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Design and Performance Evaluation of Adaptive Antenna System in CDMA Transceiver Based on Fourier Signals in SUI Channels

Lecturer. Dr. Mohammed Aboud Kadhim
makaboud@gmail.com

Lecturer. Dr. Faeza Abbas Abed
Dr.faeza@yahoo.com

Asst. Lecturer. Oday Mohammed Abdulwahhab
oday.m1974@gmail.com

Foundation of Technical Education, Institute of Technology Baghdad, Iraq

Abstract

The Code division multiple access (CDMA) and adaptive antenna system(AAS)system are two approaches that show realpromise for increasing spectrum efficiency. In this research, we investigate the performance of AAS in the CDMA transceiver. The CDMA transceiver has been developed to adaptively correct antenna impedance mismatch.AAS has been deployed at the receiver module to reduce the fading effects caused by proposedStanford University Interim(SUI)channels model. SUI channel model proposes a set of six empirical time-dispersive channels for three typical terrain type'sAAS uses various beamforming 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. Least Mean Square (LMS) algorithm is used. It has been proved through Matlab simulations that the performance of the system significantly improves by AAS in SUI channel model has been proposed for simulations, design, development and testing of technologies suitable for CDMA transceiver. The performance of the system more increases by increasing the number of antennas at receiver.

Keyword: OFDM, CDMA, Antenna, adaptive, Beamforming, AAS.

تصميم وأداء النظام الهوائي المتكيف لجهاز الإرسال والاستقبال لتعدد الوصول باستخدام تقسيم الشفرة(CDMA) المبني على إشارات فورير (FFT) في قنوات جامعة ستانفورد المؤقتة (SUI)

م.د. محمد عبود كاظم   م.د. فائزة عباس عبد   م.م. عدي محمد عبد الوهاب
هيئة التعليم التقني- معهد التكنولوجيا / بغداد- العراق

الخلاصة

تعدد الوصول باستخدام تقسيم الشفرة (CDMA)ونظام الهوائي المتكيف طريقتان تتعهدان لزيادة كفاءة الطيف. في هذا البحث تحقق أداء نظام الهوائي المتكيف في جهاز الإرسال والاستلام لتعدد الوصول باستخدام تقسيم الشفرة هذا الجهاز تم تطويره لتصحيح عدم الموائمة التي تحدث في مقاومة الهوائي. نظام الهوائي المتكيف تم نشرة في مرحلة الاستقبال للحد من الآثار الناجمة عن تلاشي الإشارات في قنوات التلاشي المقترحة (SUI)، هذه القنوات نموذج مفترض لثلاث تضاريس نموذجية. نظام تكيف الهوائي(AAS) يستخدم مختلف التقنيات لتكوين الشعاع وتركيزه بين محطة ومحطة وأخرى. إي بين جهاز الإرسال (SS) وجهاز الاستقبال(BS) ونظام تكيف الهوائيAAS يركب في جهاز الاستقبال لاستلام الشعاع الرئيسي عبر إشارة LOS المطلوبة واستخدام التشكيل ألحزمي للإشارات 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 الإشارات في اتجاه المستخدم المطلوب. إن أداء النظام يتحسن أكثر كلما زاد عدد الهوائيات في جهة الاستلام.

1. Introduction

The system spectral efficiency can be improved by radio resource management techniques, resulting in that a higher number of simultaneous calls and higher data rates can be achieved without adding more radio spectrum or more base station sites. Most efficient solutions at the physical layer are demonstrated in cellular systems using spread spectrum Code Division MultiplexAccess (CDMA), and indoor Wireless Local Area Networks (WLAN) using Orthogonal Frequency Division Multiplexing (OFDM). Both techniques use temporal signal processing to mitigate the Inter-Symbol Interference (ISI) introduced by wideband frequency selective fading channel. Recent research on Multiple Input Multiple-Output (MIMO) systems [1] claims that spectral efficiency can be improved by combining temporal processing with spatial processing that exploits spatial dimension of the wireless channel. Such space-time processing operates with multiple Transmit/Receive (Tx/Rx) antennas and improves the link capacity by exploiting diversity and multiplexing gain [2]. It also reduces the Co-Channel Interference (CCI) and furthermitigates the ISI by spatial filtering. Foschini has shown that capacity grows linearly with the number of antennas in narrow-band flat-fading channels [3]. This gain is attributed tospatial multiplexing. However, in wideband systems, the capacity gain due to combined time and spatial processing depends not only on the frequency selectivity of wideb and MIMO channel, but also on the relationship, sequence, and implementation of signal processing algorithms used for space-time processing. 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 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 CDMA 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 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 Line of Sight(LOS) signal from the multipath signals and nulls are formed at the interfering signals.

