Design and Implementation of Adaptive Antenna System in a New LTE 3GPP Transceivers Based Multiwavelet Signals

The new Long Term Evolution (LTE) transceivers based multiwavelet signals design and implementation are discussed in this paper. LTE is the evolution of the Universal Mobile Telecommunications System (UMTS) is a third generation mobile cellular system for networks based on the Global System for Mobile Communications (GSM) standard in response to ever-increasing demands for high quality multimedia services according to users’ expectations; to increase the efficiency of such transceiver successive Adaptive Antenna System (AAS) has been used at receiver to provide an effective reduction of multiuser access interference at an affordable complexity. An AAS has been deployed at the receiver module to reduce the fading effects signal caused by proposed Stanford University Interim (SUI) Channel Models. AAS uses beamforming technique to focus the wireless beam between the base station and the subscriber station. 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 demonstrated through MATLAB simulations that the performance of the system is significantly improved by AAS, where beam forming is implemented in the direction of desired user. The results give SNR gain of 1.8dB gained to achieve an error of $10^{-3}$ in SUI channels. The performance of the system can be more improved by increasing the number of antennas at receiver.

Keywords: OFDM; DMWT; CDMA; AAS; LMS; Beam forming

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1. Introduction

Through the last decade along with continued expansion of networks and communications technologies and the globalization of 3rd Generation of Mobile Communication Systems, the support for voice and data services have encountered a further development compared to 2nd Generation Systems. Simultaneously the requirements for high quality wireless communications with higher data rates increased owing to users demands. On the other hand, the conflict of limited bandwidth resources and rapidly growing numbers of users becomes exceptional, so the spectrum efficiency of system should be enhanced by adopting some advanced technologies [1].

It has been shown in both theory and practice that some novel technologies such as orthogonal frequency division multiplexing (OFDM), can improve the performance of the current wireless communication systems. The high data rates and the high capacity can be realized by using the advantages of the two technologies. From a standardization perspective 3G era is now well advanced. While improvements continue to be made to leverage the maximum performance from at present deployed systems, there is a bound to the level to which further improvements will be effective. If the only purpose were to deliver superior performance, then this in itself would be relatively easy to accomplish [2]. The added complexity is that such superior performance must be delivered during systems which are cheaper from installation and maintenance prospect. Users have experienced an incredible reduction in telecommunications charges and they now anticipate receiving higher quality communication services at low cost. so, in deciding the subsequent standardization step, there must be a dual approach; in search of substantial performance enhancement but at reduced cost.

Long Term Evolution (LTE) is that next step and will be the basis on which future mobile telecommunications systems will be built. LTE is the first cellular communication system optimized from the outset to support packet-switched data services, within which packetized voice communications are just one part. The 3rd Generation Partnership Project (3GPP) started work on Long Term Evolution in 2004 with the specification of targets illustrated in [1]. The specifications associated to LTE are formally recognized as the evolved UMTS terrestrial radio access network (E-UTRAN) and the evolved UMTS terrestrial radio access (E-UTRA). These are
collectively referred to by the project name LTE. In December 2008, release 8 of LTE has been approved by 3GPP which will allow network operators to appreciate their deployment plans in implementing this technology. A few motivating factors can be identified in advancing LTE development; enhancements in wire line capability, the requirement for added wireless capacity, the need for provision of wireless data services at lower costs and the competition to the existing wireless technologies [3].

In addition to the continued advancement in wire line technologies, a alike development is necessary for technologies to work fluently with defined specifications in the wireless domain. 3GPP technologies must match and go beyond the competition with other wireless technologies which guarantee high data capabilities – including IEEE 802.16. To take maximum advantage of available spectrum, large capacity is an essential requirement. LTE is required to provide superior performance compared to High Speed Packet Access (HSPA) technology according to 3GPP specifications [4]. 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 [5]. 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 Beam forming techniques can be employed for interference rejection as compared to Diversity-oriented schemes [6].

