Symbol Generation and Enhanced Capacity in LTE-A Network using MIMO-OFDM

Md. Faizan Hasan, Md. Javed Hossain, Mohammed Humayun Kabir, Mohammed Nizam Uddin

Abstract—The development of networks is running toward wireless systems. To attach more services to the handy devices, the demand of more bandwidth as well as better data rate in wireless systems are hiking. Even in developing countries, this demand is increasing. While the service providers are providing telecom services using GSM, EDGE, CDMA, WCDMA, WiMAX, HSPA, HSPA+ etc. technologies, it is call from time to move with better technologies which will facilitate the provision of ubiquitous and affordable broadband (very high speed) wireless connectivity. The ultimate goal of LTE-A network is to design a real wireless world without facing obstacles of the earlier generations. Modulation and Multiplexing has been the main issues in higher capacity, quality, cost and design. So most reliable OFDM with efficient modulation techniques like as QPSK, 16-QAM & 64-QAM are seen as main backbone principles for LTE-A network. This paper aims at highlighting the concepts of LTE-A network, its architecture, features, comparative studies with preceding technologies, applications and the possibility of betterment.

Index Terms— LTE-A, MIMO, OFDM, ISI, ICI, SNR, 4G

1 INTRODUCTION

Now a day we are living in the world of technology. According to Moore's law, the development of technology will be doubled within every eight years. His law may be dead in present times, but the people used to current technologies, feel the demand of new technology especially in mobile communication. The first analog mobile communication system was introduced in 1981, comes in front with the AMPS technology providing data bandwidth up to 2.4Kbps. Its deal was only with the voice channels. In 1992, the second generation mobile communication system was launched. This was the first digital system has run their system with GSM & CDMA one providing data bandwidth up to 64Kbps. The upgraded generations of these technologies came with the feature of data. Then the addition in the list of development came in front in 2002 with EDGE, CDMA2000 providing bandwidth up to 2Mbps. Now as the latest fully standardized running technology offering service since 2012 using WiMAX & LTE (Long Term Evolution) technology. Now it's the time to board on LTE-A network to meet the demand. Basically LTE-Advanced is considered as 4th generation of mobile communication [1].

Wireless technologies are going to take new dimension in our lives. LTE-A should make an important difference and add more services and benefit to the world over previous technologies. LTE-A should be more intelligent technology that interconnects the entire world without limits. We refer to this goal as enabling the 4A paradigm: "any rate, anytime, anywhere, affordable". The wireless broadband will soon become readily available to everybody.

We know ICI & ISI are main factors in any wireless communication responsible for performance degradation and bit errors. It plays significant roles where we have to send single data using multiple carriers like MIMO-OFDM system. By reducing ICI and ISI we can reduce BER hence more SNR and more capacity [2].

This report looks up the performance of OFDMA and MIMO configurations of LTE-Advanced physical layer using QPSK, 16QAM, 64QAM. The orthogonally, path loss and capacity are also described thoroughly. The numerical results obtained by MATLAB simulations are then demonstrated on graphs.

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2 OBJECTIVES OF RESEARCH WORK

There is huge market for highly bandwidth networks because of almost everything are available on internet and mobile devices are doing most popular and easier way.

- Gaining the knowledge of LTE-Advanced.
- Comparative studies on different communication technology with respect to LTE-A in Bangladesh.
- Study on the physical layer of LTE-Advanced.
- Implementation of LTE-advanced transceiver for downlink with the help of MATLAB SIMULINK.
- Study on the implementation of different MIMO configurations.
- Implementation of different MIMO configurations along with different modulation schemes and different fading channels.
- Comparison of the impact of different modulation schemes and different channels with different MIMOs configurations.
- Investigation the influence of different values of signal to noise ratio (SNR) obtained by using different

modulation, channel schemes, and different antenna configurations on bit error rate (BER).
- By reducing ICI and ISI we can reduce BER hence more SNR and more capacity.

