Effect of Modulation Schemes on Performance of OFDM based Wireless Network using Smart Antenna

[1]Mr.Balaji G.Hogade,
[1]Research Scholar, EXTC, SVKM's, NMIMS, MPSTME Vileparle, Mumbai, Associate Professor,Terna Engineering College,Navi Mumbai, India,
E-mail: bghogade@gmail.com

[2]Dr Shrikant K Bodhe
[2] Principal, Pandharpur, COE, Solapur, Maharashtra, India,
E-mail: s_k_bodhe@yahoo.co.in

[3]Mrs.Vrishali M Patil
[3] Student, ME (EXTC), Terna Engineering College, Nerul, Navi Mumbai
E-mail: vmsipa10@gmail.com

ABSTRACT : **In this paper we have presented the effect of different modulation Techniques (QPSK, 16QAM and 64QAM) and number of antenna elements at the receiver (Smart Antenna) on the performance of beamforming in OFDM based Wireless network. The performance of the proposed technique is tested for adaptive beam forming algorithm, Least Mean Square (LMS), improved LMS and conventional beamforming for different number of antenna elements. Proposed system not only has good ability of suppressing interference, but also significantly improves the bit-error rate (BER) performance of the system. Simulation results show that an adaptive beam forming gives the optimum performance on urban channels. SNR vs. BER, are compared using same set of parameters.**
Keywords - Beamforming, LTE, OFDM, Smart Antenna, WiMAX, WLAN.

I. Introduction

In Wireless Communication systems, capacity and performance of network are usually limited by two major impairments, multipath and co-channel interference. Smart antenna is one of the most promising technologies that will enable a higher capacity in wireless networks by effectively reducing multipath and co-channel interference. Smart Antenna use adaptive beam forming algorithms in a dynamic environment continuously adjusting the weight of antenna arrays for creating a beam to track desired users automatically, and minimize interference from other users by placing nulls in their directions. Proposed system not only has good ability of suppressing interference, but also significantly improves the bit-error rate (BER) performance of the system. Orthogonal frequency division multiplexing (OFDM) system is a promising scheme for broadband communications. As wireless communication systems look intently to compose the transition from voice communication to interactive internet data, achieving higher bit rates becomes both increasingly desirable and challenging.

In today's world a large number of wireless transmission technologies exist. These technologies are distributed over different network families depending upon the network scale such as PAN (Personal Area Network), WLAN (Wireless Local Area network), WMAN (wireless Metropolitan Area Network), WAN (wireless Area Network) and LTE (Long Term Evolution). As the demand for data transmission with higher rates changed so is the focus on the deployment of wireless networks. Technologies that promise to deliver higher data rates are attracting more and more vendors and operators towards them.

II. LITERATURE SURVEY.

Basically the three main factors which limit transmitting high data rate over the wireless medium are multipath fading, delay spread and co-channel interference [1]. The released WiMAX standard (802.16d) [2] reports a MAC layer and five physical layers, each suited for especial application and frequency range. Wireless MAN-OFDM is one of them [3]. The Wireless MAN-OFDM interface can be highly limited by the presence of fading caused by multipath propagation and as result the reflected signals arriving at the receiver are multiplied with different delays, which cause Intersymbol interference (ISI). OFDM basically is designed to overcome this issue and for situations where high data rate is to be transmitted over a channel with a relatively large maximum delay. If the delay of the received signals is larger than the guard interval, ISI may cause severe degradations in system performance. To solve this issue multiple antenna array can be used at the receiver, which provides spectral efficiency and interference suppression [4]. Smart antenna System (SAS) is an optional feature in IEEE 802.16d standard but to enhance the coverage, capacity and spectral efficiency, it should be essential for an OFDM air interface. It has an advantage of having single antenna system at the subscriber station and all the burden is on base station [3]. An array of antenna is set up at the base station to cut down inter-cell interference and fading effects by furnishing either beamforming or diversity gains. When small spacing is adopted, the fading is highly correlated and Beamforming techniques can be employed for interference rejection as compared to Diversity-oriented schemes [5]. As a result receiver can separate the desired LOS signal from the multipath signals and nulls are formed at the interfering signals.

As specialized in the standard, 802.16a OFDM PHY layer baseband transmitter is compiled of three major parts: channel coding, modulation, and OFDM transmitter. For the receiver complimentary operations are applied in the reverse order.

Channel coding cites to the class of signal transformations considered to improve communications performance by enabling the transmitted signal to better endure the effects of various channel deteriorations, such as noise, fading, and jamming. The goal of channel coding is to improve the bit error rate (BER) performance of power-limited and bandwidth limited channels by adding structured idleness to the transmitted data [6].

Modulation is the process of mapping the digital information to analog form so that it can be transmitted over the channel. For an OFDM system the changing of phase and amplitude can be done but the frequency cannot change because they have to be kept orthogonal. The modulations used in 802.16 are *QPSK,* 16 QAM, and 64QAM.

Smart Antenna System (SAS) consist of set of radiating elements capable of sending and receiving signals in such a way that radiated signals combine together to form a switchable and movable beam towards the user. However it may be noted that the hardware of the smart antenna does not make them “smart”, in fact it is the signal processing technique that is used to focus the beam of the radiated signals in the desired direction. This process of combining the signal and then focusing the signal in particular direction is called Beamforming [9].

The smart antenna system performs the following functions. First it calculates the direction of arrival of all incoming signals including the multipath signal and the interferers using the Direction of Arrival (DOA) algorithms with for example MUSIC and ESPIRIT [11]. This is just two of many used algorithms. DOA information is then fed into the weight updating algorithm to calculate the corresponding complex weights. For that adaptive beamforming algorithm like Least Mean Square (LMS), Recursive Least Squares (RLS) or Sample Matrix Inversion (SMI),Improved LMS, conventional beamforming can be used [10,11].

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING:

WiMAX uses OFDM as the physical layer. OFDM allows large amounts of digital data to be transmitted over a lump of spectrum with greater efficiency than existing wireless technologies. OFDM works by splitting the radio signal into multiple smaller signals that are then transmitted simultaneously at different frequencies to the receiver. An OFDM-based system is able to squeeze a 72 Mbit/s data rate out of 20 MHz of channel spectrum under ideal conditions. The key to OFDM is that the different frequencies can be transmitted and received entirely independently of each other (this is the orthogonal property).

Typically in a wireless system the radio waves travel from the transmitter to the receiver in a like mode to light rays some rays might go straight from the transmitter to the receiver and other will take a hop off trees, buildings and cars [7]. These various multipath, as they are known, can interfere constructively or destructively which causes varying signal power at the receiver. If the data rate of the channel is low, compared to the time difference between the various multipath components, then a fade (a reduction in the received signal strength) can result — deep fades of up to 1000 times (30 dB) are possible in such systems. If, however, a channel is transmitting high rates of data then multipath propagation results in a frequency-selective fading, i.e. the channel is distorted in phase and amplitude. Complex equalizers are often used to measure the channel distortion and correct it in real time.