The objective of this paper is to develop the physical layer of CDMA standard by uses adaptive antenna array at the receiver tocombat multi-path channel. 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 Quality of service (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 beamforming 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 beamforming [8].On the other hand AAS 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 beamforming 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.

2. SUI Channel Models

This model can be used for simulations, design, and evolvement and testing of technologies agreeable for fixed broadband wireless performances .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 [10].

3. The Simulation Block Diagram

The new proposed structures for the CDMA-OFDM system with AAS will be studied in this paper. The Block diagram in **Figure (1)** represents the whole system model or signal chain at the base band. The CDMA-OFDM based Fourier signals system is used for multicarrier modulation.

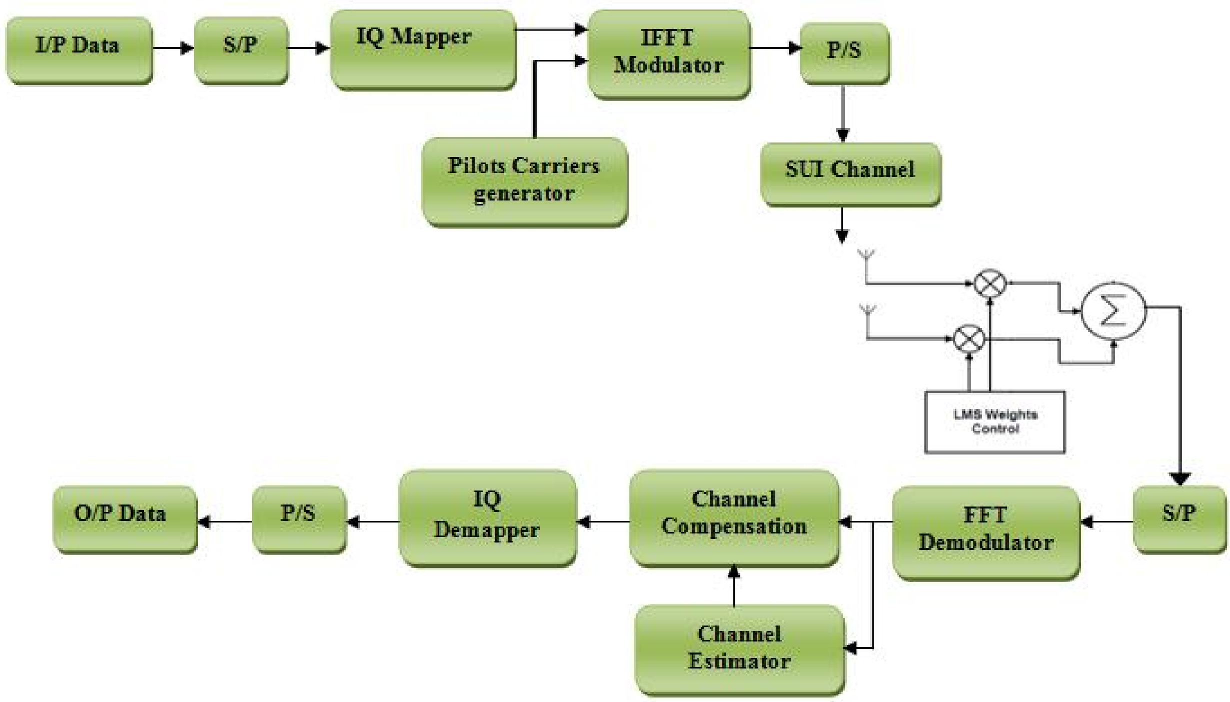

Fig .(1) Simulation Block Diagram

The block diagram structure is divided into four main sections: transmitter, receiver, adaptive antenna array algorithm and channel. The transmitter accepts data, and converts it into lower rate sequences via serial to parallel conversion, these lower rate sequences are mapped to give sequences of channel symbols. This process will convert data to corresponding value of M-ary constellation which is complex word, i.e. real and imaginary part. The bandwidth (B =(1/T_S)) is divided into Nequally 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, 16 QAM with constellation C_{QAM} is assumed for the symbol mapping. 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 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. 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 SUI models. In This section will introduce the system model of an Nsubcarrier OFDM system with transmit antenna and MR receive antennas in the presence of transmit antenna and path correlations. The worst performance of the SUI channels 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 beamforming algorithm such as Least Mean Square (LMS), be used [7,11].The calculated weight is then multiplied by the signal from the antenna array and required radiation pattern is formed. 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 beamforming 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 beamforming. So multiple antennas are installed at the receiver and performance is investigated in the presence of receiver antennas. The receiver performs the same operations as the transmitter, but in a reverse order. In addition, the receiver includes operations for synchronization and compensation for the destructive SUI channels.

4. Simulation Results

In this section the simulation of the proposed adaptive antenna array system in CDMA and comparing with conventional, without adaptive antenna array system is executed, beside the BER performance of the system regarded in SUI channel models.

Table .(1) System parameters

Number of transmitter antenna	1
Number of receiver antenna	2
Spacing between receiver antennas	λ/2
Fading correlations	ρ_R=0.5
Channels	SUI
Cyclic prefix	1/8
Number of FFTpoints	256
Modulation type	16 QAM

4.1 Performance of SUI-1 channel:

In this scenario, the results obtained with AAS and without AAS it can be seen that for BER=10^{-3} the SNR required for AAS is about 15.6 dB while in without AAS the SNR about 17.5 dB from **Figure (2**) 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.

