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Implementation of Adaptive Antenna System in CDMA Transceivers Based Multiwavelet Signals

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Abstract

In this paper, we optimization of the Code division multiple access **(**CDMA**)** transceiver by using Adaptive Antenna System (AAS) at the receiver it has been shown that receivers based on successive AAS provide an effective reduction of multiuser access interference at an affordable complexity. The Least Mean Square (LMS) algorithm is used at the receiver to direct the main beam towards the desired LOS signal and nulls to the multipath signals. It has been proved through this idea by MATLAB simulations that the performance of the system significantly improves by AAS, where beamforming is implemented in the direction of desired user. The performance of the system can more improve by increasing the number of antennas at receiver.

Keywords: OFDM, DMWT, CDMA, LMS, Beamforming

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1. Introduction

High data rate in wireless communication devices use advanced signal processing techniques in order to attain spectrally efficient communication links in the limited radio spectrum. mainly efficient solutions at the physical layer are demonstrated in cellular systems using spread spectrum code division multiplex access (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. New research on multiple input multiple-output (MIMO) systems [1] claims that spectral efficiency can be enhanced 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 more mitigates 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 to spatial multiplexing. However, in wideband systems, the capacity gain due to combined time and spatial processing depends not only on the frequency selectivity of wideband MIMO channel, but also on the relationship, sequence, and accomplishment 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 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 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. 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 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 to combat 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 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 [9]. 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 [9] 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 [9].

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 [10]. This is just two of many used algorithms. DOA information is then fed into the weight upgrade algorithm to calculate the corresponding complex weights. In this paper considers Least Mean Square (LMS) algorithm to subsequently modify the AAS performance. Widrow (1971) proposed the least mean squares (LMS) algorithm, which has been extensively applied in adaptive signal processing and adaptive control. The LMS algorithm is based on the minimum mean squares error. On the basis of the total least mean squares error or the minimum Raleigh quotient, we propose the total least mean squares (TLMS) algorithm more information about(LMS) algorithm in [6,11]. The corresponding filter is used to cancel multipath signals caused by interference contained reserving signal.

2. The Simulation Block Diagram

The new proposed structures for the CDMA-OFDM system based on discrete multiwavelet transform (DMWT) 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 multiwavelet signals system is used for multicarrier modulation.

The block diagram structure is divided into four main sections: transmitter, receiver, adaptive antenna array algorithm and SUI 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 N equally spaced subcarriers at frequencies ($k\Delta f$), $k=0,1,2,...,N-1$ with $\Delta f = B/N$ 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. N_c and is the number of sub-carriers carrying data. *N* is the multicarrier size. Consequently, the number of virtual carriers is $N\text{-}N_c$. 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 create channel estimation, which is used to compensate for the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse multi-wavelet transform IDMWT is used, as in conventional OFDM. Zeros are inserted in some bins of the IDMWT to compress the transmitted spectrum and reduce the adjacent carriers' interference. The added 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 chosen 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 efficiency of the transceiver is reduced by a factor of $\frac{K}{K+V}$; thus, it is desirable to make the *v* as small or *K* as large as possible. Therefore, the drawbacks of the CP are the loss of data throughput as precious bandwidth is wasted on repeated data. For this reason, finding another structure for FFT-OFDM as DWT-OFDM to mitigate these drawbacks is necessary. The Fourier based OFDM uses the complex exponential bases functions and it's replaced by orthonormal wavelets in order to reduce the level of interference. It is found that the Haar-based orthonormal wavelets are capable of reducing the ISI and ICI, which are caused by the loss in orthogonality between the carriers. In Multi-wavelet setting, GHM multi-scaling and multi-wavelet function coefficients are 2×2 matrices, and during transformation step they must multiply vectors (instead of scalars) [12]. This means that multi-filter bank needs 2 input rows. The aim of preprocessing is to associate the given scalar input signal of length N to a sequence of length-2 vectors in order to start the analysis algorithm, and to reduce the noise effects. In the one dimensional signals the "repeated row" scheme is convenient and powerful to implement. 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 types of channels, multicarrier modulation has long been known to be optimum when the number of sub-channels is large. The size of sub-channels required t approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. The computation of DMWT and IDMWT for 256 point as in [13]. After this, the data converted from the parallel to the serial form are fed to the SUI channels more information about SUI channels in [14]. 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 SUI 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 beamforming algorithm such as Least Mean Square (LMS), used [6,11]. 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 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, multiwavelet OFDM includes operations for synchronization and compensation for the destructive SUI channels.