IV. SYSTEM MODEL

A Transmitter Module:

At the transmitter, the input random data is serial to parallel converted and then mapped to either of the modulation types (QPSK, 16QAM, 64QAM). The obtained N samples are then passed through the IFFT block. As a result an OFDM symbol is generated consisting of a block of N samples. So the frequency domain signal consisting of data symbol, pilot symbols and virtual symbols are transformed by IFFT into time domain signal and then transmitted over the radio channel.

i. OFDM Symbol Description**:**

The WMAN-OFDM-PHY is based on OFDM modulation. An OFDM symbol is made up from carriers, and the FFT size is determined by the carrier number. Three types of carriers are used here:

Data carriers: for data transmission

Pilot carriers: for various estimation purposes
Null carriers: no transmission at all, for guard bands and DC carrier
The purpose of the guard bands is to enable the signal to decay and create the FFT ‘brick wall’ shaping [8]. This also contributes for canceling inter-channel interference. Figure 1 shows the OFDM frequency description.

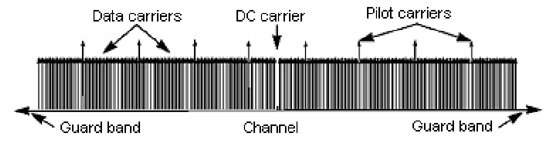


Figure 1 OFDM frequency description.

The transmitted signal voltage to the antenna, as a function of time during any OFDM symbol can be written as [2]:

$$s(t) = \mathrm{Re}\{e^{j2\pi f_c t} \sum_{\substack{k=-N_{used/2} \\ k\neq 0}}^{N_{used/2}} c_k e^{j2\pi k\Delta f(t-T_g)}\} \quad (1)$$

Where t is the time elapsed since the beginning of the OFDM symbol with $0 < t < Ts$ and C_k is a complex number; the data to be transmitted on the subcarrier whose frequency offset index is k during the subject OFDM symbol.

OFDM wave form is created by Inverse Fast Fourier transforming: this time duration is referred to as useful symbol time T_b [2]. A copy of the last of the useful symbol period T_g, termed CP, is used to collect multipath, while maintaining the orthogonality of the codes. Data is sent in the form of OFDM symbols. The basic structure of an OFDM symbol is represented in frequency domain.

ii. Random Data Generation:

The input data is generated in the form of random numbers i.e. series of ones and zeros (110000111001). The length of the information bits depends upon the type of the modulation scheme used to map the bits to symbols (QPSK, 16QAM, 64QAM). The generated data is then passed to the Modulation sub-module for symbol mapping.

iii. Modulation:

The generated data is then passed to the constellation mapper, where depending upon its size the data was modulated using the following three different modulation schemes: QPSK, 16QAM, and 64QAM to form an OFDM frequency-domain signal [2]. Modulation is done by dividing the incoming bits into groups of i bits to represent a modulated signal. As a result there are 2^i points, and the total number of points represents a constellation. The size of i for QPSK, 16QAM, 64QAM is, 2, 4, and 6 respectively.

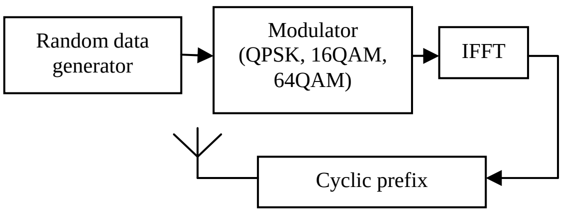


Figure 2: Transmitter Module.

iv. Pilot Modulation:

Pilot symbols allocate specific subcarriers in all OFDM data symbols. To constitute the symbol, the pilot subcarriers are inserted into each data burst and they are modulated according to their carrier location within the OFDM symbol. For that, pseudo random binary sequence (PRBS) generator is used to produce a sequence w_k .

v. IFFT:

After successful data Modulation Inverse Fast Fourier Transform was applied on the modulated data to convert it from frequency domain into time domain. IFFT is simple to use and it guarantees that the carriers signal ready to be sent towards the receiver are orthogonal in nature. The t^{th} time domain sample at the n^{th} subcarrier at the output of IFFT is given by [12].

$$x_t = \sum_{n=0}^{N-1} X_n \exp\{j\frac{2\pi tn}{N}\}\ 0 \le t \le N-1 \qquad (2)$$

Where N is the number of subcarriers and is the data symbol on the nth subcarrier. As a result an OFDM symbol is generated. FFT is just a computationally fast way to calculate the DFT. We can move back and forth between the time domain and frequency domain without losing information [13].

vi. Cyclic Prefix Insertion:

Cyclic Prefix (CP) was added to the data once the data was converted into time domain and ready to be transmitted. The addition of CP to the data before it was actually transmitted helped the data to cater the problems related to the multipath propagation and provided a resistance against ISI. IEEE 802.16d allows the insertion of Cyclic Prefix of various lengths such 1/4, 1/8, 1/16, and 1/32, here a CP of length 1/4 is added to the OFDM symbol before it was transmitted. The transmitted data is then fed into the channel.

B. Channel Module:

The basic aspire of wide area networks using broadband wireless channels is to accomplish high data rates with sane bandwidth and power consumption. Maintaining high coverage and quality of service standard was something that was considered undoable until the arrival of WiMAX which promises to deliver high data rates with improved coverage.

One of the main problems faced by the wireless networks is cope with the ecology challenges once the signal is on air from its way towards the receiver.

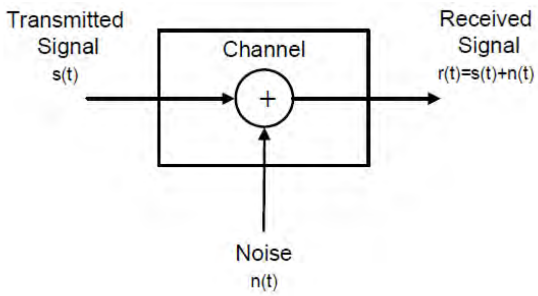
Whenever a deployment of a wireless communication system is considered, the first thing that must be addressed properly is the design of a channel model. Once the signal is sent from the transmitter towards the receiver it has to come across several environmental effects or conditions. These effects play a significant role in wireless communication technology and this is where the design of the channel model comes into play. In order to design an efficient wireless channel model following things must be kept in mind [14]:

Multipath delay spread, Fading characteristics, Path loss, Doppler spread, Co-channel interference.