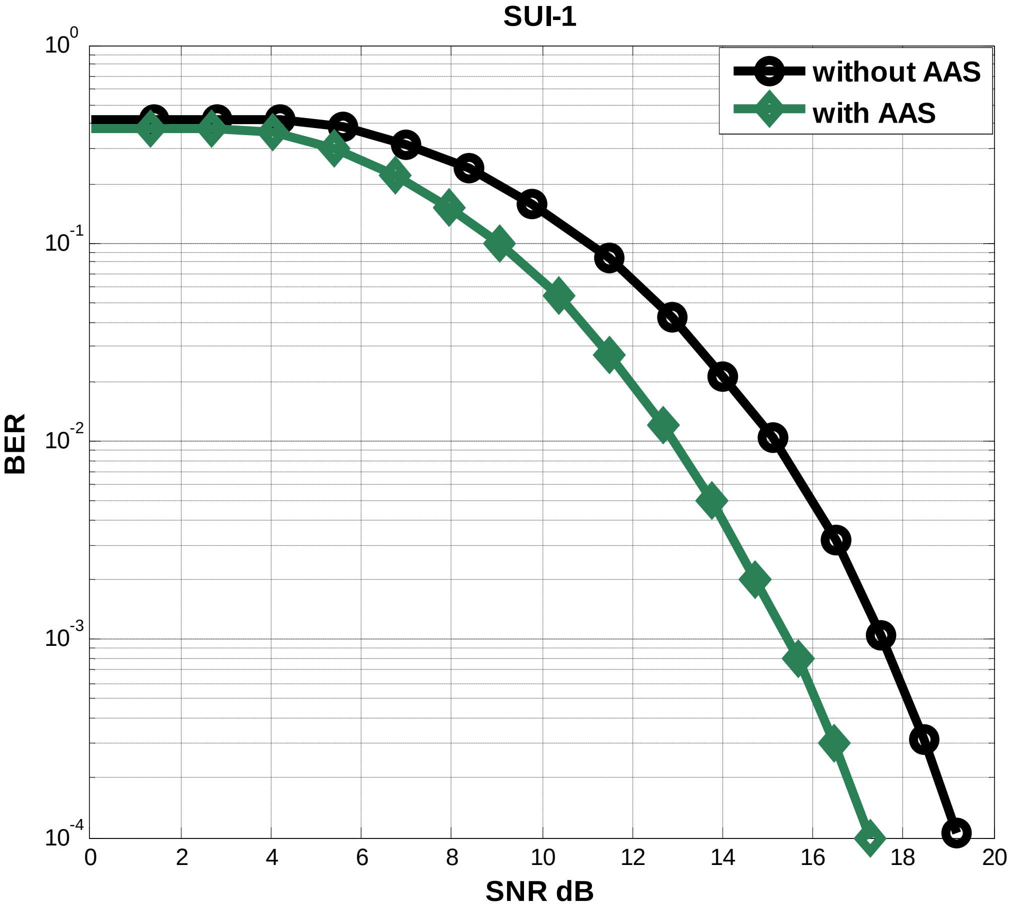

Fig .(2) BER performance of proposed model in SUI-1 channel

4.2 Performance of SUI-2 channel:

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 the system with AAS is about 20 dB while in without AAS the SNR about 22.5dB from **Figure (3)** it is found that the system with AAS outperforms significantly other system for this channel model.

