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Design and Performance of Adaptive Antenna System in LTE 3GPP Transceivers Based Fourier Signals in ITU Channels

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Abstract

3G LTE is next generation step in mobile communications with the promise of peak download rates of at least 100 Mbit/s and upload rates 50 Mbit/s. The evolved version of Long Term Evolution is LTE-Advanced which is being developed by the Third Generation Partnership Project (3GPP). LTE-Advanced will meet or go beyond the requirements of the International Telecommunication Union (ITU) for the fourth generation (4G) radio communication standard. In this paper, we investigate the performance of Adaptive Antenna System in the LTE 3GPP Transceivers. Adaptive Antenna System (AAS) has been developed to adaptively correct antenna impedance mismatch for the LTE 3GPP Transceivers. (AAS) has been deployed at the receiver module to reduce the fading effects caused by proposed channels model. (AAS) 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 **International Telecommunication Union** (ITU) channels , where beamforming is implemented in the direction of desired user. The performance of the system more increases by increasing the number of antennas at receiver.

Keywords: OFDM, LTE 3GPP, LMS, ITU, AAS.

1. Introduction

Long Term Evolution (LTE) is the next step forward in cellular 3G services. LTE will bring many technical benefits to cellular networks. Bandwidth will be scalable from 1.25 MHz to 20MHz. This will suit the needs of different network operators that have different bandwidth allocations, and also allow operators to provide different services based on spectrum. LTE is also expected to improve spectral efficiency in 3G networks, allowing carriers to provide more data and voice services over a given bandwidth (3GPP TS36.300, 2011). This paper provides an overview of the LTE physical layer (PHY), including technologies that are new to cellular such as LTE 3GPP transceivers based Fourier signals in ITU channels with adaptive antenna system. The 3GPP Long Term Evolution (LTE) represents a major advance in cellular technology. LTE is designed to meet carrier needs for high-speed data and media transport as well as high-capacity voice support well into the next decade. It encompasses high-speed data, multimedia unicast and multimedia broadcast services. Although technical specifications are not yet finalized, significant details are emerging (Ericsson, 2009). This paper focuses on the LTE physical layer (PHY) with adaptive antenna system. The LTE PHY is a highly efficient means of conveying both data and control information between an enhanced base station and mobile user equipment. The LTE PHY employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) LTE employs OFDM for downlink data transmission. OFDM is a well-known modulation technique, but is rather novel in cellular applications. A brief discussion of the basic properties and advantages of this method is therefore warranted. When information is transmitted over a wireless channel, the signal can be distorted due to multipath. Typically there is a line-of-sight path between the transmitter and receiver. 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) (D. Sirkova, 2006). 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 (Clercks, 2007). Adaptive Antenna System (AAS) is an optional feature in LTE 3GPP 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. As a result receiver can separate the desired LOS signal from the multipath signals and nulls are formed at the interfering signals (KARAKAYA, 2009, Daniele Borio, 2006). The objective of this paper is to develop the physical layer of LTE 3GPP Transceivers 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)(K.Sheikh, 1999, Lal Chand Godara, 2004). 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 (C.Godara, 1997). 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 (C.Godara, 1997). 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 (C.Godara, 1997) 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 (C.Godara, 1997). 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(C.Godara, 1997). 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(C.Godara, 1997). 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. The Simulation Block Diagram

The new proposed structures for the LTE 3GPP transceivers with adaptive antenna system will be studied in this paper. The Block diagram in Figure 1 represents the whole system model for proposed LTE transceiver design with adaptive antenna system.