- Additive White Gaussian Noise (AWGN) Channel:

This channel adds white Gaussian noise to the transmitted signal. In this channel model fading, interference and dispersion are not considered. The mathematical model for the received signal passed through an AWGN channel is shown in figure 3 and is represented by equation 3,

$$r(t) = s(t) + n(t) \qquad (3).$$



A. Figure 3 an AWGN channel.

C Receiver Module:

At the receiver an array of antennas is deployed. The different sub modules at the receiver are now explained.

a) Antenna Array Model:

A general case of linear antenna array with uniformly spaced sensors is considered as shown in figure 4.

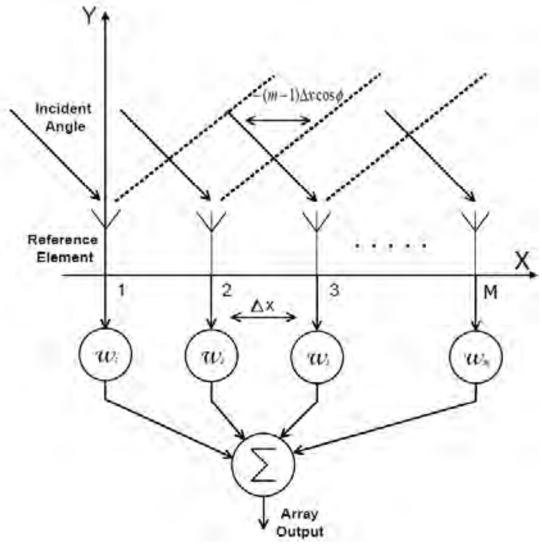


Figure 4: Antenna Array Model

It is assumed that the entire signals incident on the antenna array is composed of plane waves and the transmitted signal is in the far field of the antenna array [15] [16]. Let *M* be the number of antenna elements. Usually an array has a reference element, here the left most elements is supposed to be considered as the reference element. So the plane wave first reaches the reference element and then it propagates all the way to the M^{th} antenna element. There are L incoming signals due to L paths. When the signals travel across the array they suffer a phase shift. The phase shift between the signal received at the reference element and the same signal received at element m is given by [16]

$$\Delta\alpha_m = -kd(m-1)\cos\phi \qquad (4)$$

Note that $\Delta\alpha_1 = 0$. Lets now define the incoming signal at the array element 1(reference element) due to l^{th} the path by

$$s_{l,t} = x_{l,t}e^{j2\pi f_0 t} \qquad (5)$$

Where $x_{l,t}$ is the modulating function of the *l* path and f_0 the frequency of the carrier signal. The incoming signal at element m will be in that case

$$r_{m,t} = x_{l,t}e^{j(2\pi f_0 t+\Delta\alpha_m)} + n_{m,t}$$

$$= s_{l,t}a_m(\phi) + n_{m,t} \qquad (6)$$

Where

$$a_m(\phi_l) = e^{j\Delta\alpha_m} = e^{-jkd(m-1)\cos\phi_l} \qquad (7)$$

Steering Vector describes the phases of the signal received at each antenna element as compared to the phase of the signal at reference element [18]. The steering vector can be represented as

$$a_m(\phi_l) = \begin{pmatrix} 1 \\ a_2(\phi_l) \\ \dots \\ a_m(\phi_l) \\ \dots \\ a_M(\phi_l) \end{pmatrix} \qquad (8)$$

Now considering all the paths simultaneously, the signal at the m^{th} element will be

$$r_{m,t} = \sum_{l=1}^{L} x_{l,t}e^{j(2\pi f_0 t+\Delta\alpha_m)} + n_{m,t}$$

$$= \sum_{l=1}^{L} s_{l,t} a_m(\phi) + n_{m,t} \qquad (9)$$

Where L is the number of incoming signals, ϕ_l is the angle of arrival of the l^{th} path as shown in figure 4, $s_{l,t}$ is the transmitted signal for the l^{th} path and $n_{m,t}$ denotes the Mx1 vector of the noise at the array elements.

b) Pre-FFT Beam-forming

Beam-forming is used to separate the desired signal from the interfering signals given that they have same frequencies but different spatial locations. Interference signals can be other user signals or can be the signals from multipath environment [15]. Pre-FFT beam-forming also called time-domain beamforming setup at receiver is illustrated in figure 4. Here beamforming is applied before the FFT operation. Adaptive beamforming involves two steps: First the weight calculation and then beamforming by applying the weights to the received signal. Consider a Narrowband beam-former, where signals from each element are multiplied by a complex weight and summed to form the array output [11].

$$y_t = \sum_{m=1}^{M} w_m^* r_{m,t} = w^H r_t \qquad (10)$$

Where subscript H denotes complex conjugate transposition of a vector or matrix and w is called the array weight vector.

$$w = [w_1, w_2, ..., w_M]^T$$

$$r_r = [r_1(t), r_2(t), ..., r_M(t)]^T$$

The output of the array system becomes

$$y_t = w^H r_t \qquad (11)$$

c) Adaptive beamforming Algorithm used:

There are many types of Adaptive beamforming algorithms. The minimum mean square error (MMSE) criterion algorithms such as the least mean squares (LMS) and recursive least square algorithm (RLS) are often used for updating weights in adaptive beamforming [15, 11]. Due to complex multiplications per update for the

RLS algorithm, the LMS algorithm is generally employed [19]. LMS which is iterative makes use of past information to minimize the computations required at each update cycle is used in this simulator [12].

The LMS algorithm is based on the steepest-decent method which recursively computes and updates the sensor array weight vectors [20]. The output of the array is compared with the reference signal generated at the receiver. Here the reference signal is assumed to be identical to the incoming signal and have similar statistical properties as the transmitted signal.

The error signal is put into the weight updating algorithm. The gradient approach which provides an iterative update solution for the MMSE criteria is given by [12]

$$w_{m,i+1} = w_{m,i} - \frac{1}{2}\mu \nabla j(w_{m,i}) \qquad (12)$$

The convergence characteristic of the algorithm depends on the parameter μ. $\nabla j(w)$ is the gradient of function $j(w)$ which is given by:

$$j(w_m) = E[\left| w_m^H r_i - d_{m,i} \right|^2] \qquad (13)$$

The function $j(w)$ is the cost function. By solving the gradient of the cost function in above equation and we can get the approximated solution for the instantaneous squared error and Sub. So the Least Mean Square algorithm is found by [12]:

$$w_{m,i+1} = w_{m,i} + \mu r_i e_{i,m}^* \qquad (14)$$

Where $e_{i,m} = w^H_{m,i} r_i - d_{m,i}$ is the error between the array output and reference signal.

After applying the adaptive beamforming algorithm the desired LOS signal was obtained, thus filtering it out from unwanted (null and interfering signals). The desired output signal from the beamformer as shown in the figure 5 i.e. Y (t) is then processed in the following way so that the original signal can be extracted.

