Design and Implementation Adaptive Antenna System in WiMAX (IEEE 802.16d)

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ABSTRACT

We live in a communication technology continuing to evolve, we generate and process information at a rate never before recorded in the history of mankind. Currently computing platforms are run on Gigahertz multi-core processors churning out Gigabits streams of data that need to be transmitted as quickly as possible. This has led to an ever increasing need to develop wireless access technologies that support high throughput regardless of the transmission environment. In order to develop WiMAX (IEEE 802.16d) PHY layer performance the Adaptive Antenna System has been considered. An Adaptive Antenna System has been deployed at the receiver module to reduce the fading effects caused by proposed channel model. Adaptive Antenna Systems (AAS) uses various beam forming techniques to focus the wireless beam between the base station and the subscriber station. In this work, the transmitter (SS) and receiver (BS) are fixed and AAS installed at the receiver is used to direct the main beam towards the desired LOS signal and nulls to the multipath signals. FFT beam former based on Least Mean Square (LMS) algorithm is used. It has been proved through MATLAB simulations that the performance of the system significantly improved by AAS, where is beam forming implemented in the direction of the desired user. The performance of the system more increased by increasing the number of antennas at receiver.

Keyword: WiMAX, Antenna, adaptive, Beam forming, AAS

تصميم وتطبيق نظام الهوائي المكيف نوع WiMAX (IEEE 802.16d)

الخلاصة:

نحن نعيش في عصر تكنولوجيا الاتصالات االمستمرة بالتطور. نحن الان نجتهد بتوليد ومعالجة المعلومات بمعدل لم تسجل من قبل في تاريخ البشرية. حاليا يتم تشغيل منصات الحوسبة على معالجات متعددة النواة تيارات من البيانات التي تحتاج إلى أن تنتقل في أسرع وقت ممكن . وقد أدى ذلك إلى الحاجة المتزايدة لتطوير هذه التقنيات الاسلكية التي تدعم إنتاجية عالية بغض النظر عن بيئة الإرسال. من أجل تطوير الوامكس (IEEE802.16d) استخدم في هذا البحث نظام الهوائي المتكيف. وقد تم نشر نظام هوائيان متكيفان في وحدة الاستقبال للحد من الآثار الناجمة عن تلاشي الاشارات في قناة التلاشي المقترحة. نظام تكيف الهوائي (AAS) يستخدم مختلف التقنيات لتكوين الشعاع وتركيزه بين محطة ومحطة واخرى. اي بين جهاز الإرسال

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(SS) وجهاز الاستقبال (BS) ونظام تكيف الهوائي AAS يركب في جهاز الاستقبال لاستلام الشعاع الرئيسي عبر إشارة LOS المطلوبة واستخدام التشكيل الحزمي للاشارات المستلمة . وقد ثبت ذلك من خلال استعمال برنامج المحاكاة MATLAB أن أداء النظام تحسن وبشكل ملحوظ باستعمال نظام تكيف الهوائي AAS ، الذي يتم فيه استلام الاشارات في اتجاه المستخدم المطلوب. ان أداء النظام يتحسن اكثر كلما زاد عدد الهوائيات في جهة الاستلام.

INTRODUCTION

What has been seen and under watch in recent years is a remarkable increase in the Broadband Wireless Access (BWA) networks as the need for broadband and mobile services are getting into demand. BWA is increasingly acquiring a great deal of popularity as an alternative "last-mile” technology to DSL and cable modems. Presently the 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, WLAN, WMAN and WAN. As the demand for data transmission with higher rates changed so is the focus on the deployment of wireless networks. Technologies that promise to supply higher data rates are attracting more and more vendors and operators towards them. One of the most promising candidates of such arising technologies is WiMAX. The word WiMAX is known as World Wide Interoperability for Micro Wave Access is the synonym given to the IEEE 802.16 standard, that specifies a frequency band in the range between 10 GHz to 66 GHz. Basically WiMAX is a wireless internet service that is capable of covering a wide geographical area by serving hundreds of users at a very low cost. It particularizes a metropolitan area networking protocol that not only provides a wireless alternative for cable, Digital Subscriber Line (DSL) and T1 level services for last mile broadband access but also provides a backhaul for 802.11 hotspots and due to its higher data rates WiMAX is also gaining interest in cellular sector as well [1]. Many researchers do suppose that WiMAX can move the wireless data transmission concept into a new dimension. There are essentially three limiting factors for transmitting high data rate over the wireless medium that mainly include multipath fading, delay spread and co-channel interference [2]. The published WiMAX standard (802.16d) [1]. characterize a MAC layer and five physical layers, each suitable for particular application and frequency range. Wireless MAN-OFDM is one of them [3]. The Wireless MAN-OFDM interface can be exceedingly 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 Inter-symbol 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 linger 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]. Adaptive Antenna System (AAS) 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 installed at the base station to reduce inter-cell interference and fading effects by providing either beam forming or diversity gains. When small spacing is adopted, the fading is highly correlated and