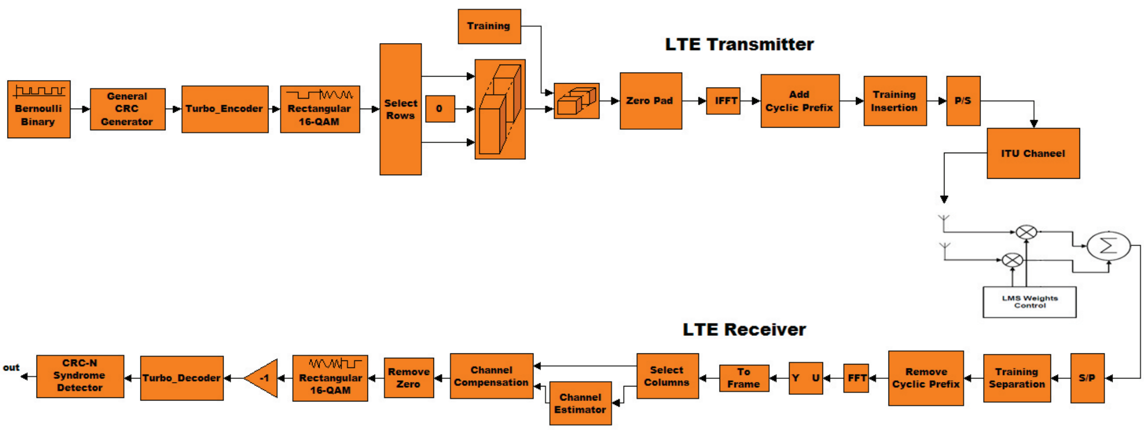

Figure 1. Simulation Block Diagram

The block diagram structure is divided into four main sections: transmitter, receiver, adaptive antenna array algorithm and channel. In this section the system models that have been used in the LTE simulator will be presented. The used system model is outlined in Figure 1 In transmitter side the digital random data set is generated uniformly. CRC Insertion: A 24-bits CRC is calculated and appended at the end of every transport block. CRC allows receiver to detect residual errors from the decoded transport block. The block diagram for CRC insertion is shown in Figure 1. The current 3G systems use turbo coding scheme, but due to the high peak data rates supported by LTE (C. Berrou, 1993) , it becomes imperative to know if this same turbo coding scheme can scale to high data rates while maintaining reasonable decoding complexity. It is currently debated that turbo coding has a particular drawback that it is not amenable to parallel implementations which limit the achievable decoding speeds. The underlying reason behind this issue is the contention for memory resources among parallel processors which occurs as a result of the turbo code internal interleaver. On the other hand, it is argued that turbo codes can also employ parallel implementations if turbo internal interleavers can be made contention-free. These blocks of digital data set have been paralleled and mapped into complex data blocks using 16-QAM modulation technique. Every complex data block referred to a symbol of data is attached to an individual sub-carrier. The Inverse Fast Fourier Transform (IFFT) is used in order to generate the time version of transmitted signal. The time domain signals corresponding to all subcarriers are orthogonal to each other. However, the frequency spectrum overlaps. After this, the data converted from the parallel to the serial form are fed to the ITU channels more information about ITU channels in (International Telecommunication Union, 2000). 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 beamforming algorithm such as Least Mean Square (LMS), be used (KUN, 2009, ZHAO, 2009). 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, OFDM includes operations for compensation for the destructive ITU channels.

3. Simulation and Results

The reference model specifies a number of parameters that can be found in Table (1).

Table (1) System parameters

Transmission Bandwidth	**2.5 MHz**
Sub-frame duration	**0.5ms**
Sub-carrier spacing	**15KHz**
Sampling Frequency	**3.84MHz**
FFT Size	**256**
OFDM symbol per slot (short/long CP	**7/6**
CP length (µsec/samples)	**SHORT (4.69/18) x 6 (5.21/20) x 1** **LONG (16.67/64)**
Modulation type	**16QAM**
Channel coding	**Turbo**
Channel type	**ITU Channel**
Receiver decoder type	**Soft sphere detection (SSD)**
Number of iterations	**1000**

In this section the simulation of the proposed channel estimation algorithms for the existing in LTE 3GPP Baseband Transceiver and comparing between when using AAS and without using AAS is executed, beside the BER performance of the system regarded in ITU channel models.

3.1AWGN Channel Performance

In this scenario, the results obtained were encouraging, the system when using AAS and without using AAS can be seen that for BER=10^{-3} the SNR required when without using AAS is about 16.2 dB while when using AAS is about 14.3 dB, from Figure 2 it is found that the channel estimation (MMSE) outperforms significantly other system for this channel model.