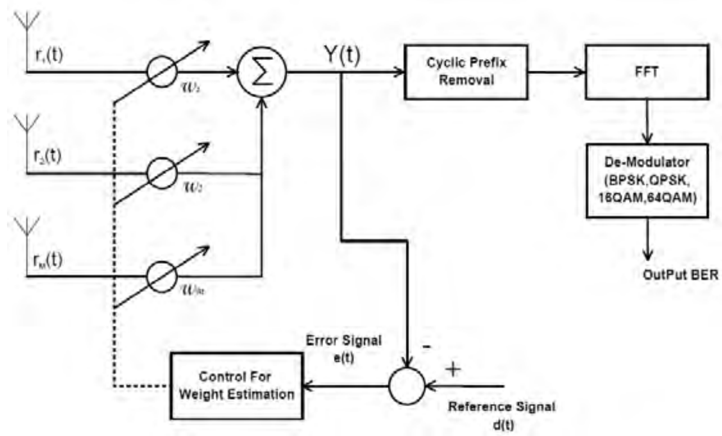


Figure 5: Receiver Module

The process starts with the removal of the cyclic prefix that was initially added to the transmitted signal as earlier on explained in the transmitter module. After cyclic prefix removal, the data was converted back into frequency domain from the time domain using the FFT. Once the data conversion is completed the data is passed to the De-Modulator where the data is De-modulated according to modulation schemes applied on the data during the transmission. The De-modulation of the data marks the end of the receiver module where the data obtained from De-modulator was compared to original data in form Bit Error Rate (BER).

D The simulation block diagram:

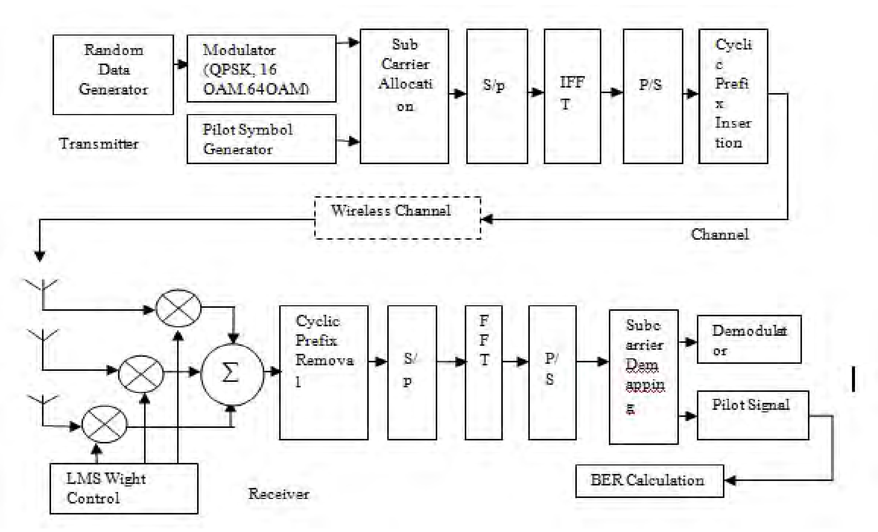


Figure 6: Simulation Block Diagram.

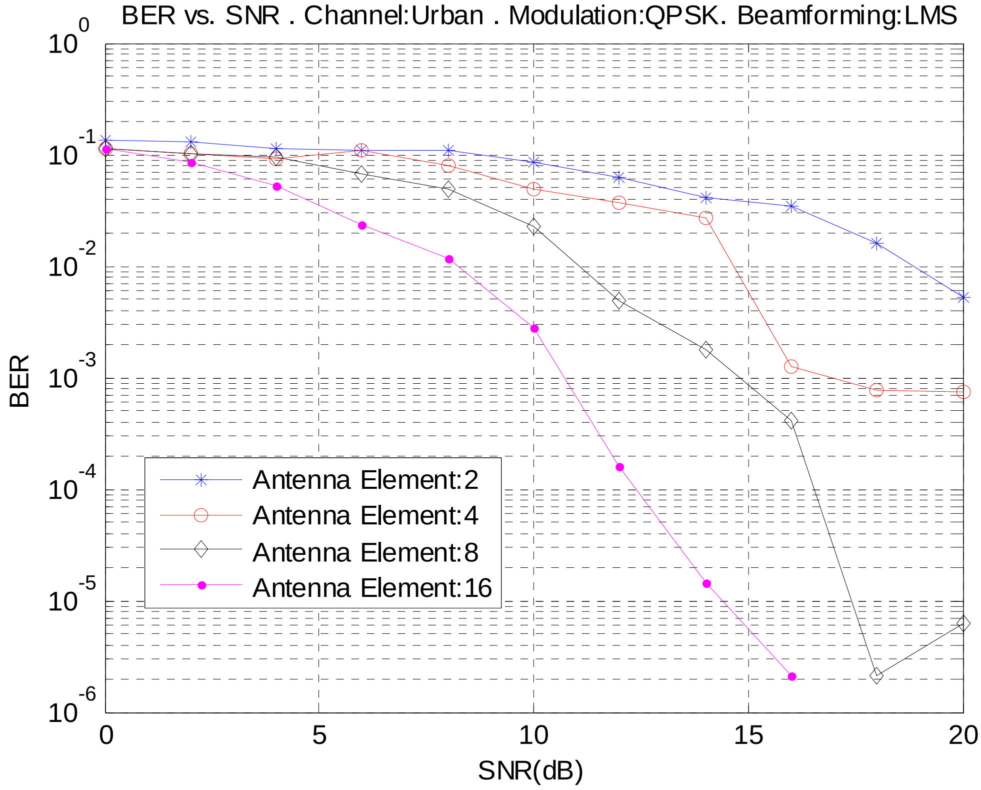
V. SIMULATION RESULTS:

The simulations implemented in this paper are all done in MATLAB. The whole system was tested using Monte Carlo based simulations [21]. The Monte Carlo simulation is used to estimate the BER which the system can achieve. In this model the simulation of the system is repeated and the number of transmitted bits and bit errors are calculated for each simulation. In the end BER rate is estimated as the ratio of the total number of observed errors and the total number of transmitted bits [21]. The parameters that can be set are: number of simulated OFDM symbols, modulation scheme, and number of antennas at receiver and range of SNR values.