Beam forming 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. The objective of this work is to develop the physical layer of Fixed WiMAX (802.16 d) standard. The increase in use of Wireless Broadband Systems (WBS) has put promoters of WBS in a competitive race with their counter parts. It’s a well known fact that wireless systems are way ahead with their counter parts when it comes to deployment and ease of installation thus reaching places where one cannot even think of deploying a wired solution for broadband communication. However wireless systems have been unable to tackle bandwidth issues for the past many years and therefore remained unable to address QoS parameters until now. In past recent years considerable amount of research work has been conducted to improve the performance of the system in terms of increasing the capacity and range. One such technology that is proving to be very useful to cater these issues is “Smart Antenna Systems” (SAS) [6,7]. Smart Antenna System uses advanced signal processing techniques to construct the model of the channel. Using the knowledge of the channel, SAS uses beam forming techniques in order to steer or direct a radio beam towards desired users and null steering towards the interferers [8]. It works by adjusting the angles and width of the antenna radiation pattern. SAS consist of set or radiating elements capable of sending and receiving signals in such a way that radiated signals combine together to form a switch able 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 beam forming [8]. On the other hand Adaptive Array System acts in a different manner as compared to switched beam Antenna system. It works by keep a constant track of the mobile user by focusing a main beam towards the user and at the same time jamming the interfering signals by forming nulls in direction towards them. A brief comparison of these two approaches can be best observed from [8] which show beam forming lobes and nulls. It can be seen that for the Adaptive Array the main beam is towards users and nulls to interferer [8]. A BS can serve multiple subscriber stations with higher throughput by using AAS. For that space Division multiplex is used to separate (in space) multiple SSs that are transmitting and receiving at the same time over the same sub-channel. By using AAS, Interference can be severely reduced that is originated from the other Subscriber Stations or the multipath signals from the same SS by steering the nulls towards the desired interference [9]. An adaptive 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 [7]. This is just two of many used algorithms. DOA information is then fed into the weight upgrade algorithm to calculate the corresponding complex weights.

ITU Channel Models

This model can be used for simulations, design, and development and testing of technologies agreeable for fixed broadband wireless performances [11]. The parameters for the model were chosen based upon some statistical models. These channel models provide a variety of situations considered typical. Three user locations are considered: indoor, pedestrian and vehicular more information about this channel can be found in [11].

The Simulation Block Diagram

The Block diagram in Figure 1 represents the whole system model or signal chain at the baseband. The WiMAX -OFDM system is used for multicarrier modulation.