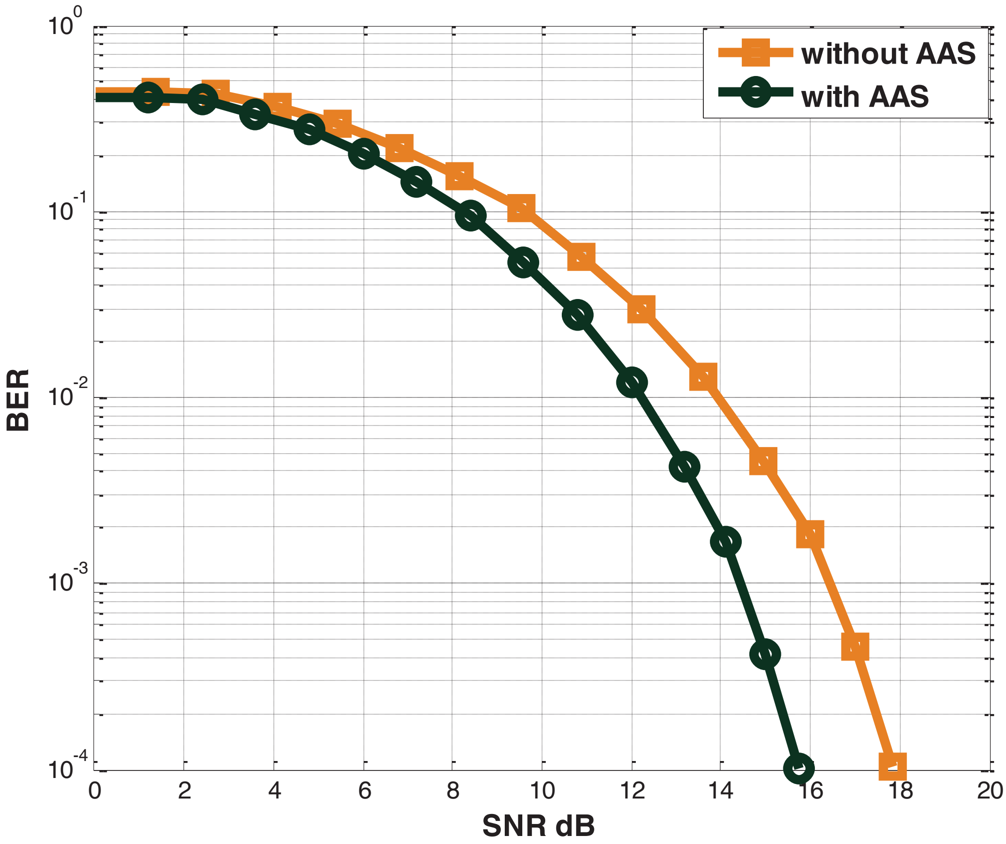

Figure 2. BER performance of LTE 3GPP Baseband Transceiver in AWGN channel

3.2 AWGN plus Multipath Channel Performance

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

3.2.1 Indoor Channel A

In this simulation profile some influential results were obtained, the system when using AAS and without using AAS it can be seen that for BER=10^{-3} the SNR required when without using AAS is about 21 dB while when using AAS the SNR is about 18 dB from, Figure 3 it is found that when using AAS outperforms significantly other system for this channel model.

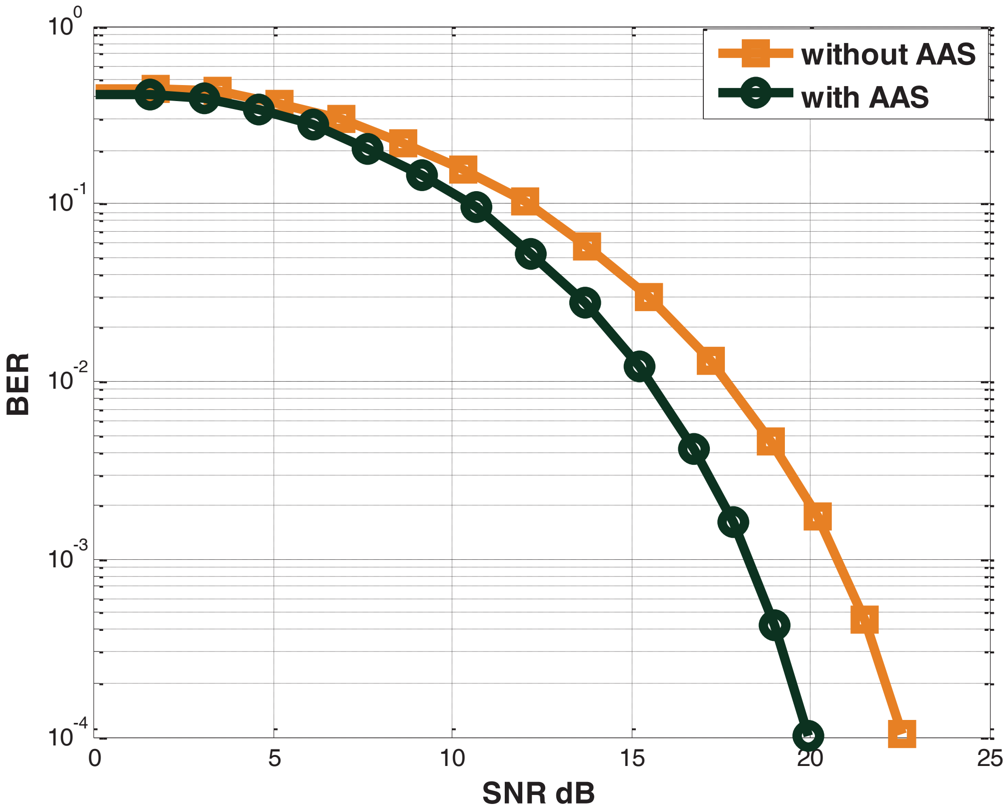

Figure.3. BER performance of LTE 3GPP Baseband Transceiver in AWGN plus Multipath Indoor A

3.2.2 Indoor Channel B

In this channel, the results are depicted in Figure 4 it can be seen that for BER=10^{-3} the SNR required for the system when without using AAS is about 27 dB, while when using AAS the SNR is about 24 dB, from Figure 4 it is found that when using AAS outperforms significantly than others systems for this channel model.