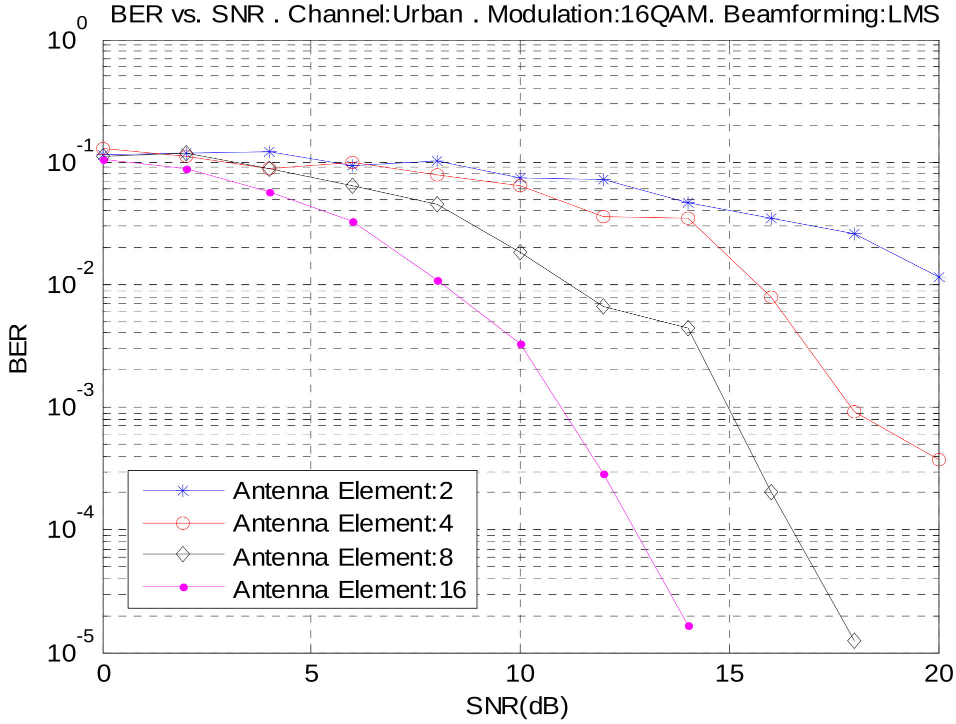
a. Performance in Urban Channel**:**

Performance of the system model tested using different modulation schemes i.e. QPSK (quadrature phase-shift keying), 16 QAM (Quadrature Amplitude Modulation) and 64QAM with an urban channel. Figure 7(a-i) shows the simulation results for QPSK, 16 QAM and 64QAM. In all of the figures a comparison is shown between the simulated BER for this system model. It has been concluded from the simulation results that simulated BER for urban channel good for all Modulation schemes and great improvement by increasing the number of antenna elements at the receiver.

The simulation results are shown using a single antenna at the transmitter and multiple antennas at the receiver. The simulations are performed for implementing the AAS(Adaptive Antenna System) using Pre-FFT beamformer in WiMAX OFDM system: QPSK,16 QAM and 64QAM modulation is used in system and half-wavelength spacing is employed and all the results are relative to smart antenna composed by K=2,K=4, K=8 and K=16 sensors. Different aspects of the complete system model were investigated such as angle of arrival of the incoming signals and number of array elements. The value of μ used is 0.001. When applying the channel conditions to adaptive array fixed WiMAX (World Wide Interoperability for Micro Wave Access) system, the receiver separated the desired LOS signal from the multipath signals. Also the bit error rate (BER) performances are evaluated. So it can be seen that the performance of the system improves if we increase the number of antennas at the receiver. It can be seen from the results that BER curve is improved after using an SAS at the receiver and the desired signal at the receiver is detected with low bit rate.

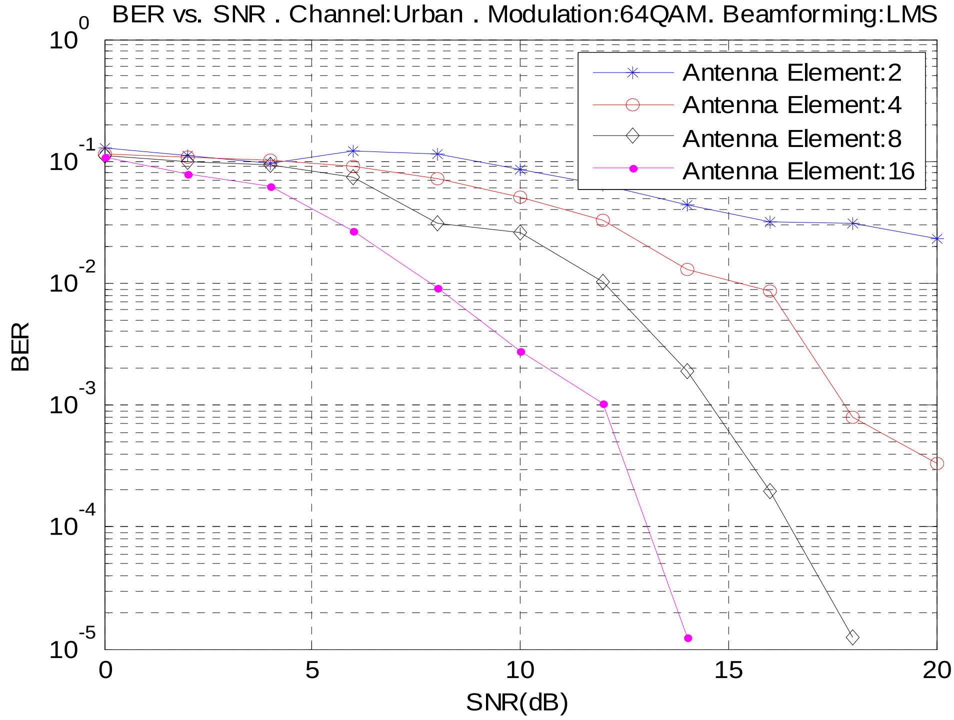


(a)



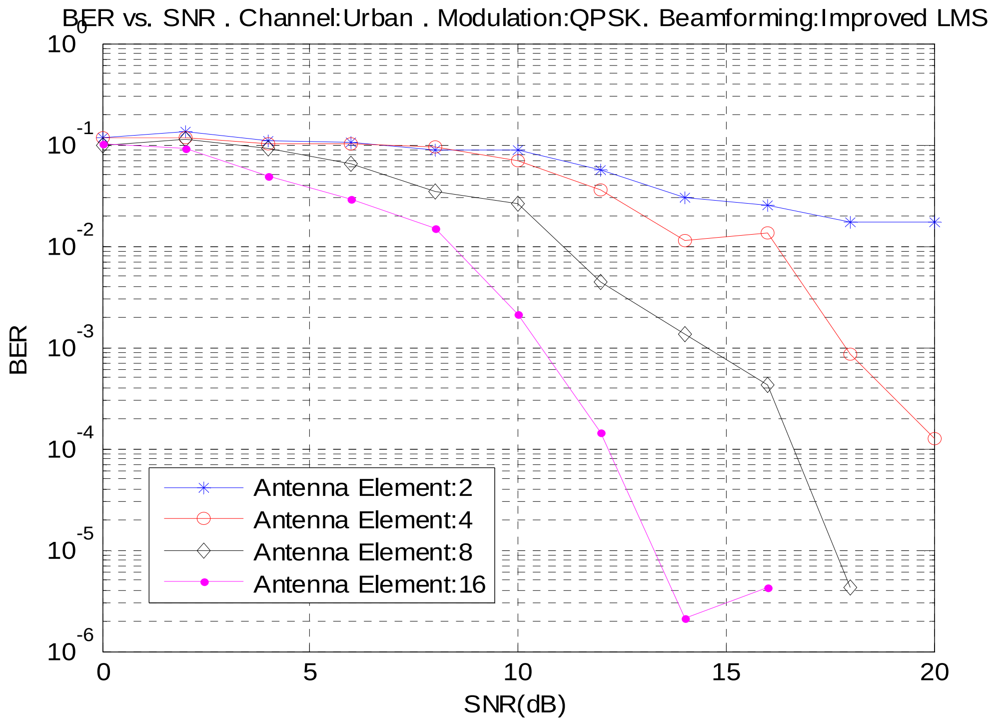
BER vs. SNR . Channel:Urban . Modulation:16QAM. Beamforming:LMS
BER
SNR(dB)
Antenna Element:2
Antenna Element:4
Antenna Element:8
Antenna Element:16