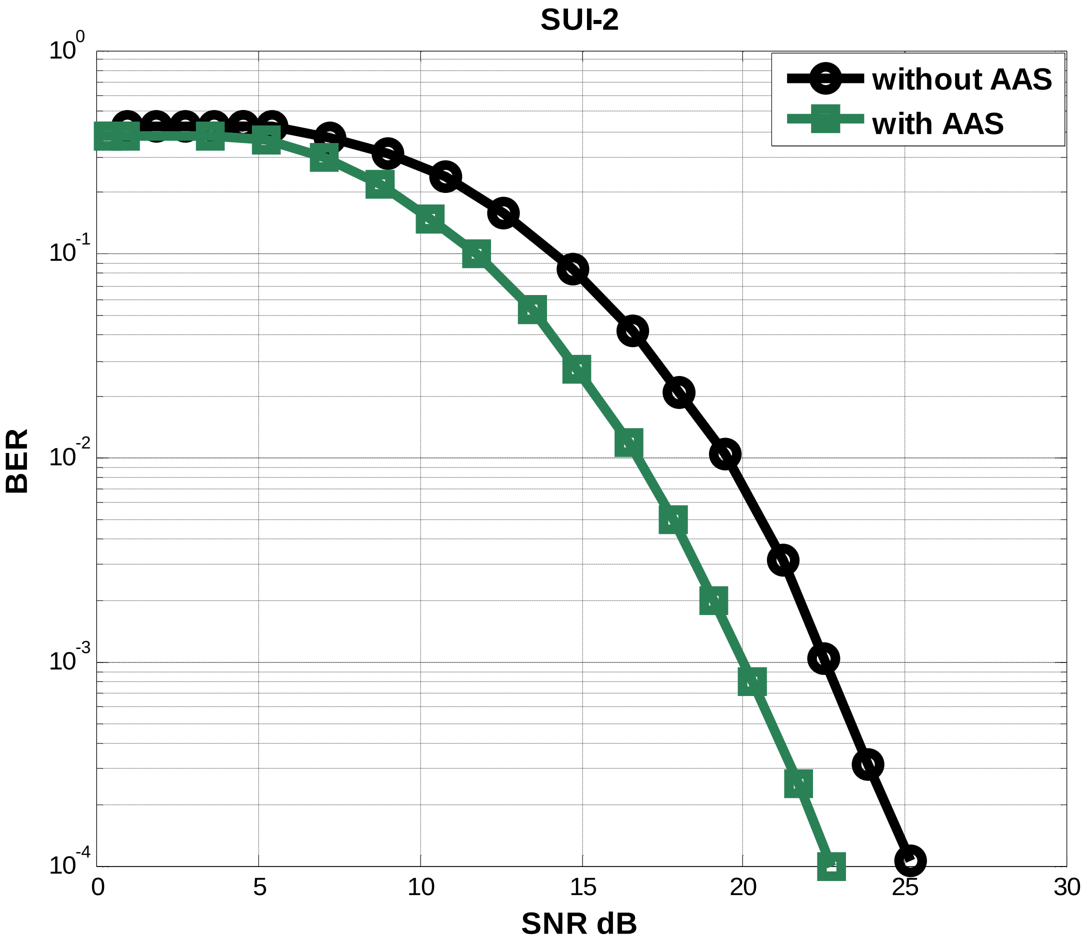

Fig .(3) BER performance of proposed model in SUI-2 channel

4.3 Performance of SUI-3 channel:

In the SUI-3 channel, the results are depicted in **Figure (4)** it can be seen that for BER=10^{-3} the SNR required for the CDMA model with AAS is about 23 dB, while in without AAS the SNR about 25dB, From **Figure (4)** it is found that the CDMA with AAS outperforms significantly than other systems for this channel model.

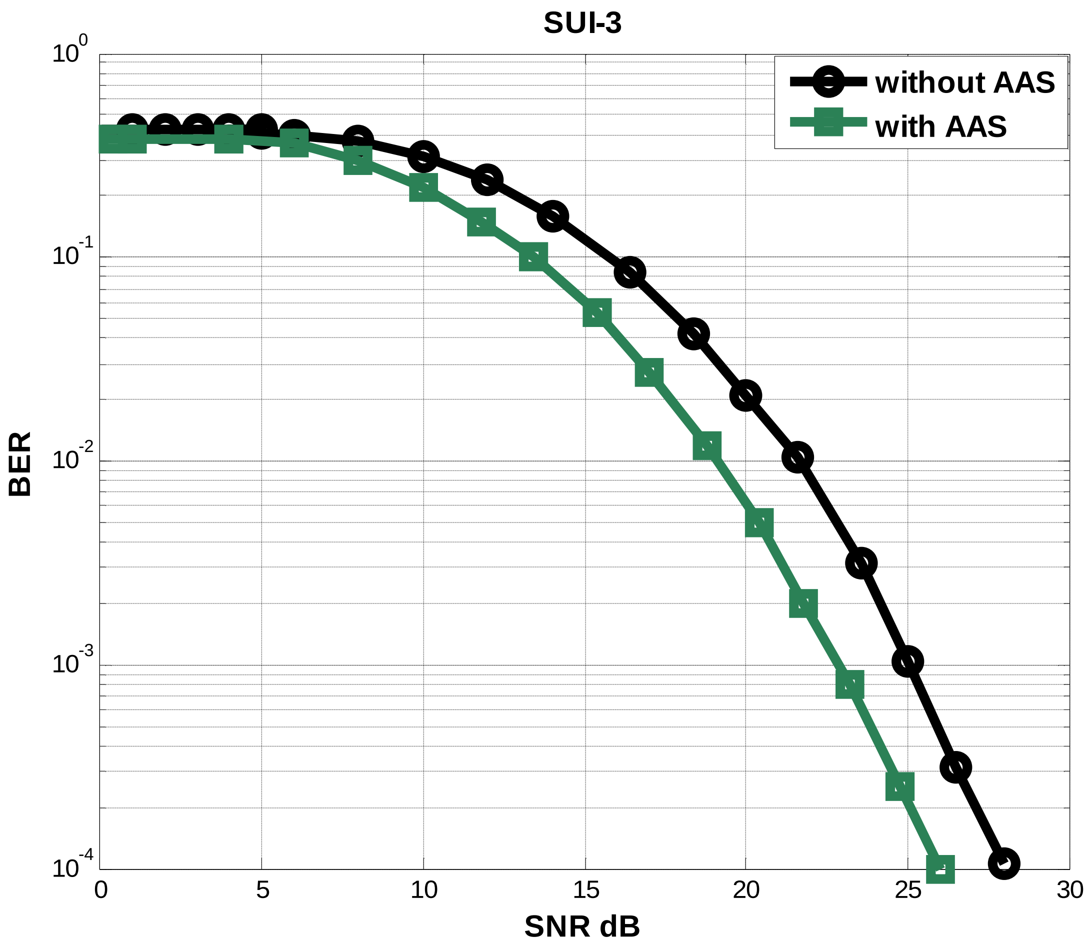

Fig .(4) BER performance of proposed model in SUI-3channel

4.4 Performance of SUI-4 channel:

Using similar methodology as in the previous section, simulations for SUI-4 channel The result depicted in Figure 5 it can be seen that for BER=10^{-3} the SNR required for the system with AAS is about 26.5 dB, while in without AAS the SNR about 30 dB. Also from **Figure (5)** it is found that the CDMA with AAS outperforms significantly than other systems for this channel model.