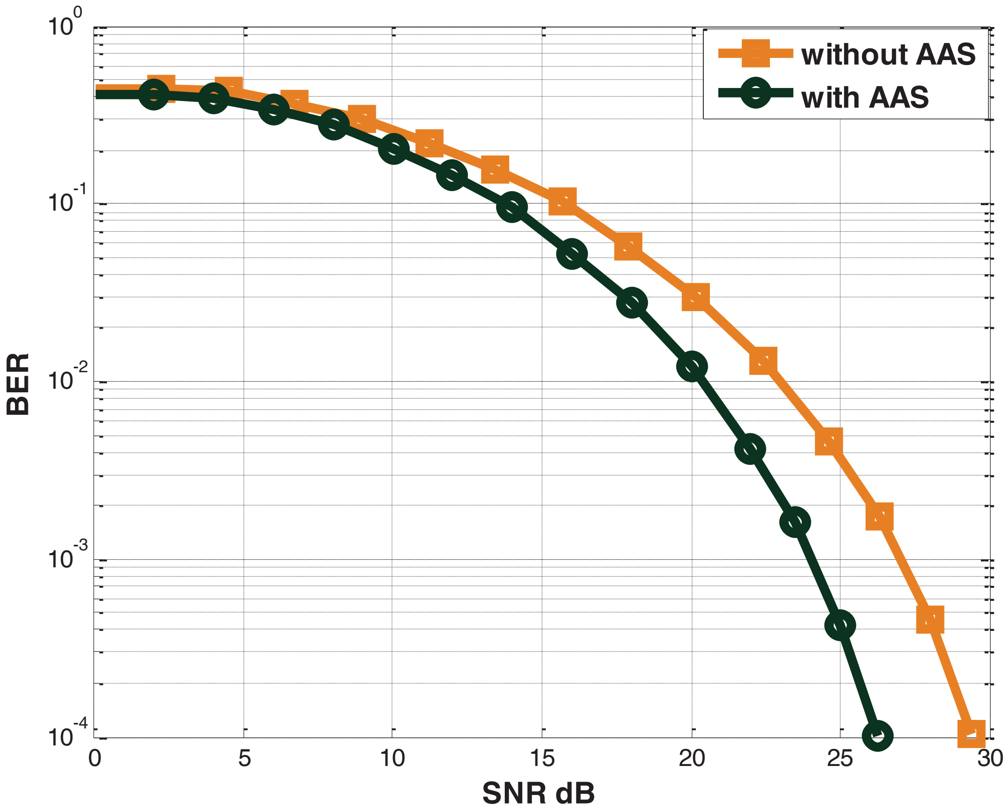

Figure 4. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath Indoor B

3.2.3 Pedestrian Channel A

In the pedestrian profile, two different situations were regarded: a stationary and a moving person

3.2.3.1 Pedestrian Channel A (a stationary person):

Using similar methodology as in the previous section, simulations for this channel the result depicted in Figure 5 it can be seen that for BER=10^{-3} the SNR required for the system when without using AAS is about 24 dB while when using AAS the SNR is about 21 dB. Also from Figure 5 it is found that when using AAS outperforms significantly than others systems for this channel model.