3 LTE-A

3.1 Introducing LTE-A

The proposed model of LTE-Advanced based on the structure of LTE/SAE where the architecture of it represents a challenge in the future of wireless broadband. The LTE/SAE presents an advanced radio interfacing with main improvement upcoming from using of Orthogonal Frequency Division Multiplexing (OFDM) with compound antenna technique. These technologies previously exist and in employment in WiMAX as itemized in IEEE 802.16. Sideways with the advanced radio interfacing, LTE/SAE states the development in the architecture of network [3].

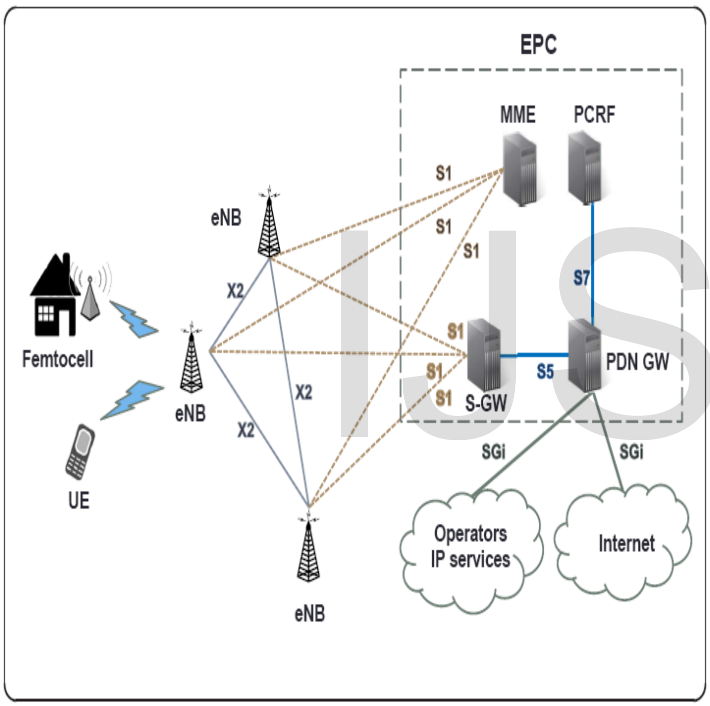

Fig. 1. LTE Advanced Network Architecture.

3.2 Features of LTE-A

- Reduced cost per bit.
- Improve spectrum efficiency.
- Reduce cost of backhaul.
- Increased service provisioning – more services at lower cost with better user experience.
- Focus on delivery of services utilizing IP.
- Reduced latency, to 10 ms round-trip time between user equipment and the base station, and to less than 100 ms transition time from inactive to active.
- Increase the support of QoS for the various types of services (e.g. VoIP).
- Increase "cell edge bit rate" whilst maintaining same site locations as deployed today.
- Reasonable terminal power consumption.
- Flexibility of use of existing & new frequency bands.
- Preserve the flexibility to support wide range of services.
- Applied in cost efficient manner.
- Compatibility of services with IMT and fixed networks.
- Ability of internetworking with other radio access systems.
- Suitable User Equipment for worldwide use.
- User-friendly applications, services and equipment.
- High quality mobile services.
- Globally roaming ability.
- Boost peak rates to sustain advanced services and applications [2].

3.3 Requirements of LTE-A

- Peak data rate Downlink: 1 Gbps, Uplink: 500 Mbps.
- Transmission bandwidth: Wider than approximately 70 MHz in downlink and 40 MHz in uplink.
- Latency: C-plane from Idle (with IP address allocated) to Connected in <50 ms and U-plane latency shorter than 5 ms one way in RAN taking into account 30% retransmissions (FFS) Cell edge user throughput 2 times higher than that in LTE.
- Average user throughput 3 times higher than that in LTE.
- Capacity (spectrum efficiency) 3 times higher than that in LTE.
- Peak spectrum efficiency DL: 30 bps/Hz, UL: 15 bps/Hz.
- Spectrum flexibility: Support of scalable bandwidth and spectrum aggregation.
- Coverage should be optimized or deployment in local areas/micro cell environments with ISD up to 1 km.
- Backward compatibility and interworking with LTE with 3GPP legacy systems [4].