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 LTE 3GPP 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) [7, 8]. 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 [9]. 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 [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 beam forming 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. 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 ESPRIT [8]. 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 block diagram in Figure 1 represents the whole system model for the proposed modified LTE transceiver design based multi-wavelet signals. The LTE transceiver structure is divided into three main sections: transmitter, channel, and receiver:
In transmitter the transport channel is the interface between the physical layer and the MAC layer. As the LTE simulator focuses on the physical layer, the initial data is generated in the form of transport blocks. The transmitter in the physical layer starts with the resource data which are in the form of transport blocks (see Figure 1). In each, one transport block will be transferred first to the channel coding part which consists of two CRC encoders and one Turbo encoder. According to [10], an encoder of Cyclic Redundancy Check (CRC) is utilized at the beginning of channel coding. There are two CRC schemes for PDSCH: ‘gCRC24A’ and ‘gCRC24B’. Both of them possess a 24 parity bits length, but work with different cyclic generator polynomials. The ‘gCRC24A’ focuses on a transport block, while the ‘gCRC24B’ focuses on the code block. The channel coding scheme for PDSCH adopts Turbo coding, which is a kind of robust channel coding. The performance of Turbo codes can be close to the theoretical Shannon capacity limits [10]. According to [11], the scheme of the Turbo encoder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one Turbo code internal inter-leaver. The theoretical structure of a Turbo encoder is presented in reference [10]. As illustrated in Figure 1, the modulation scheme used is the 16 QAM 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 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 [11], 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 sub-carriers (N_P) 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 orthogonally by introducing a cyclic prefix (CP). This CP consists of the final \nu samples of the original K samples to be transmitted, prefixed to the transmitted symbol. The length \nu 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 \nu, the CP is sufficient to eliminate ISI and ICI. The efficiency of the transceiver is reduced by a factor of \frac{K}{K+\nu}, thus, it is desirable to make the \nu as small or 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 [12]. In Multi-wavelet setting, GHM multiscale and multi-wavelet function coefficients are 2x2 matrices, and during transformation step they must multiply vectors (instead of scalars) [13]. 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 approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. The computation of DMWT and IDMWT for 256 points is similar to that presented in [12]. 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 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), be used [15,16]. The calculated weight is then multiplied by the signal from the antenna array and the required radiation pattern is formed. In the antenna array system, 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. The receiver performs the same operations as the transmitter, but in a reverse order. In addition, multi-wavelet OFDM includes operations for synchronization and compensation for the destructive SUI channels.

3. Simulation Results
In this section the simulation of the proposed adaptive antenna array system in LTE 3GPP transceivers based multi-wavelet signals and comparing without adaptive antenna array system is executed, beside the BER performance of the system regarded in SUI channel models.

<table>
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<tr>
<th>Table (1) System parameters</th>
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<tbody>
<tr>
<td>Number of transmitter antenna</td>
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<tr>
<td>Number of receiver antenna</td>
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<td>Spacing between receiver antennas</td>
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<td>Fading correlations</td>
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<td>Transmission Bandwidth</td>
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<td>Sub-frame duration</td>
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<td>Sub-carrier spacing</td>
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<td>Sampling Frequency</td>
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<td>DMWT Size</td>
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<td>Receiver decoder type</td>
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<td>Number of iterations</td>
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3.1 Performance of SUI-1 channel:
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 2.07dB while in “without AAS” the SNR about 3.6 dB. From Fig. (2) it is found that the “with AAS” outperforms significantly other system for this channel model.

![Fig. (2) BER performance of proposed model in SUI-1 channel](image)

3.2 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 AAS is about 4.14 dB while in without AAS the SNR about 5.85 dB from Fig. (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](image3.png)

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

### 3.3 Performance of SUI-3 channel

In this simulation profile some significant results were taken. The results are depicted in Figure 4 it can be seen that for BER=$10^{-3}$ the SNR required for with AAS is about 7.425 dB, while in without using AAS the SNR about 9 dB. From Figure 4 it is found that the using AAS outperforms significantly than without using AAS for this channel model.

![Figure 4](image4.png)

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

### 3.4 Performance of SUI-4 channel

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 10.8 dB also for without using AAS was approximately 12.6 dB. From Figures 5 clearly illustrate that when using AAS significantly outperforms other system for this channel model.

![Figure 5](image5.png)

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

### 3.5 Performance of SUI-5 channel

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 13.9 dB while in without using AAS the SNR about 15.75 dB from Figure 6 it is found that when using AAS best significantly other system for this channel model.

![Figure 6](image6.png)

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

### 3.6 Performance of SUI-6 channel

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 18.45 dB while in without using AAS the SNR about 20.7 dB from Fig. (6), it is found that when using AAS better significantly other system for this channel model.

![Figure 7](image7.png)

**Fig. (7)** BER performance of proposed model in SUI-6 channel
A number of important results can be taken from Table (2); in this simulation, in most scenarios, the LTE 3GPP Transceivers Based Multi-wavelet Signals with AAS was better than the 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 LTE 3GPP Transceivers Based Multi-wavelet Signals 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 transceiver with AAS outperform than without using AAS therefore, this structure can be considered as an alternative to the conventional 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 transceiver based the AAS structure. Simulations provided proved that proposed design accomplishes much lower and it can be used at high transmission rates.

References
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