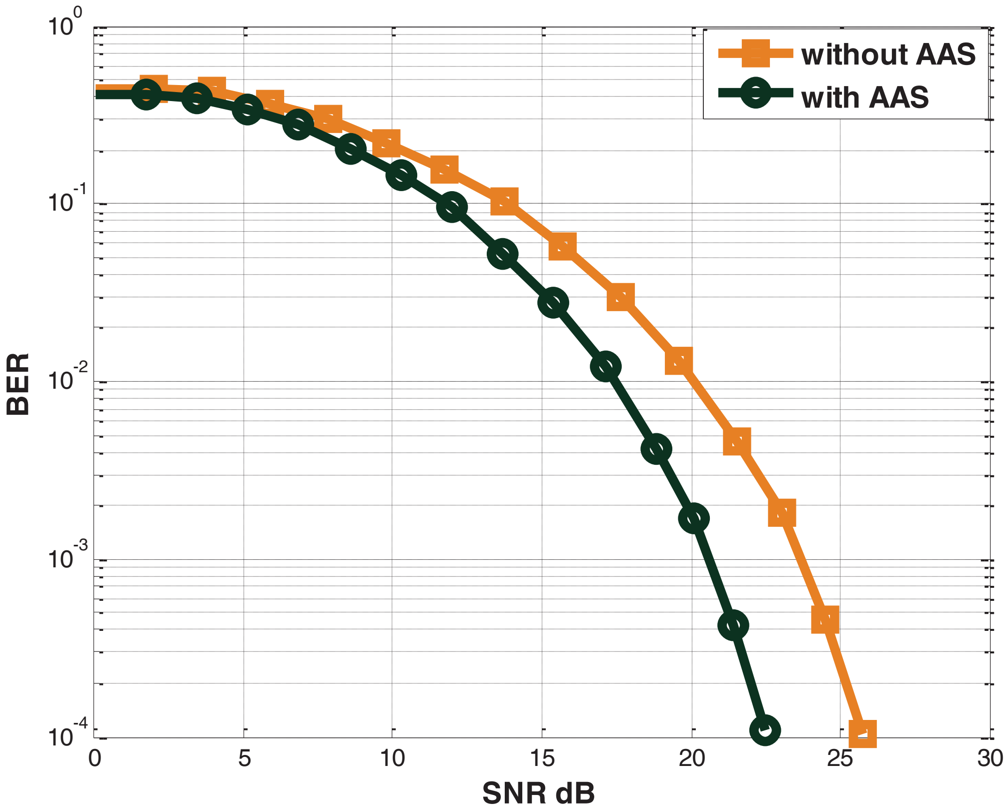

Figure 5. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath Stopped Pedestrian A

3.2.3.2 Pedestrian Channel A (a moving person):

In this model, the results obtained were encouraging. The system when using AAS and without using AAS it can be seen that for BER=10^{-3} the SNR required is about 33.5 dB when without using AAS while when using AAS the SNR is about 29 dB from Figure 6 it is found that when using AAS the system is best significantly other system for this channel model.

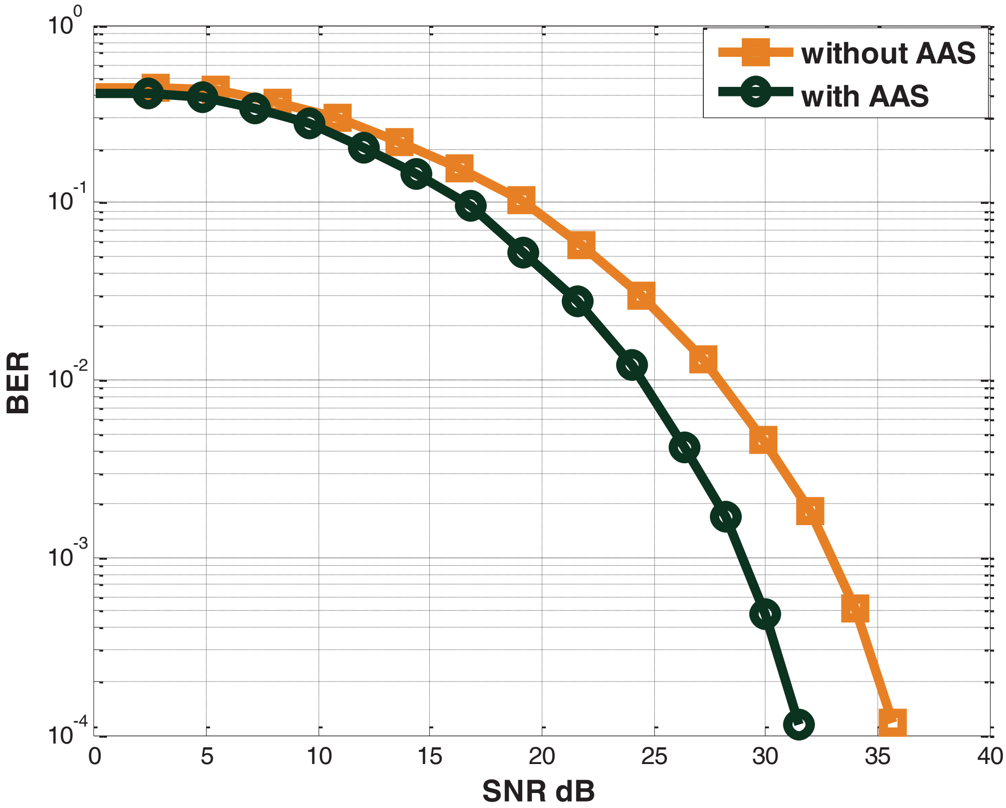

Figure 6. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath moving Pedestrian A