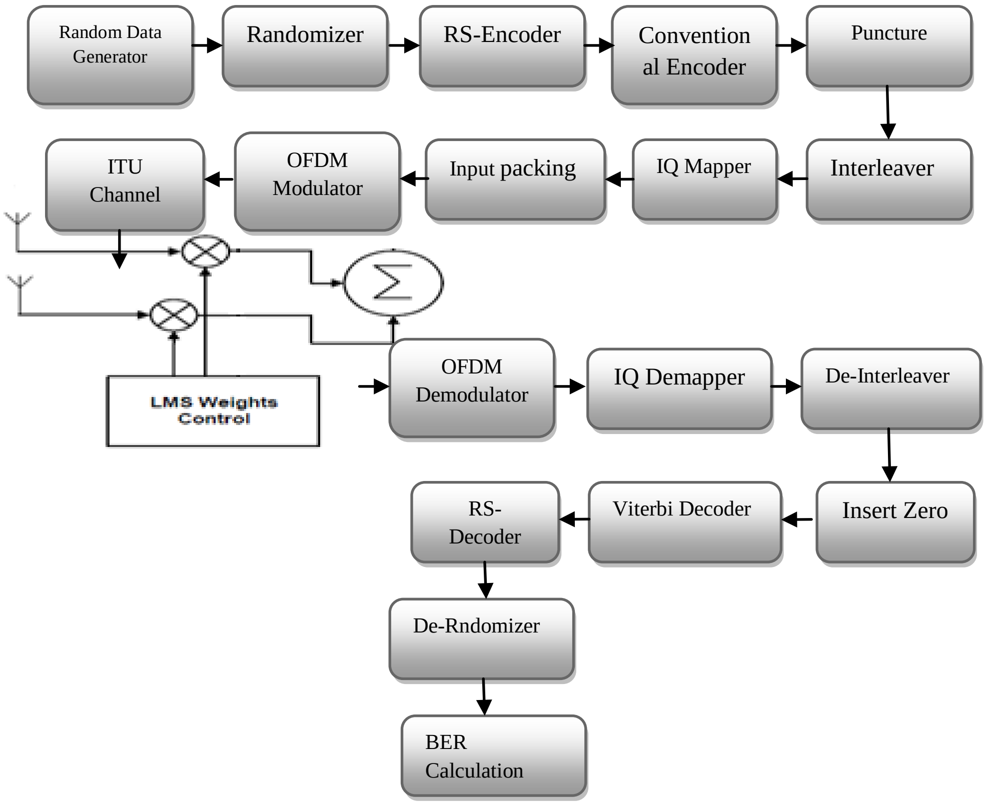

Figure (1) Simulation Block Diagram

The block diagram structure is divided into four main sections: transmitter, receiver, adaptive antenna array algorithm and channel. Data are generated from a random source and consist of a series of ones and zeros. Since transmission is conducted block-wise, when forward error correction (FEC) is applied, the size of the data generated depends on the block size used. These data are converted into lower rate sequences via serial to parallel conversion and randomized to avoid a long run of zeros or ones. The result is easier in carrier recovery at the receiver. The randomized data are encoded when the encoding process consists of a concatenation of an outer Reed-Solomon (RS) code. The implemented RS encoder is derived from a systematic RS Code using field generator GF (2^8 and an inner convolutional code (CC) as an FEC scheme. This means that the first data pass in block format passes through the RS encoder and goes across the convolutional encoder. It is a flexible coding process because of the puncturing of the signal and allows different coding rates. The last part of the encoder is a process of interleaving to obviate long error bursts using tail biting CCs with different coding rates (puncturing of codes is provided in the standard) [2].