(b)

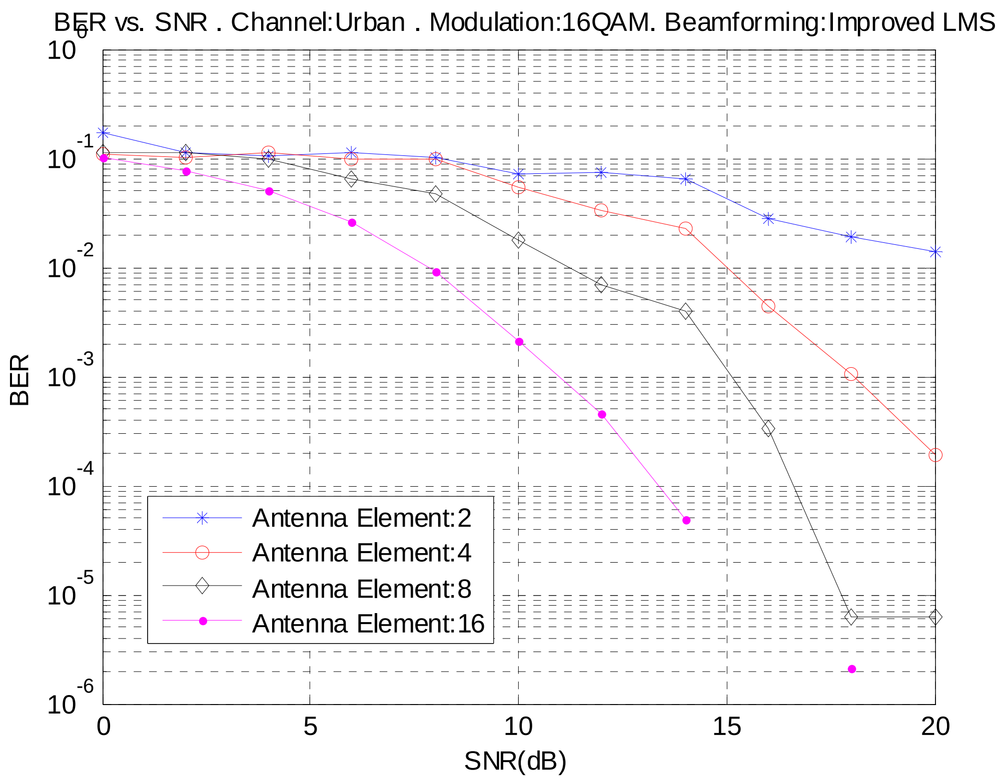


BER vs. SNR . Channel:Urban . Modulation:64QAM. Beamforming:LMS
BER
SNR(dB)
Antenna Element:2
Antenna Element:4
Antenna Element:8
Antenna Element:16

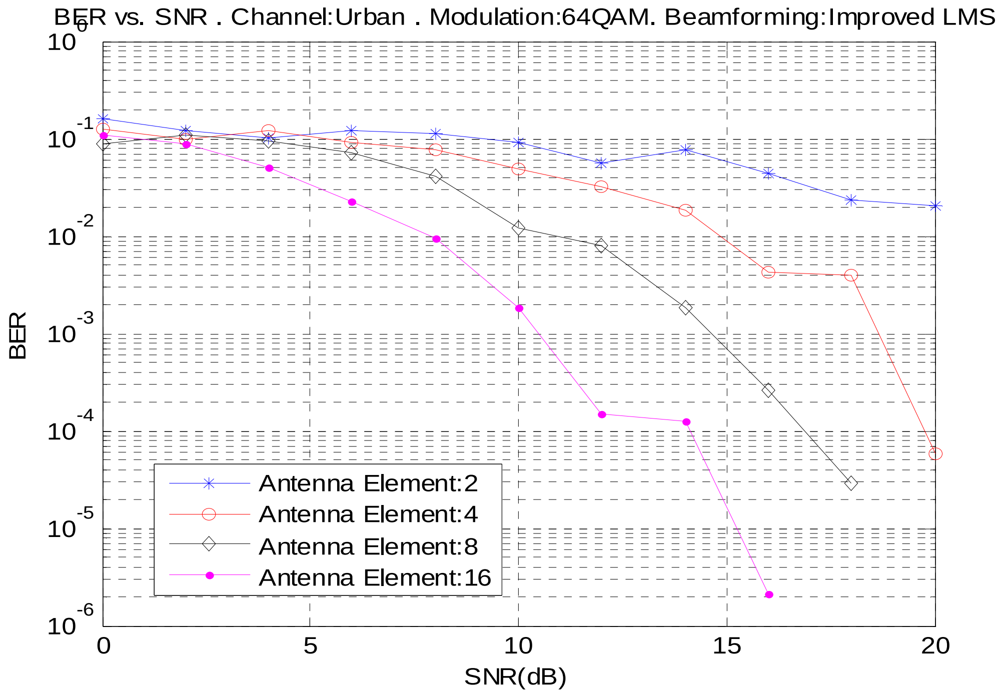
(c)


BER vs. SNR . Channel:Urban . Modulation:QPSK. Beamforming:Improved LMS
BER
SNR(dB)
Antenna Element:2
Antenna Element:4
Antenna Element:8
Antenna Element:16