3.2.4 Pedestrian Channel B

Using such as methodology as in the previous section, simulations for both a stationary and a moving pedestrians were carried out:

3.2.4.1 Pedestrian Channel B (a stationary person):

In this state, the results obtained were hopeful. The system when using AAS and without using AAS it can be seen that for BER=10^{-3} the SNR required when without using AAS is about 36.5 dB while when using AAS the SNR is about 31.5 dB from Figure 7 it is found that when using AAS is better significantly other system for this channel model

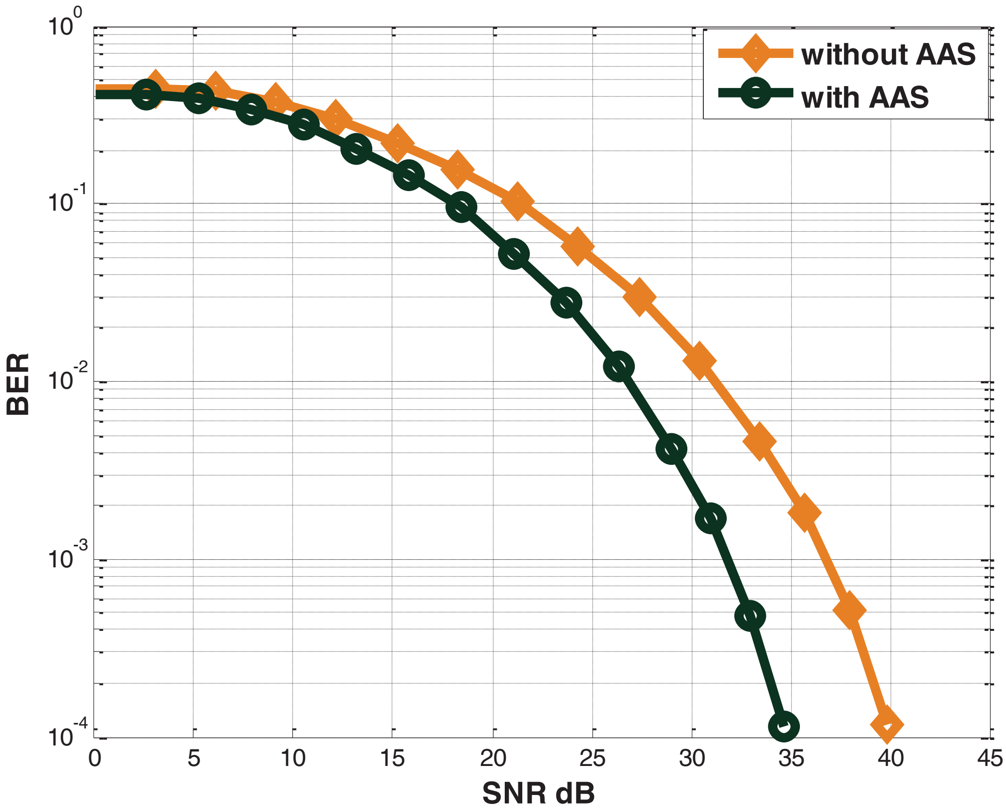

Figure 7. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath Stationary Pedestrian B

3.2.4.2 Pedestrian Channel B (a moving person):

In this scenario, the results obtained were encouraging. it can be seen that for BER=10^{-3} the SNR required when without using AAS is about 42.5 dB, while when using AAS the system showed a performance 36.25 dB better than when without using AAS. These results are presented in Figure 8.