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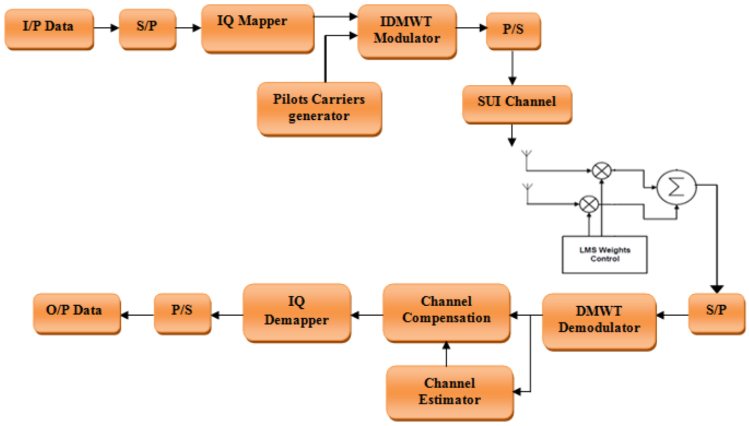

Fig (1) Simulation block diagram

3. 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).

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

Table (1) System parameters

Number of receiver antenna	2
Spacing between receiver antennas	λ/2
Fading correlations	ρ_R=0.5
Channels	SUI
Number of sub-carriers	256
Number of DMWT points	256
Modulation type	16 QAM

A. SUI- 1 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 5.3 dB while in without AAS the SNR about 7.1 dB From Figure 2 it is found that the with AAS outperforms significantly other system for this channel model.

B. SUI- 2 Channel Performance

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 8.2 dB while in without AAS the SNR about 10 dB 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.

C. SUI- 3 Channel Performance

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 10.5 dB, while in without using AAS the SNR about 12.05 dB, From Figure 4 it is found that the using AAS outperforms significantly than without using AAS for this channel model.

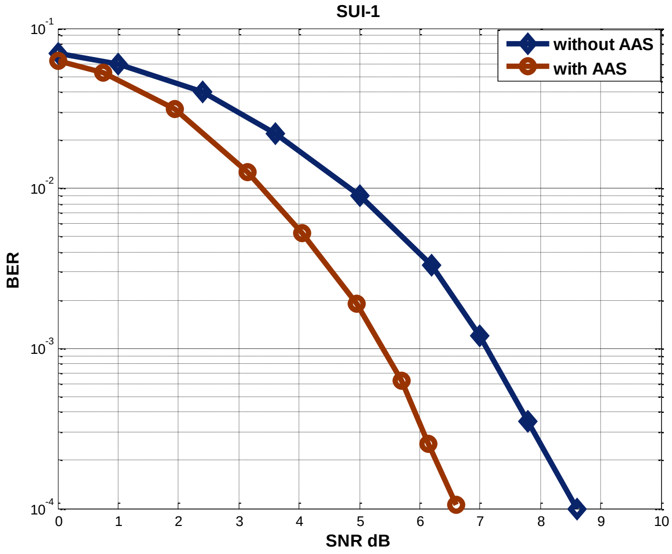

Fig. (2) BER performance of proposed model in SUI-1 channel

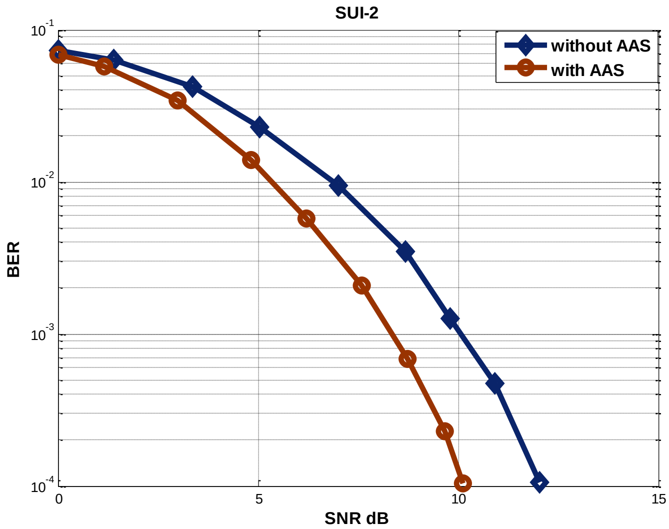

Fig. (3) BER performance of proposed model in SUI-2 channel

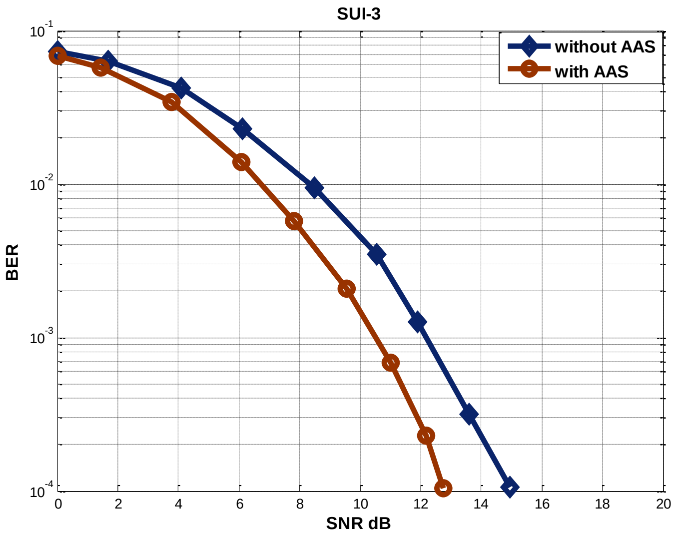

Fig. (4) BER performance of proposed model in SUI-3 channel

D. SUI -4 Channel Performance

In the SUI-4 channel performance. These results are depicted in figure 5, it can be seen that for BER= 10^{-3} the SNR required when using AAS was approximately 14.95 dB also for without using AAS was approximately 17 dB. From Figures 5 clearly illustrate that when using AAS significantly outperforms other system for this channel model.