In the end, interleaving is followed using a two-stage permutation. The first stage aims to avoid the mapping of adjacent coded bits on adjacent subcarriers, while the second ensures that adjacent coded bits are mapped alternately onto relatively significant bits of the constellation, thereby avoiding long runs of lowly reliable bits. The training frame (pilot subcarriers frame) is forced and sent prior to the information frame. The pilot frame is used to create channel estimation to compensate for the channel effects on the signal. The coded bits are then mapped to form symbols. The modulation scheme used is the QPSK coding rate (1/2) with gray coding in the constellation map. This process converts data to the corresponding value of constellation, which is a complex word (with a real and an imaginary part). The bandwidth (B =(1/T_s)) is divided into N equally spaced subcarriers at frequencies (kΔf), k=0,1,2,...,N-1 with Δf=B/N and, T_s , the sampling interval. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, QPSK with constellation C_{QPSK} is assumed for the symbol mapping. The space-time block-coded code is transmitted from the two antennas simultaneously during the first symbol period (*l*=1) for each $k\epsilon\kappa$. During the second symbol period, (*l*=2) are transmitted from the two antennas for each $k\epsilon\kappa$. The set $\kappa \cong \kappa\{(N - N_c/2), \dots, (N + N_c/2) - 1\}$is the set of data-carrying sub-carrier indices, N_c and is the number of sub-carriers carrying data. *N* is the multicarrier size. Consequently, the number of virtual carriers is N-N_c. We assume that half of the virtual carriers are on both ends of the spectral band [1]. Which consists of the OFDM modulator and demodulator. The training frame (pilot sub-carriers frame) are inserted and sent prior to the information frame. This pilot frame is used to provide channel estimation, which is used to compensate for the channel effects on the signal. The spread data symbol is modulate on the orthogonal carriers, an N-point Inverse Fourier Transform IFFT is used, as in conventional OFDM. Zeros are inserted in some bins of the IFFT to compress the transmitted spectrum and reduce the adjacent carriers' interference. The appended zeros to some sub-carriers limit the bandwidth of the system, while the system without the zeros pad has a spectrum that is spread in frequency. The last case is unacceptable in communication systems, since one limitation of communication systems is the width of bandwidth. The addition of zeros to some sub-carriers means not all the sub-carriers are used; only the subset (N_c) of total subcarriers (N_F) is used. Therefore, the number of bits in OFDM symbol is equal to $\log_2$ (M)* N_c. Orthogonality between carriers is normally destroyed when the transmitted signal is passed through a dispersive channel. When this occurs, the inverse transformation at the receiver cannot recover the data that was transmitted perfectly. Energy from one sub-channel leaks into others, leading to interference. However, it is possible to rescue orthogonality by introducing a cyclic prefix (CP). This CP consists of the final *v* samples of the original *K* samples to be transmitted, prefixed to the transmitted symbol. The length *v* is determined by the channel's impulse response and is selected to minimize ISI. If the impulse response of the channel has a length of less than or equal to *v*, the CP is sufficient to eliminate ISI and ICI. The Fourier based OFDM utilize the complex exponential bases functions. If the number of sub-channels is sufficiently large, the channel power spectral density can be assumed virtually flat within each sub-channel. In these kinds of channels, multicarrier modulation has long been familiar to be optimum when the number of sub-channels is large. The size of sub-channels needed t approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. The computation of FFT and IFFT for 256 point. After which, the data changed from parallel to serial are fed to the channel WiMAX model. In This section will introduce the system model of an N subcarrier OFDM system with transmit antenna and MR receive antennas in the presence of transmit antenna and path correlations. The worst performance of the ITU channel is due to multipath effect, delay spread and Doppler effects. Although the impact of the delay spread and the Doppler effect is low so the major degradation in the performance is due to the multipath effects. There are various methods to reduce the multipath effect. However in this model it is done by implementing AAS. For that adaptive beam forming algorithm such as Least Mean Square (LMS), Recursive Least Squares (RLS) or Sample Matrix Inversion (SMI) can be used [12,7]. The calculated weight is then multiplied by the signal from the antenna array and required radiation pattern is formed. The block diagram of an antenna array system. So a beam is steered in the direction of the desired signal and the user is tracked as it moves while placing nulls at interfering signal directions by constantly updating the complex weights by using any of the beam forming algorithms. AAS has the feature that requires only multiple antennas at the BS and thus putting whole burden on the BS. As AAS is known to reduce inter-cell interference and multipath fading by providing beam forming. So multiple antennas are installed at the receiver and performance is investigated in the presence of receiver antennas.

Simulation Results

In this section the simulation results are shown using a single antenna at the transmitter and two antennas at the receiver, the reference model specifies a number of parameters that can be found in Table (1).

Table (1) System parameters

Number of receiver antenna	2
Spacing between receiver antennas	$\lambda/2$
Fading correlations	$\rho=0.5$
Number of sub-carriers	256
Number of FFT points	256
Modulation type	QPSK
Coding rate	1/2
Cyclic prefix	1/8
Channel bandwidth B	3.5MHz
Carrier frequency fc	2.3GHz
N cpc (Number of transmitted bits per symbol)	4
N cbps(number of coded bits per the specified allocation)	768
Number of data bits transmitted	10^6

In this section the simulation of the proposed adaptive antenna array system in WiMAX IEEE802.16d and comparing without adaptive antenna array system is executed, beside the BER performance of the system regarded in ITU channel models

AWGN Channel Performance

In this part, the results taken were emboldening. adaptive antenna array system (AAS) and without adaptive antenna array system (AAS) it can be seen that for BER=10^{-3} the SNR required for AAS is about 5.64 dB while in without AAS the SNR about 7.55dB From Figure 2 it is found that the with AAS outperforms significantly other system for this channel model.