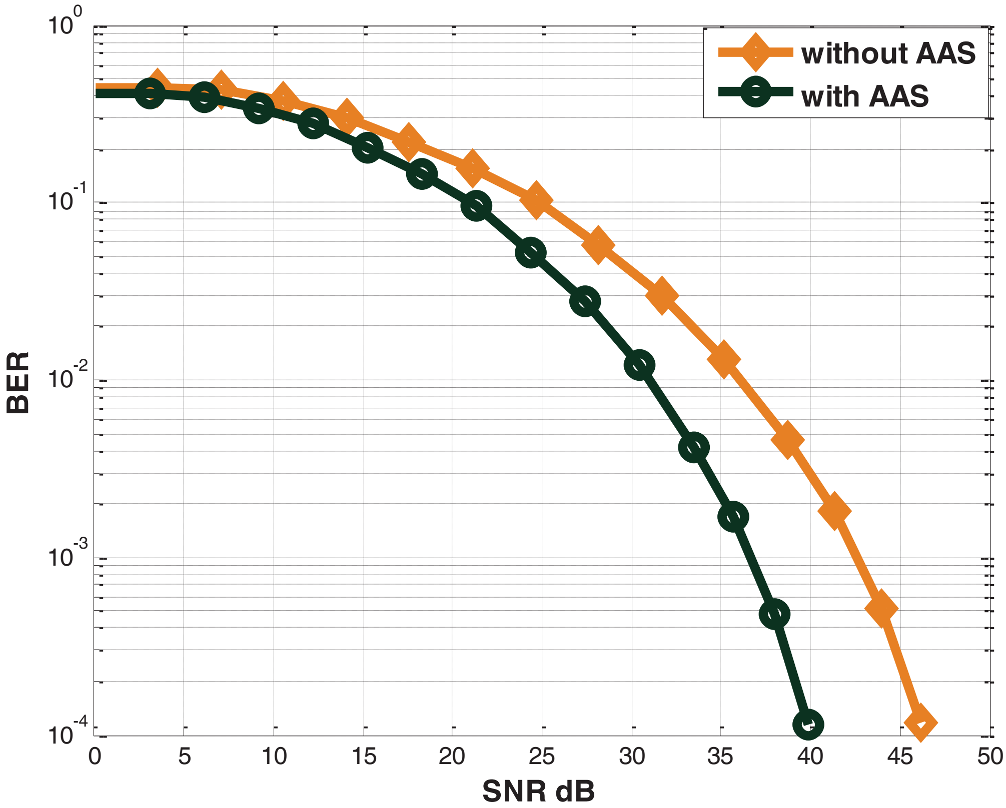

Figure 8. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath a moving person Pedestrian B

3.2.5 Vehicular Channel A

In this channel was proposed for communication links under mobility, i.e., vehicular use. However, simulations under these conditions were performed to get a sense of the effects and to eventually reflect on solutions to combat the negative consequences. In this section the performance of the link under the user-channel vehicular A profile with 60 km *h* is addressed the results obtained for the user-channel vehicular A. As shown in Figure 9 when without using AAS clearly poor performance and it can be seen that for BER=10^{-3} the SNR required when using AAS the system performed is about 40dB.

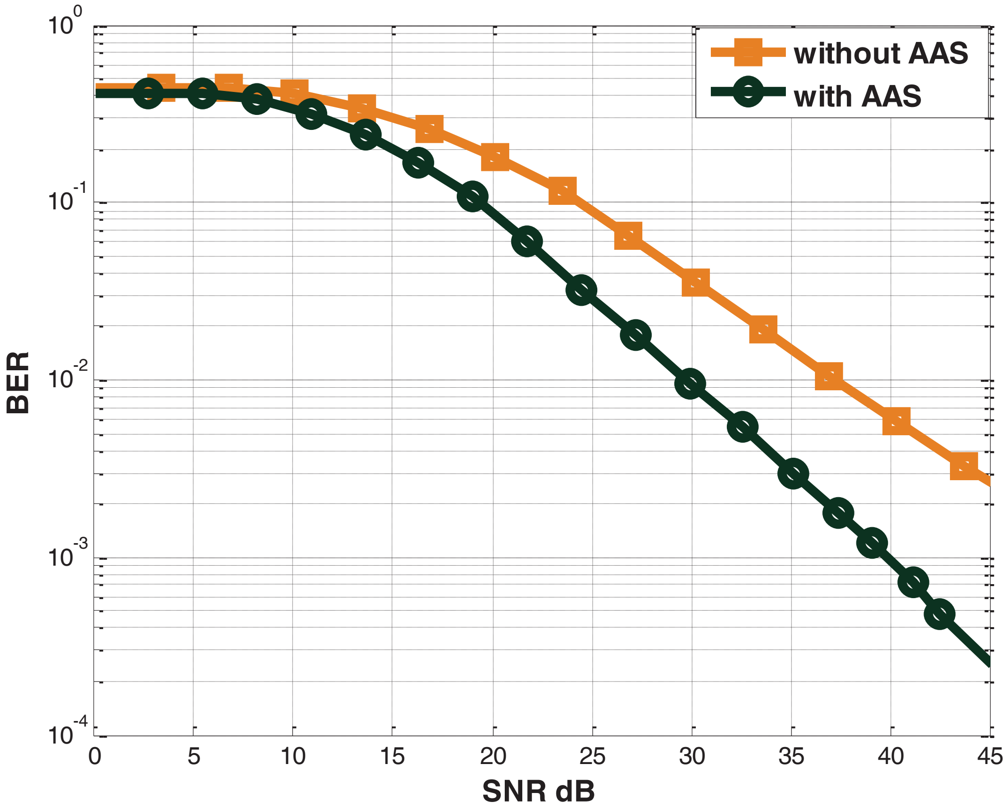

Figure 9. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath a Vehicular Channel A

