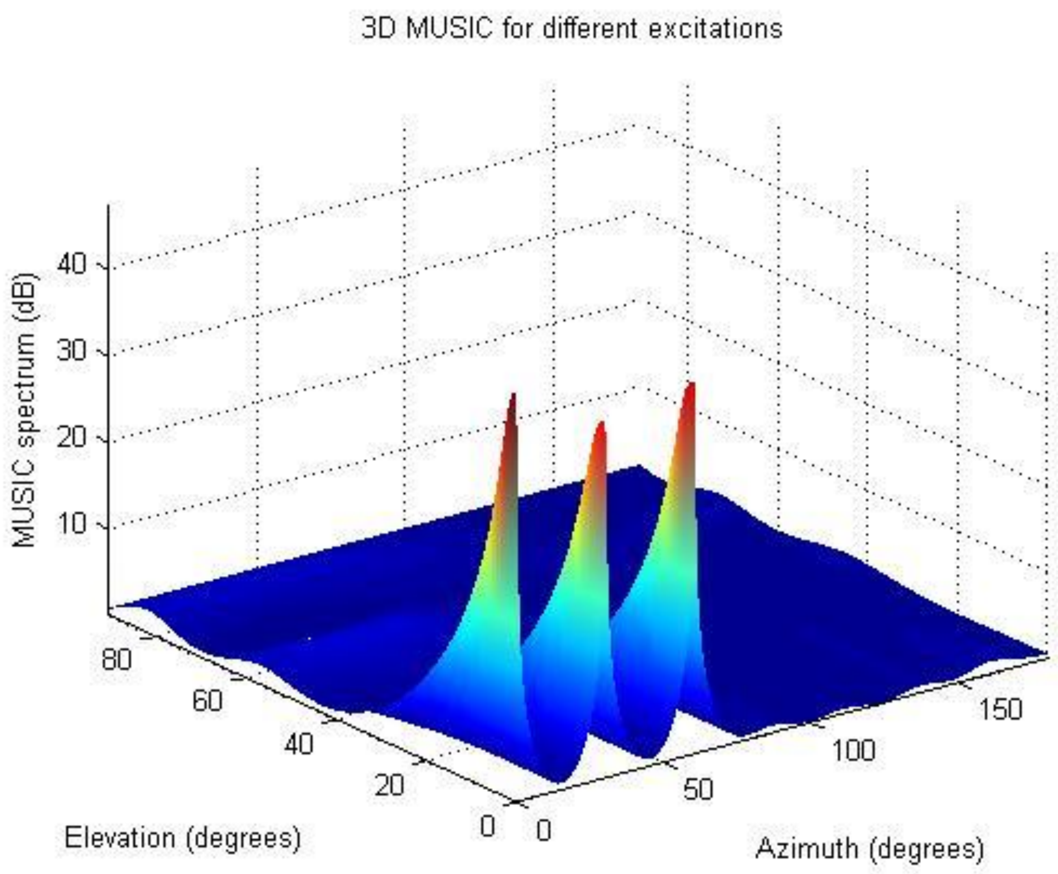

Fig. 7.18: 3D plot for the radiation pattern by using MUSIC algorithm at the receiver for antenna array with different excitations.

The figures shown above i.e. figure 7.17 and 7.18 depicts the MUSIC spectrum obtained for the twenty elements array all with same excitations and different excitations respectively in the desired directions. From the above figures, this can be concluded that the array antenna in which all the elements are given the same excitation behave better to the MUSIC algorithm being used as the adaptive technique as compared to the antenna array with different excitations. However the array factor denoting the radiation pattern of the array structures have better results in the antenna array with same excitation inputs than the antenna array with different excitation inputs. The 20 element antenna array having same excitations have the maximum value of MUSIC spectrum of about 18 dB while the antenna array with different excitations have the maximum value of MUSIC spectrum of about 13dB. These values of the spectrum of the radiation pattern are better then the one obtained from the designing at the transmitter which was 20.74dB for the antenna array with same excitation and 19 dB for antenna array with different excitations. Hence the enhancement and improvement in the value of radiation pattern is obtained at the receiver in context with the radiation pattern that is being obtained and measured at the transmitter.

7.6 CALCULATION OF BER PERFORMANCE

The performance of bit error rate (BER) for the antenna array is checked on the basis of the number of the elements used in the designing of the array of the antenna. The results drawn shows the if the number of elements are more, then the formed bit error rate is less as compared to the antenna array which has less number of elements in the antenna. The bit error rate comparison is compared by using the quadrature amplitude modelling that uses 16 input signals obtained from the sixteen elements in all with the quarature phase shift keying that uses 8 input signals that are obtained from the eight elements used in the array antenna. The graph shown below shows the results obtained using these two techniques for the different number of elements used in the antenna array.