E. SUI-5 Channel Performance

In this model, the results obtained were encouraging. When using AAS and without using AAS it can be seen that for BER=10^{-3} the SNR required when using AAS is about 19.9 dB while in without using AAS the SNR about 21.3 dB from Figure 6, it is found that when using AAS best significantly other system for this channel model.

F. SUI-6 Channel Performance

In this state, the results obtained were hopeful. When using AAS and without using AAS it can be seen that for BER=10^{-3} the SNR required when using AAS is about 27.2 dB while in without using AAS the SNR about 24 dB from Figure 6, it is found that when using AAS better significantly other system for this channel model.

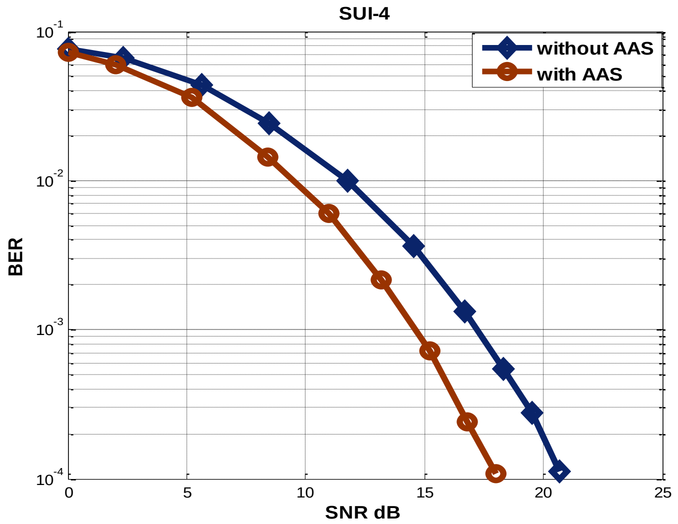

Fig. (5) BER performance of proposed model in SUI-4 channel

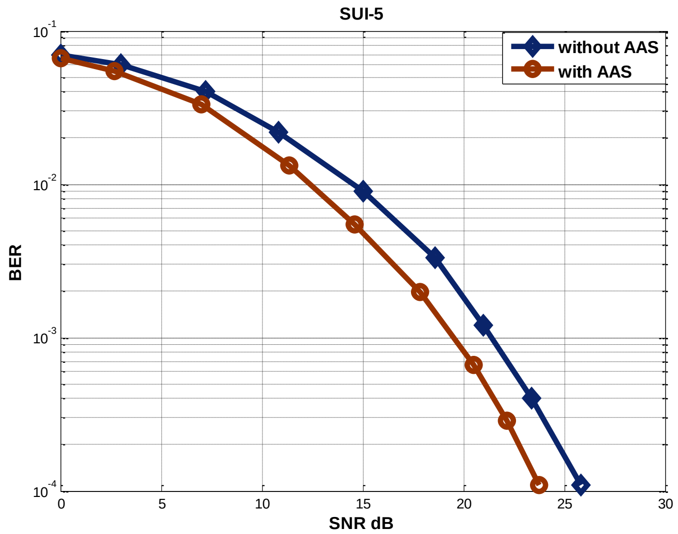

Fig. (6) BER performance of proposed model in SUI-5 channel

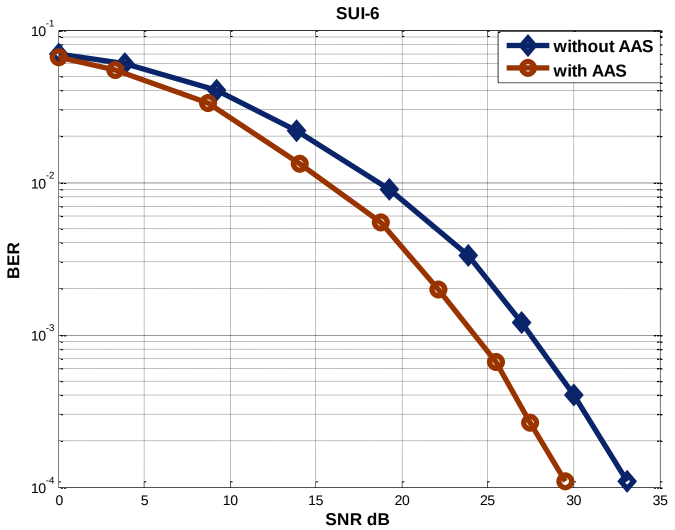

Fig. (7) BER performance of proposed model in SUI-6 channel

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	7.1	10	12.05	17	21.3	27.2
With AAS	5.3	8.2	10.5	14.95	19.9	24

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.

4. Conclusion

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