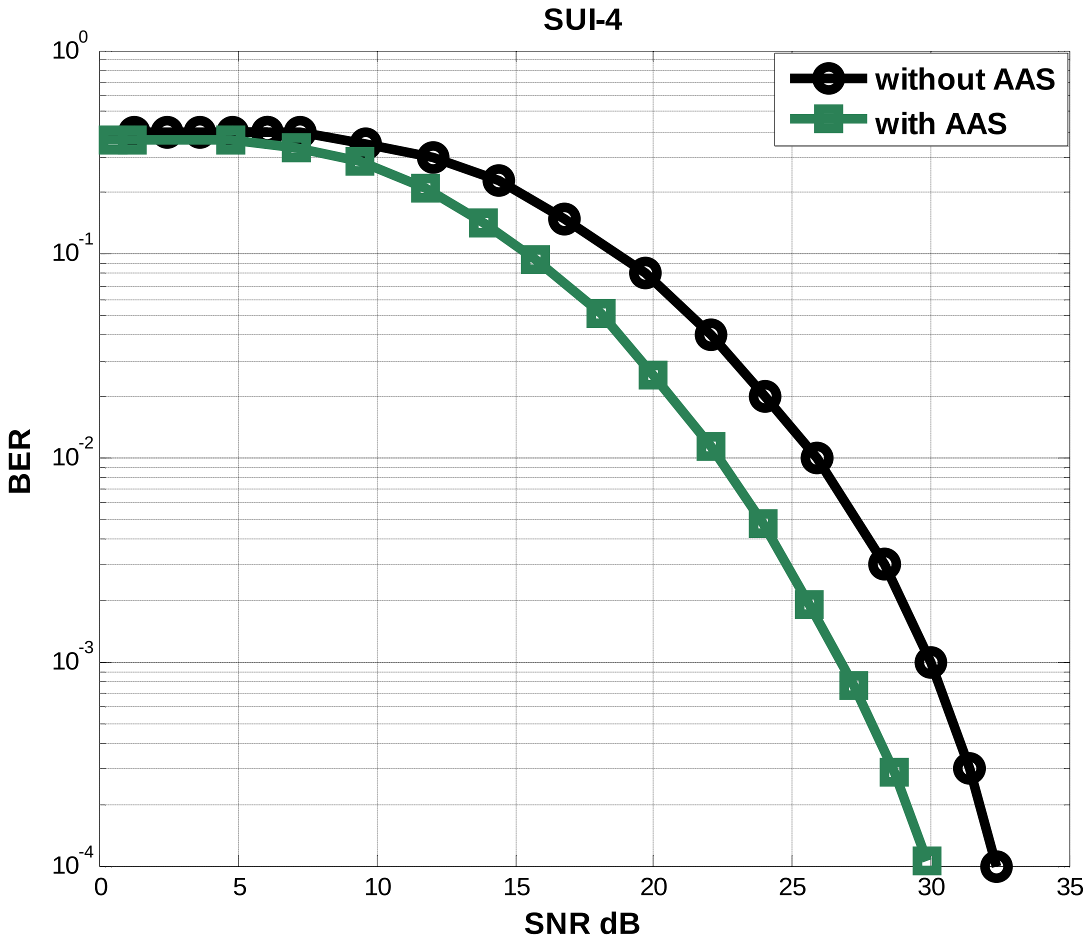

Fig .(5) BER performance of proposed model in SUI-4channel

4.5 Performance of SUI-5 channel:

In this model, the results obtained were encouraging. The system With AAS and without AAS it can be seen that for BER=10^{-3} the SNR required for with AAS is about 31.2 dB while in without AAS the SNR about 35.63 dB From **Figure (6)** , it is found that the CDMA with AAS is best than other system for this channel model.