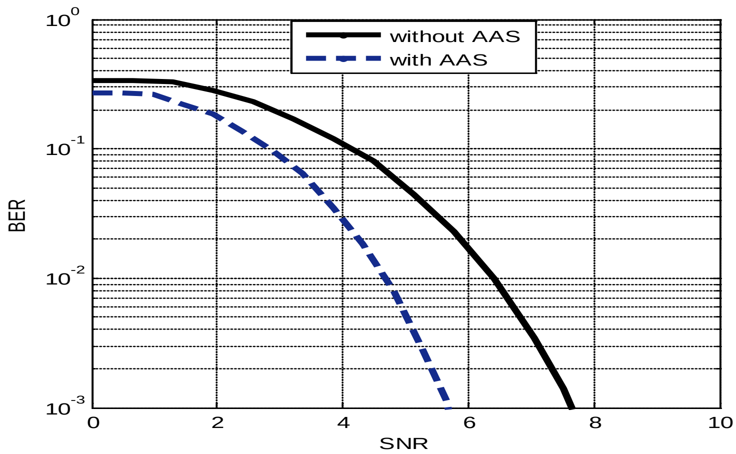

Figure (2) BER performance of WiMAX IEEE802.16d with AAS in AWGN channel

AWGN plus Multipath Channel Performance

In this general channel scenario, in the next sections the relevant results are discussed.

Indoor Channel A

In this simulation profile some influential results were obtained. With AAS and without AAS it can be seen that for BER=10^{-3} the SNR required for AAS is about 10.34 dB while in without AAS the SNR about 12.25dB from Figure 3 it is found that the using AAS outperforms significantly other system for this channel model. It can be concluded that the With AAS is more significant than the other systems in this channel that have been assumed.

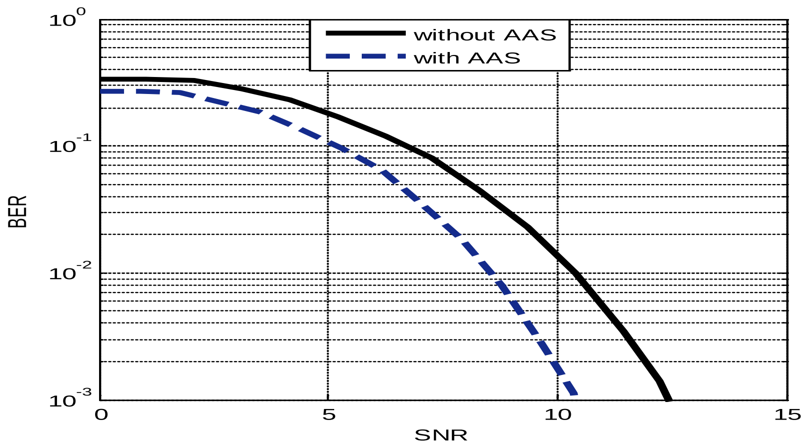

Figure (3) BER performance of WiMAX IEEE802.16d with AAS in AWGN plus Multipath Indoor A

Indoor Channel B

In this simulation profile some significant results were taken. Remembrance that the profile of channel B has a bigger time delay spread than the profile of channel A, more than twice to be more quantitative. This factor plays a big role in the systems' performances, the results are depicted in Figure 4 it can be seen that for BER=10^{-3} the SNR required for With AAS is about 20.12 dB, while in without using AAS the SNR about 24 dB, From Figure 4 it is found that the using AAS outperforms significantly than without using AAS for this channel model.