3.2.5 Vehicular Channel B

In this section, we present the results obtained under the user-channel vehicular B profile with speed 120km h. It is clear that all systems performed poorly since none of them can combat the multipath and Doppler spread combined effect of this kind of channel these results are presented in Figure 10. Important results can be taken from Table (2); in this simulation, in most scenarios, by using AAS system was better than when without using AAS. By using AAS proved its effectiveness in combating the multipath effect on the channels.

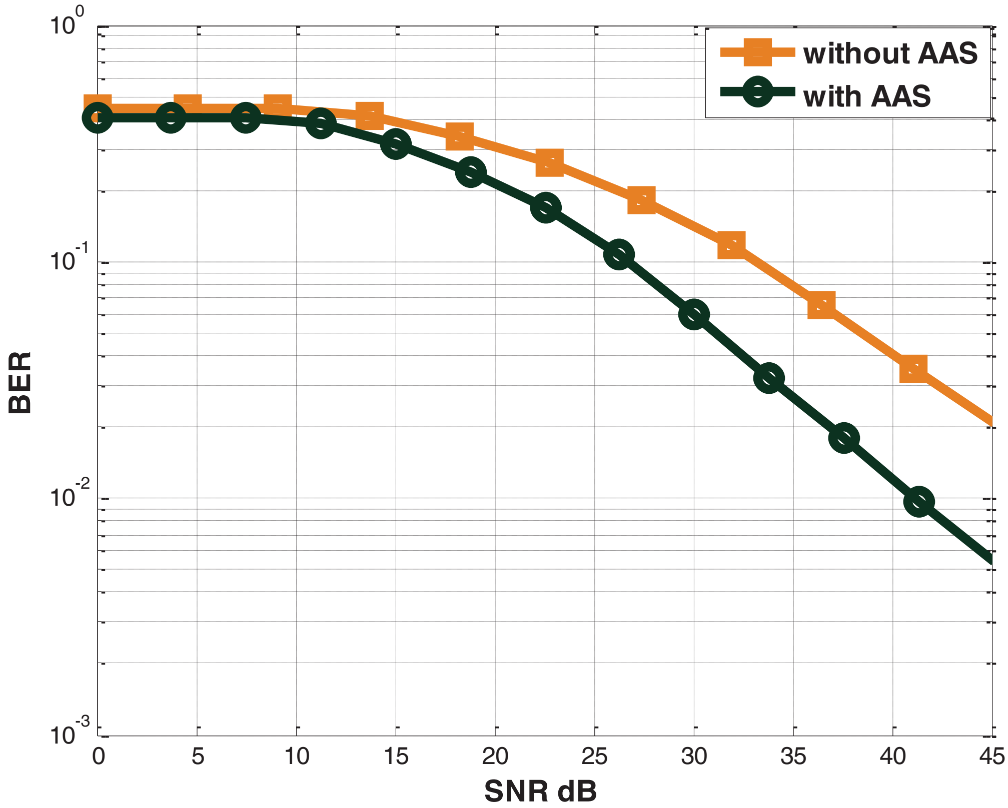

Figure 10. BER performance of LTE 3GPP Baseband Transceiver in AWGN & Multipath a Vehicular Channel B

Table (2) Performance Comparison and Analysis

Channel For BER=10^{-3}	AWGN	Indoor Channel A	Indoor Channel B	Pedestrian Channel A		Pedestrian Channel B		Vehicular	
				AWGN & Multipath Stationary Pedestrian A	AWGN & Multipath Moving Pedestrian A	AWGN & Multipath Stationary Pedestrian B	AWGN & Multipath Moving Pedestrian B	Channel A	Channel B
LS dB	16.2	21	27	24	33.5	36.5	42.5	poor	poor
MMSE dB	14.3	18	24	21	29	31.5	36.25	40	poor

A number of important results can be taken from Table (2); In this simulation, in most scenarios, the LTE 3GPP Baseband Transceiver with AAS was better than the LTE 3GPP Baseband Transceiver 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 ITU 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 ITU fading channels.

4. Conclusion

In this paper, the LTE 3GPP Baseband 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 AWGN, and other channels the LTE 3GPP Baseband Transceiver with AAS outperform than without using AAS therefore, this structure can be considered as an alternative to the conventional LTE 3GPP Baseband 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 LTE 3GPP Baseband Transceiver 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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