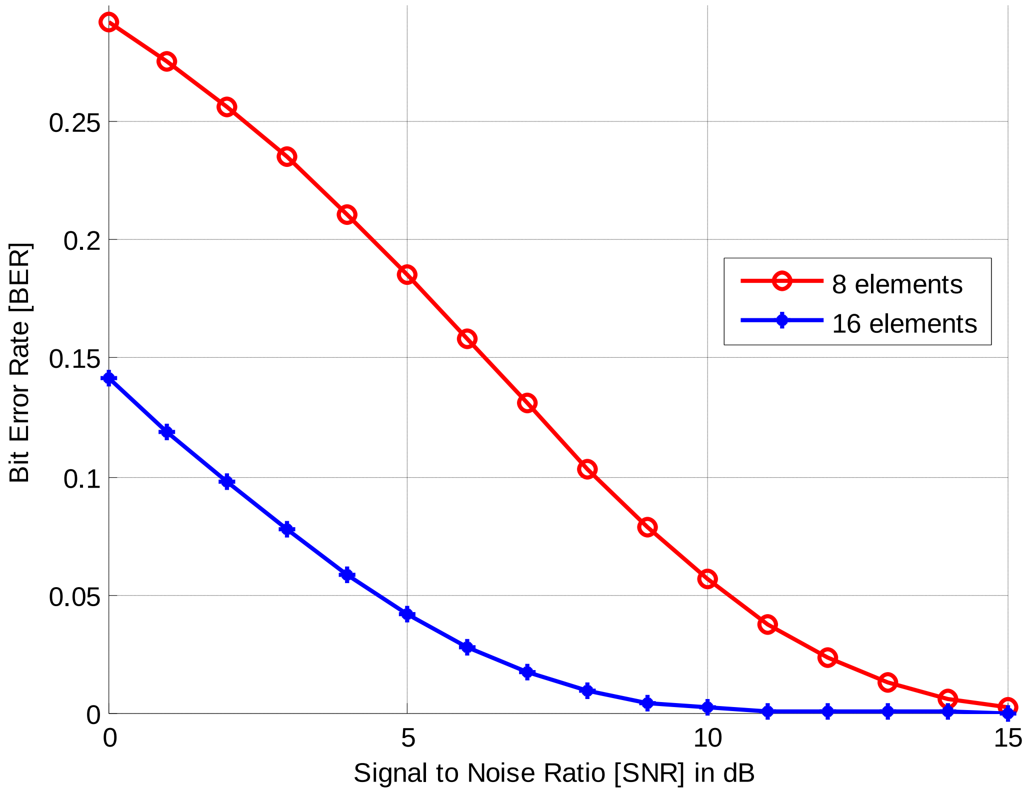

Fig. 7.19: BER performance for 8 elements and 16 elements that are used in designing of the antenna array structure.

From the above diagram, that is figure 7.19 we can hence conclude that the designing of the smart antenna that uses adaptive techniques for the removal of the noise component and hence increasing the radiation pattern consists of the different number of elements of the same patch to define the array structure when are validated on the basis of different number of elements results that BER for a particular value of SNR decreases with the increase in the number of elements in the array and hence increasing the performance of the BER vs. SNR graph.

7.7 COMPARISON OF RESULTS

From all of the results drawn above, the following comparison can be made so as to define the difference between then based on different parameters obtained. The table below shows all the differences discussed in the above sections.

ANTENNA	RADIAION PATTERN (dB)	GAIN (dB)	DIRECTIVITY (dB)
Single Patch	24.09	7.3455	7.3402
8 Element Array	13.15	7.6019	7.5776
16 Element Array with Same Excitation	20.74	8.0544	8.2973
16 Element Array with Different Excitations	10.2	8.2970	8.3145
16 Element Array with Same Excitation Using MUSIC algorithm	13	-	-
16 Element Array with Different Excitation Using MUSIC algorithm	19	-	-

Table 7.1 Difference between all the Antenna structures for Different Parameters

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

Smart antennas are the intelligent antenna systems that extremely improve the efficiency of the wireless transmissions and for the use of the connections between the wireless devices they are most likely to become the standard. Smart antenna is used for the removal of noise component from the signal received at the receiver array and for estimating its spectrum. The removal of noise components will gradually increase the signal to noise ratio while decreasing the BER (bit error rate) and hence increasing the capacity of the system. The smart antennas are not actually smart rather these are the use of adaptive techniques that make the antenna smart. The various beamforming techniques when applied vary with different parameters such as beam width, array factor, null depth. Use of adaptive beamforming techniques can detect the message signal from the noisy distorted signal. Moreover, with increase in number of antenna elements, the radiation pattern of antenna increases and hence increasing the directivity of the signal. The MUSIC algorithm is used for the purpose of removing the noise component from the signals. Also from the whole dissertation work, it can be concluded that the array antenna having more number of antenna elements have better radiation pattern, higher gain and more directivity as compared to the antenna array with less number of array elements. Also the array having more elements behaves better in order to determine the spectrum of the MUSIC algorithm. Hence BER decreases with increase in the number of elements

8.2 FUTURE SCOPE

In the emerging communication system world, there has been wide growth in the necessity for the high data rates in within the vast applications of the usage of the mobile Internet, high-speed downlink packet access (HSDPA), and evolution-data optimized (EV-DO). This growth in the necessity has increased the need for improving the range as well as the speed for the wireless links and has promoted the interest in the deployment of these emerging technologies.

The substantial increasing the signal processing power at the decreasing costs with wider range for wireless broadband systems can reach the high transmission data rates and coverage areas by effectively reducing the multipath effect and the co-channel interference. As the technology is becoming cheaper, it is more likely that the smart antennas will be utilized in almost all the devices. There is a need for the study of the smart antenna systems as with increase in the number of users, interference and propagation complexity grows. The main motive of using the smart antenna in these days mobile application is to increase the capacity of the system.

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PUBLICATIONS

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