3.4 Why LTE-A?

It is widely known that since the advent of LTE-Advanced in 3GPP Release 10, the LTE family of standards now fulfills the criteria of a true 4G (fourth generation) mobile system, as laid down by the ITU (International Telecommunication Union).
As we have pointed out many times before, while the peak performance of these technologies is one measure of their capabilities, it should not be taken to reflect typical performance in a real wide-area network. For example, peak throughput figures will be attainable only when the ultimate configuration is deployed (e.g. using the maximum bandwidth and the highest order MIMO configuration) and when the mobile terminal is operating in ideal radio conditions (e.g. strong radio signaling and low loading of the cell). Typical performance in a real network may be significantly lower than the peak figures, but nonetheless these are highly impressive numbers, and it is worth pointing out that LTE-A system includes features to improve their performance in less than ideal conditions, such as near the edge of a cell.

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Technology Name	Access Method	Characteristics	Typical Downlink Speed	Typical Uplink Speed
UMTS	CDMA	3G technology providing voice and data capabilities. Current deployments implement HSPA for data service.	200 to 300 kbps	200 to 300 kbps
HSPA	CDMA	Data service for UMTS networks. An enhancement to original UMTS data service.	1 Mbps to 4 Mbps	500 kbps to 2 Mbps
HSPA+	CDMA	Evolution of HSPA in various stages to increase throughput and capacity and to lower latency.	1.5 Mbps to 7 Mbps	1 Mbps to 4 Mbps
LTE	OFDMA	New radio interface that can use wide radio channels and deliver extremely high throughput rates. All communications handled in IP domain.	4 Mbps to 24 Mbps (in 2 x 20 MHz)	3 Mbps to 10 Mbps
LTE-Advanced	OFDMA	Advanced version of LTE designed to meet IMT-Advanced requirements.	up to 3Gbps in low mobility situations	up to 1.5Gbps in low mobility situations

Fig. 2. Comparison between communication technologies.

If we look up the technical differences, the HSPA+ uses CDMA as multiple access method, where LTE-A uses Orthogonal Frequency Domain Multiple Access (OFDMA)for downlink and Single Carrier Frequency Domain Multiple Access (SC-FDMA) for uplink. Duplex methods are quiet same but the modulation technique supported by HSPA+ is up to 64QAM and up to 128QAM in LTE-A. Carrier frequency is higher than HSPA+, up to 20 MHz In aspect to carrier aggregation, multi-carrier High Speed Downlink Packet Access (MC-HSDPA) allows aggregation of up-to eight 5MHz downlink carriers in HSPA+. Dual-Carrier High Speed Uplink Packet Access (DC-HSUPA) allows aggregation of up to two 5MHz uplink carriers. In LTE-A, carrier aggregation enables the combination of up to five individual carriers to achieve a maximum bandwidth of 100MHz in the uplink or downlink. Downlink Multiple Input Multiple Output (MIMO) support for up to 4 transmit and 4 receive antennas. Uplink MIMO support for up to 2 transmit and 2 receive antennas to provide services using HSPA+. And using LTE-A, the antenna support can be maximized up to 8 transmit and 8 receive antennas for downlink MIMO up to 4 transmit and 4 receive antennas for uplink MIMO. Spectral frequency range also differs in both, Peak spectral efficiency for downlink is 16.8bps/Hz, and for uplink is 6.9bps/Hz (64QAM, 2x2 MIMO) in HSPA+. Downlink: 30bps/Hz (128QAM, 8x8 MIMO) and Uplink: 15bps/Hz (128QAM, 4x4 MIMO) is for LTE-A [5], [6].
Moreover if we consider the case of Bangladesh, a highly populated developing country, where the high speed data users are increasing day by day LTE-A would be a better strategy in the pace of communication technology. Because of its latency support, high data rate, less call drop, high mobility, improved carrier frequency and high antenna support.

3.5 MIMO & OFDM Techniques in LTE-A networks

Both Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) Technologies are used in LTE-A systems in order to obtain high throughput with better mitigation against multipath fading.