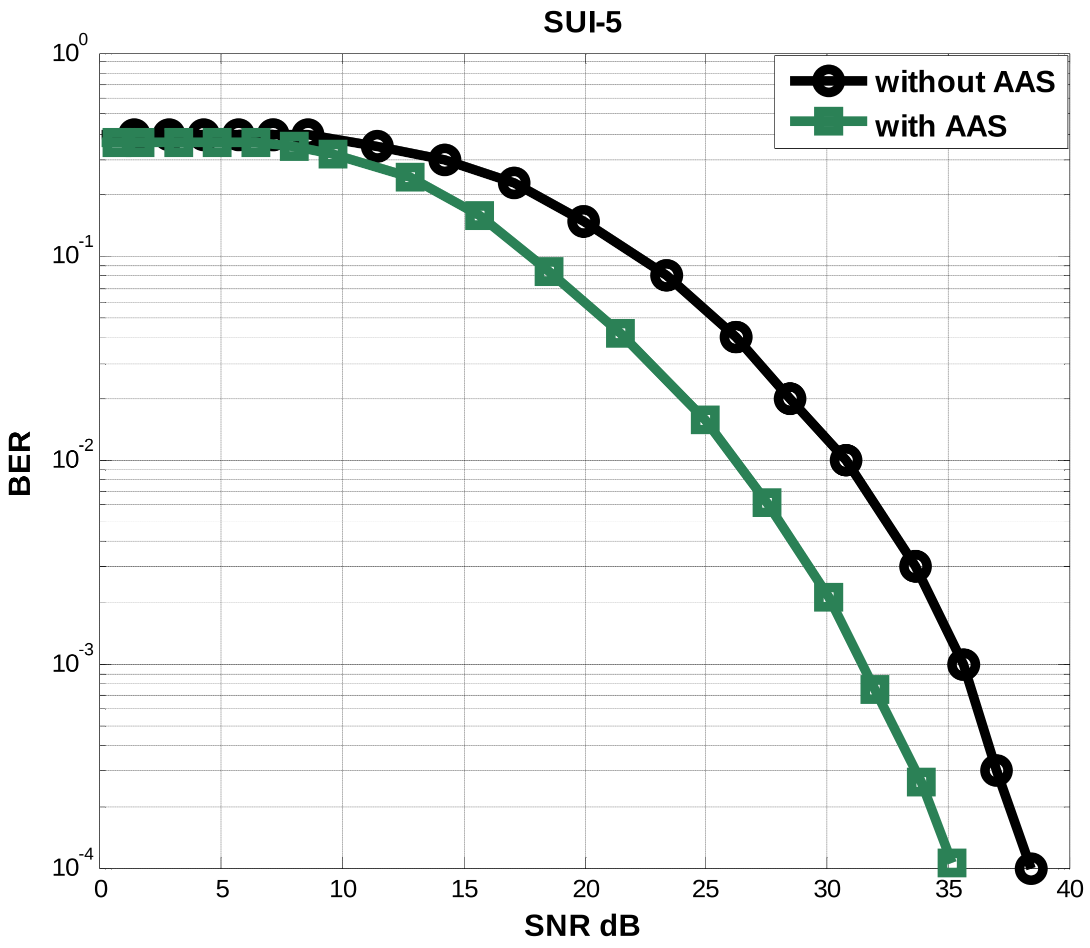

Fig .(6) BER performance of proposed model in SUI-5channel

4.6 Performance of SUI-6 channel:

In this state, the results obtained were hopeful. With AAS and without AAS it can be seen that for BER=10^{-3} the SNR required for the system with AAS is about 41 dB while in without AAS the SNR about 46.25 dB From **Figure (7)** it is found that the CDMA with AAS is better than other system for this channel model