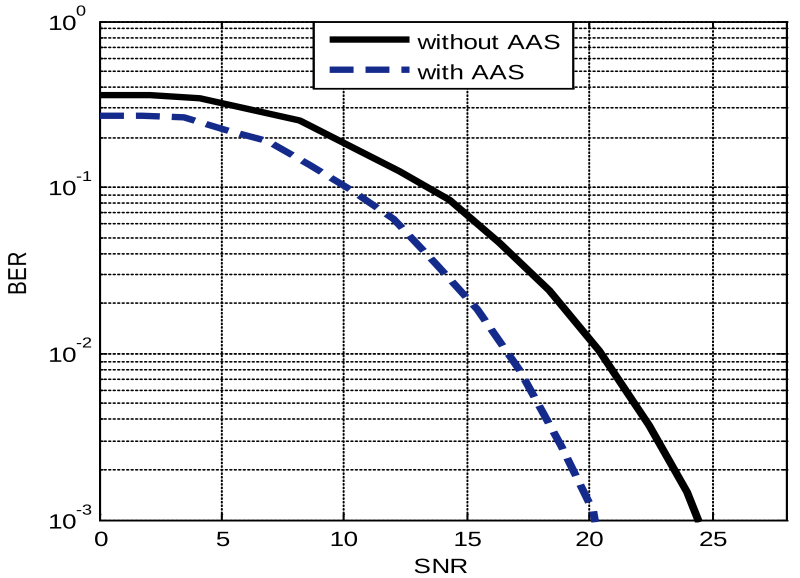

Figure (4) BER performance of WiMAX IEEE802.16d with AAS in AWGN plus Multipath Indoor B

Pedestrian Channel A

In the pedestrian profile, two different situations were regarded: a moving and a stationary person. These results are depicted in figure 5 and 6. Figure 5 represents the case of the stationary person. It can be seen that for BER= 10^{-3} the SNR required when using AAS was approximately 11.28 dB also for without using AAS was approximately 14.3dB. Figure 6 presents the case of a moving person. It can also be seen that for BER=10^{-3} the SNR required when using AAS is approximately 24.91 dB and when without using AAS is approximately 28.4 dB. Figures 5 and 6 clearly illustrate that when using AAS significantly outperforms other system for this channel model.

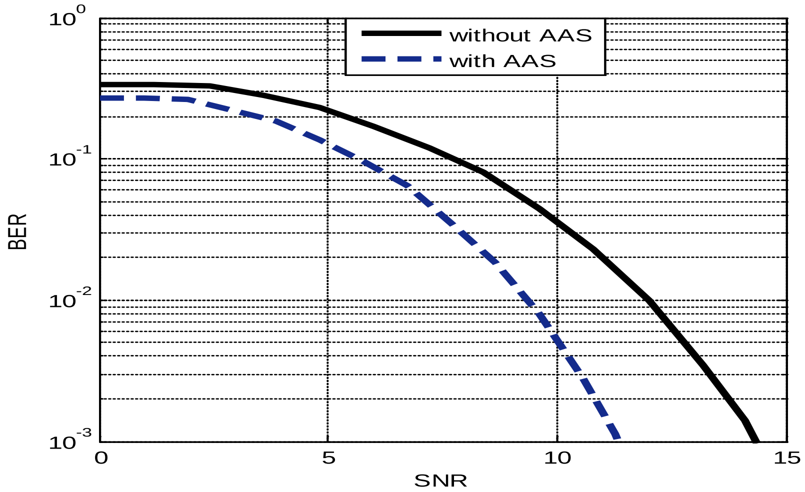

Figure (5)BER performance of WiMAX IEEE802.16d with AAS in AWGN & Multipath Stopped Pedestrian A

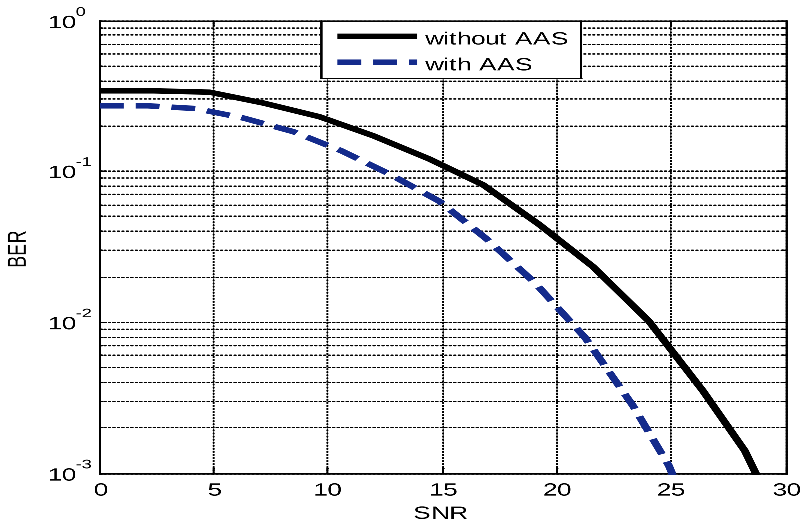

Figure (6) BER performance of WiMAX IEEE802.16d with AAS in AWGN & Multipath Active Pedestrian A