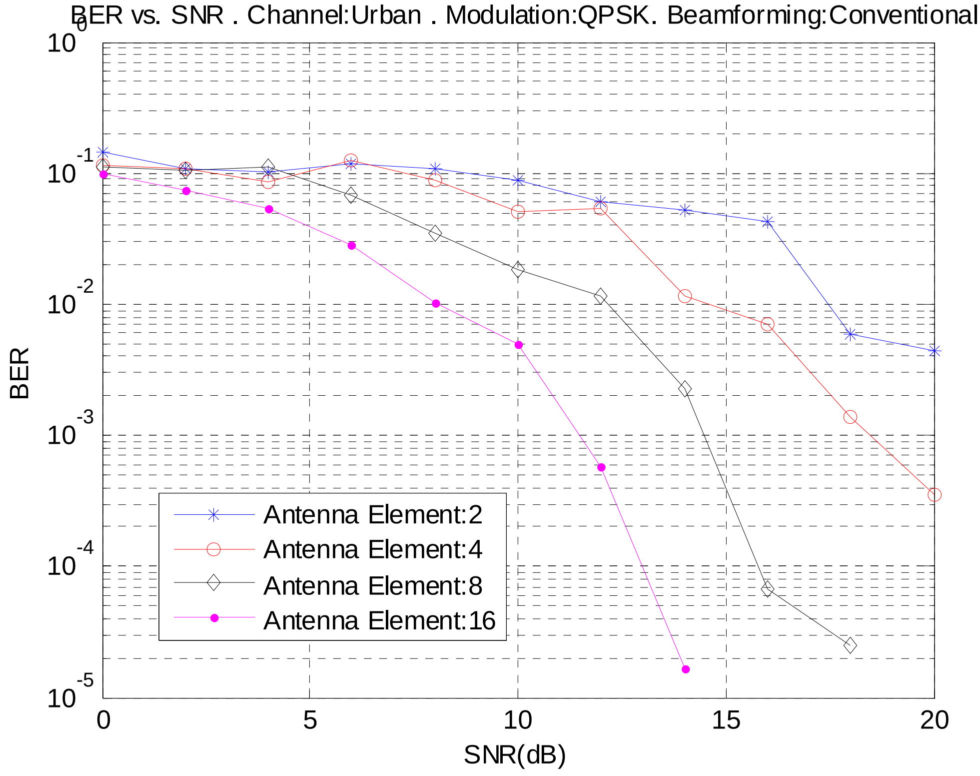
(d)


BER vs. SNR . Channel:Urban . Modulation:16QAM. Beamforming:Improved LMS
BER
SNR(dB)
Antenna Element:2
Antenna Element:4
Antenna Element:8
Antenna Element:16

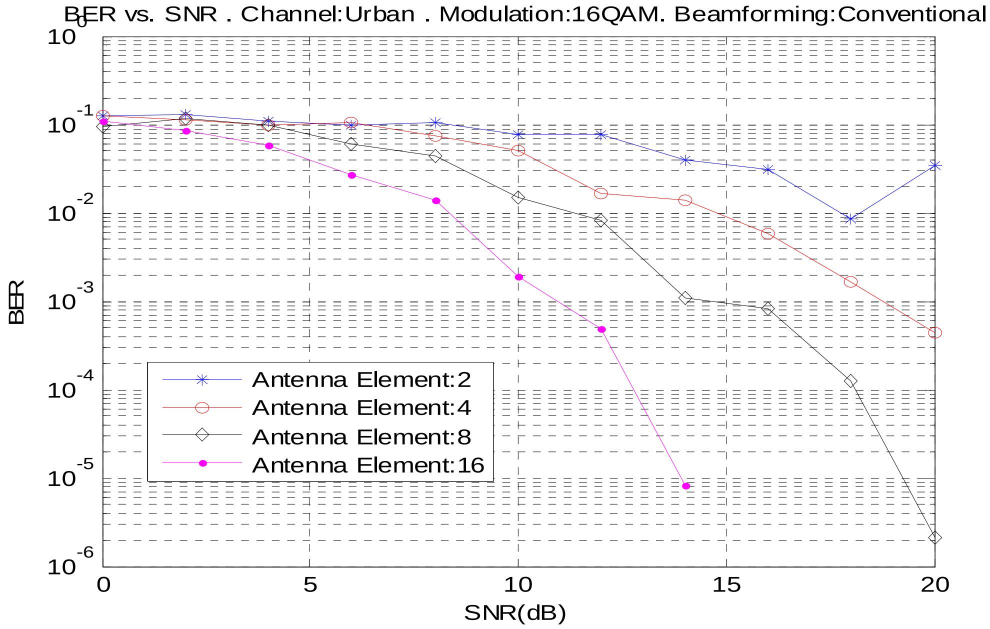
(e)


BER vs. SNR . Channel:Urban . Modulation:64QAM. Beamforming:Improved LMS
BER
SNR(dB)
Antenna Element:2
Antenna Element:4
Antenna Element:8
Antenna Element:16

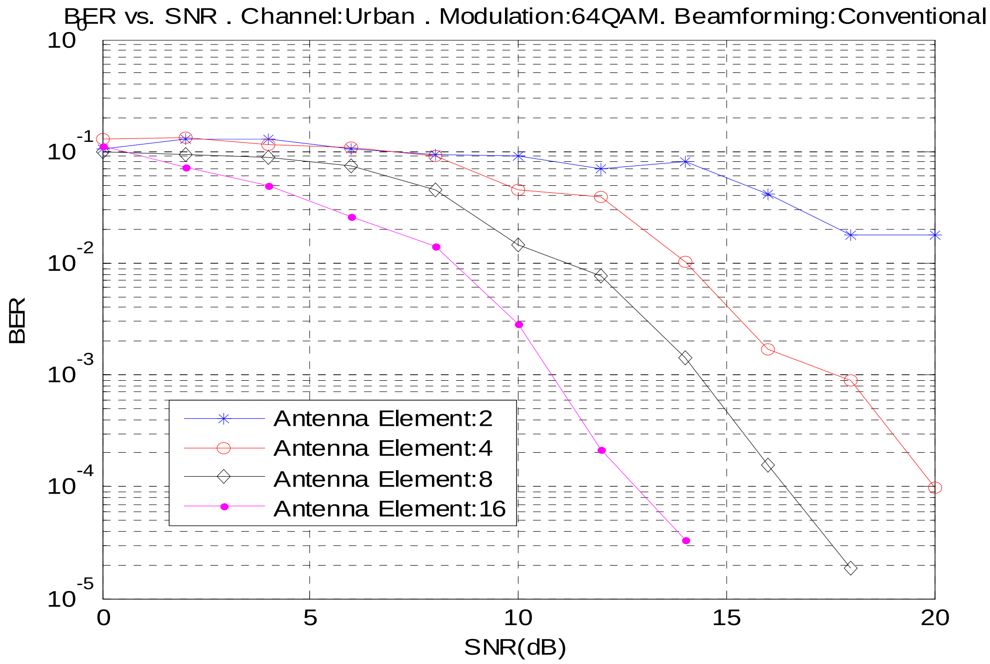
(f)


BER vs. SNR . Channel:Urban . Modulation:QPSK. Beamforming:Conventional
BER
SNR(dB)
Antenna Element:2
Antenna Element:4
Antenna Element:8
Antenna Element:16

(g)



(h)



(i)

Figure 7 (a-i) BER vs. SNR for different modulation schemes and number of antenna elements at the receiver

VI. CONCLUSION:

To reduce the effect caused by fading, SAS is implemented at the receiver module by using LMS algorithm, improved LMS, conventional beamforming and pre-FFT beamforming. The whole system was tested with SAS using different modulation schemes.