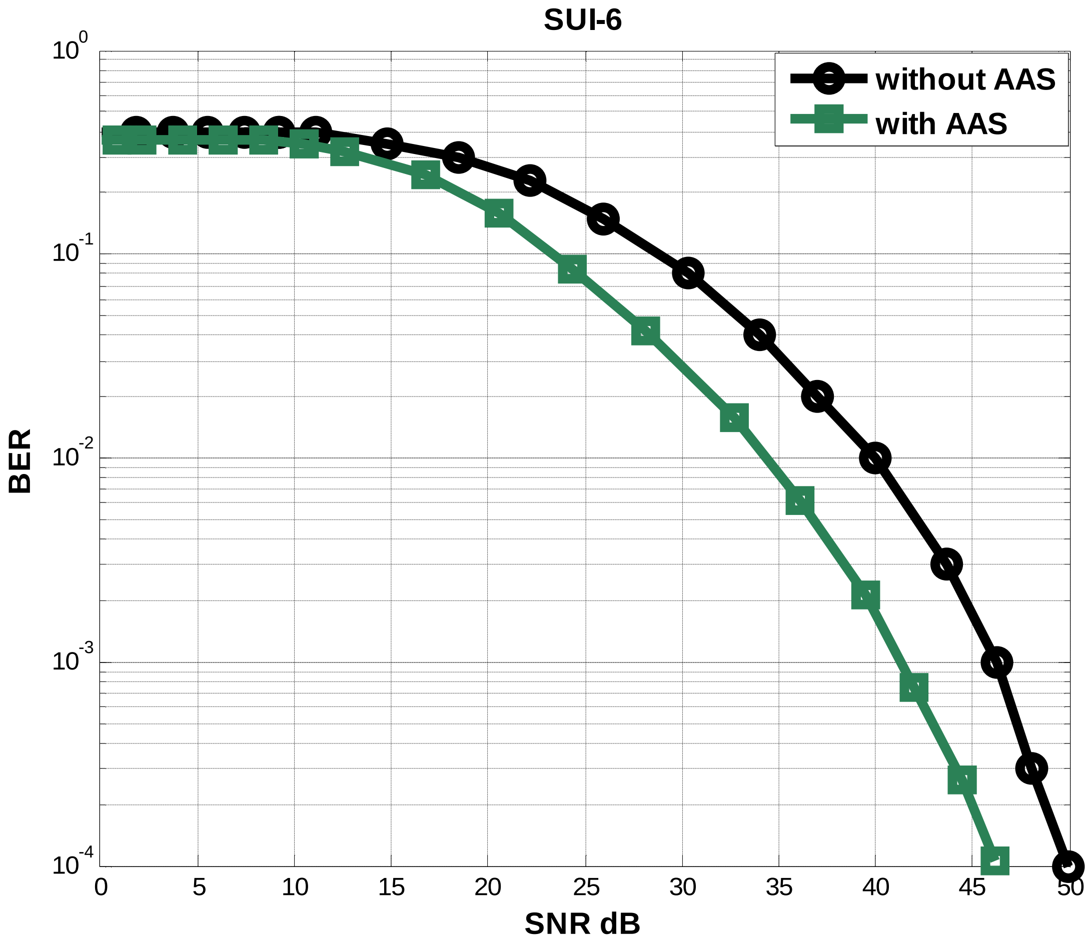

Fig .(7) BER performance of proposed model in SUI-6 channel

Table .(2) Comparison between results

Channel for BER= 10^{-3}	SUI-1 dB	SUI-2 dB	SUI-3 dB	SUI-4 dB	SUI-5 dB	SUI-6 dB
Without AAS	17.5	22.5	25	30	35.63	46.25
With AAS	15.6	20	23	26.5	31.2	41

A number of important results can be taken from Table (2); In this simulation, in most scenarios, the CDMA system with AAS was better than the CDMA system without AAS, user-channel characteristics under which wireless communications is tested or used have important impact on the systems overall performance. It became clear that SUI channels with larger delay spread are a bigger challenge to any system. The AAS system proved its effectiveness in combating the multipath effect on the SUI fading channels.

5. Conclusion:

In this paper, the CDMA 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 all SUI channels the CDMA with AAS outperform than without using AAS therefore, this structure can be considered as an alternative to the conventional CDMA 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 CDMA PHY layerbased 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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