Pedestrian Channel B

Using such as methodology as in the previous section, simulations for both active and stationary pedestrians were carried out. The results for a situation of the stationary Pedestrian B channels are depicted in Figure 7, which shows that for BER=10^{-3}, the SNR required using AAS is approximately 31.02 dB, for without using AAS is approximately 35.75 dB. The results for the a situation of the active pedestrians are depicted in Figure 8, also when without using AAS which shows that for BER=10^{-3}, the SNR required when using AAS is approximately 36.96 dB, for without using AAS is approximately 42 dB, Figures7 and 8 clearly show that the using AAS significantly improved the other systems for this channel model.

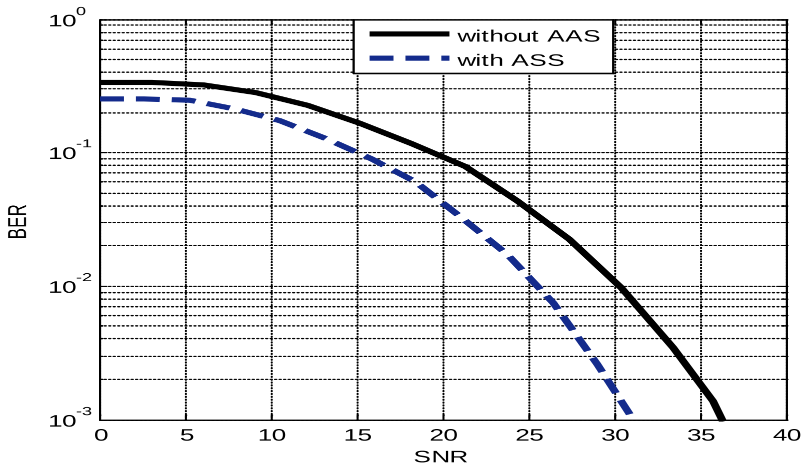

Figure (7) BER performance of WiMAX IEEE802.16d with AAS in AWGN & Multipath Stopped Pedestrian B

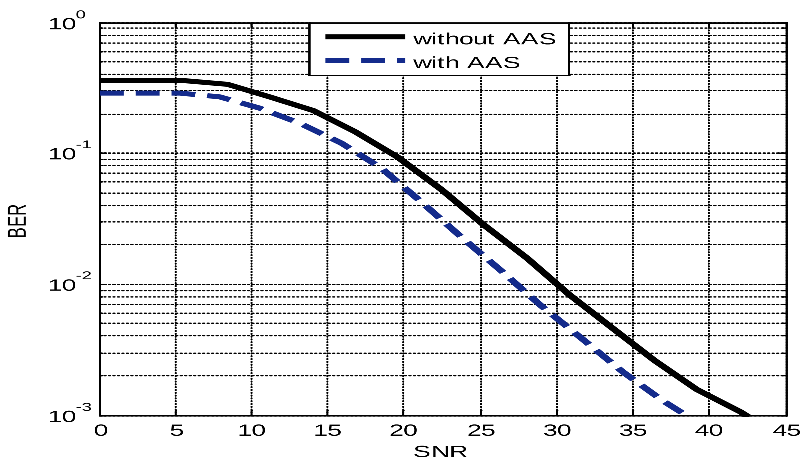

Figure (8)BER performance of WiMAX IEEE802.16d with AAS in AWGN & Multipath Active Pedestrian B

CONCLUSION

In this paper, the WiMAX (IEEE 802.16d) with AAS structure was proposed and tested. These tests were carried out to confirm its successful operation and its possibility of implementation. It can be concluded that this structure accomplishes much lower bit error rates. In AWGN, and other channels the WiMAX (IEEE 802.16d) with AAS outperform than WiMAX (IEEE 802.16d) without using AAS therefore, this structure can be considered as an alternative to the conventional WiMAX (IEEE 802.16d) structure. It can be concluded from the results obtained, that S/N measure can be successfully increased using the proposed AAS designed method. The key contribution of this paper was the execution of the IEEE 802.16d PHY layer based the AAS structure. Simulations provided proved that proposed design accomplishes much lower and it can be used at high transmission rates.

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