Finally performance in terms of BER vs. SNR has been driven. It can be concluded from the simulation results that, if there is an SAS installed at the receiver then performance of the system drastically increases as we go on increasing the number of antenna elements at the receiver.

REFERENCES:

[1] Hidehiro Matsuoka and Hiroki Shoki, Comparison of pre-FFT and post-FFT processing adaptive arrays for OFDM systems in the presence of co-channel interference. Corporate R&D Centre. Toshiba Corporation I Komukai-Toshiba-cho, Saiwai-kit, Kawasaki 212-8582, Japan

[2] Wireless MAN Group. IEEE standard for local and metropolitan area networks. Technical Report IEEE Std 802.16-2001, wirelessMAN.org, 2001. Part 16, Air Interface for Fixed Broadband Wireless Access Systems.

[3] Y. Li, D. Kenyon, An Examination of the Processing Complexity of an Adaptive Antenna System (AAS) for WiMAX. IEE 2005 First presented at the 2nd IEE/EURASIP DSPEnabledRadio Conference, September 2005, Southampton .

[4] Daniele Borio, Laura Camoriano, Letizia Lo Presti and Marina Mondin, Beamforming and Synchronization Algorithms Integration for OFDM HAP-Based Communications International Journal of Wireless Information Networks, Vol. 13, No. 1, January 2006.

[5] M. Nicoli, L. Sampietro, C. Santacesaria, U. Spagnolini, D. Archetti, A. Bonfanti, M. Sala, Deployment and Design of Multi Antenna Solutions for Fixed WiMax Systems. Dip. di Elettronica e Informazione, Politecnico di Milano, Milano, Italy, Siemens Networks S.p.A., Cassina de' Pecchi (Milano), Italy

[6] Juha Heiskala, John Terry, "OFDM Wireless LANs: A Theoritical and Practical Guide", First Edition, Sams Publishing, December 2001.

[7] Hodgkinson T: 'Wireless communications — the fundamentals', BT Technol J, 25, No 2, pp 11—26 (April 2007).

[8] IEEE 802.16a WMAN organization, "Air Interface for Fixed Broadband Wireless Access Systems. PartA:Systems between 2-11 GHz", April 2003.

[9] Online Education, "Smart Antenna Systems,"International Engineering Consortium.http://www.iec.org/online/tutorials/smart_ant/topic01.html . 2003

[10] Book, Smart Antennas by Lal Chand Godara, 2004 by CRC press LLC .

[11] Lal.C.Godara, Application of Antenna Array to Mobile communications, Part II: Beam-forming and DOA considerations, Proceedings of the IEEE, VOL NO.85, NO.8, August 1997.

[12] Mohamed S. Heakle, Mohab A. Mangoud and Said Elnoubi, LMS Beamforming Using Pre and Post-FFT Processing for OFDM Communication Systems, 24th National Radio Science Conference (NRSC 2007), Faculty of Engineering, Ain shams Univ, Egypt. March 13-15, 2007

[13] Bores Signal Processing, Introduction to DSP.http://www.bores.com/courses/intro/index.hm

[14] Book, S. Rappaport, Wireless Communications Principles and Practice' Second Edition.

[15] Book, Smart Antennas by Lal Chand Godara, 2004 by CRC press LLC.

[16] Tom Mathes, Algorithm for Direction of Arrival Estimation in a Smart Antenna, Lausanne, July 2007.

[17] A. A. Shishegar, N. Hojjat, R. Alihemmati, G. Dadashzadeh, A. Mehrtash, B. Boghrati, "The Effect of the Number of Smart Antenna Elements on the Performance of 802.11a WLAN with Pre and Post-FFT Methods", International Symposium on Telecommunications, September ,10-12, 2005,Shiraz, Iran

[18] Fabrizio Sellone, Fundamentals of Smart antennas For Wireless Communications.

[19] Y. S. Cho, C. K. Kim, and K. Lee, Adaptive beamforming algorithm for OFDM systems with antenna arrays, IEEE Transactions on Consumer Electronics, Vol. 46, No. 4, pp. 1052–1058, November 2000.

[20] UOY, POLITO, EUCON, Report on Adaptive Beamforming Algorithms For Advanced Antenna Types For Aerial Platform And Ground Terminals, Jan 2006.

[21] Dr. B.P. Paris, Simulation of Wireless Communication Systems using MATLAB, fall 2007.

[22] Prof.B.G. Hogade , Ms. Jyoti Chougale-Patil , Dr.Shrikant K.Bodhe, "Analysis of Improved and Traditional LMS Beamforming Algorithm for Smart Antenna," International Journal of Engineering Research and Applications (IJERA) **,**ISSN: 2248-9622 Vol. 2, Issue 3, May-Jun 2012, pp.1816-1820.

[23] B.G. Hogade , Ms. Sheetal Wadhe , Dr.Shrikant K.Bodhe, "Mitigating the Effect of CCI and Multipath in Mobile Communication using Smart Antenna," International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, (VNCET-30 Mar'12), pp 366-370.

[24] Mr R.B.Waghmare,Prof B.G.Hogade,Dr S.K.Bodhe, "MIMO The Next Generation Wireless Communication System,"(IJGTI) International Journal of Global Technology Initiatives , ISSN 2277- 6591,Issue 1,March 29, 2012,ppD38-D42.

[25] B. G. Hogade, Jyoti Chougale-Patil ,Shrikant K.Bodhe, "Performance improvement in beamforming of Smart Antenna by using LMS algorithm," International Journal of Computer Applications® (IJCA), (NCIPET-2012)28Th January, 2012, pp31-35.

[26] Mr. Balaji G.Hogade, Dr Shrikant K Bodhe **,** "Effect of Wideband Signals on Smart Antenna," Vol.3 No.1 (©(IJoAT) International Journal of Advancements in Technology , ISSN 0976-4860 , (January 2012) pp 55-63.

AUTHORS PROFILE

Balaji G. Hogade received M.E. in Power Electronics from Gulbarga University, Karnataka, in 1999. He is an Associate Professor in Electronics Engineering in Terna Engineering College, And a Research Scholar in EXTC in SVKMS, NMIMS, and MPSTME Mumbai. He has guided number of projects and thesis in graduate and post-graduate level program. He has produced several national and international publications. He is a Member of BOS in Electronics Engineering In University Of Mumba.His research interests include Wireless Network, Smart Antenna and Power Electronics.