3.5.1 Orthogonal Frequency Division Multiple Access

The principle of the OFDMA is based on the use of narrow, mutually orthogonal subcarriers. In LTE-A the sub-carrier spacing is typically 15 kHz regardless of the total transmission bandwidth. Different sub carriers maintain orthogonal, as at the sampling instant of a single subcarrier the other sub-carriers have a zero value. Much more efficient use of bandwidth can be obtained with a parallel system if the spectra of the individual sub channels are permitted to overlap. With the addition of coherent detection and the use of subcarrier tones separated by the reciprocal of the signaling element duration (orthogonal tones), independent separation of the multiplexed tones is possible. The transmitted signal now has the following key properties.

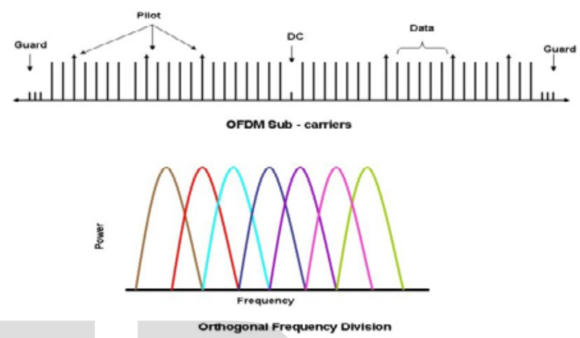

Fig. 3. OFDM principle.

- The symbol duration is clearly longer than, for example, with WCDMA and also longer than the channel impulse response; thus, the channel impact is equal to a multiplication by a (complex-valued) scalar.
- There is no inter-symbol interference, as the transmitter uses a guard period (cyclic prefix) longer than the channel impulse response, which is ignored in the receiver and, thus, the effect of the previous symbol is not visible.
- The outcome of an FFT is thus a single signal which is basically a sum of sinusoids and having an amplitude variation that is larger the more sub -carriers have been used as an input to an FFT block.

This kind of signal is ideal from the receiver perspective as one does not need equalizer but only need to compensate the channel amplitude and phase impact on the different subcarriers .In the receiver side one uses again the FFT to convert back from the frequency domain single signal to the time domain representation of multiple sub-carriers .The channel estimation is done based on the known data symbols that need to be placed periodically on parts of the sub-carriers. The equalizer refers to the estimator to cancel out the complex-valued multiplication caused by the frequency selective fading of the channel and does not present a great complexity. Also, the FFT and Inverse FFT (IFFT) operations are old numerical principles by which computationally efficient algorithms have long been developed [7], [8].

3.5.2 Multiple Input Multiple Output

Multiple-Input Multiple-Output (MIMO) technology is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. MIMO technology takes advantage of a radio-wave phenomenon called multipath where transmitted information bounces off walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times. Multipath is a natural occurrence for all radio sources. Radio signals bounce off objects and move at different speeds towards the receiver. In the past multipath caused interference and slowed down wireless signals. MIMO takes advantage of multipath to combine the information from multiple signals improving both speed and data integrity LTE-A uses this advantage.

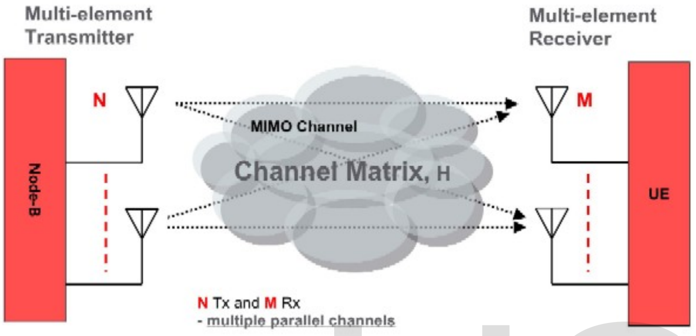

Fig. 4. MIMO system.

MIMO-SM scheme can provide a linear increase in data transmission rate with the same bandwidth and power by transmitting multiple independent data streams unlike transmission diversity where a single data stream is always transmitted independently. There exist a linear relation between the number of transmit/receive antenna pairs in a MIMO and the theoretical increase in capacity. During the first symbol time, the first data symbol, So, is transmitted from the upper transmit antenna, Tx0, and the second data symbol, s1, is transmitted from the lower transmit antenna, Tx1, this occurs simultaneously. The data rate is therefore doubled as alternate symbols are transmitted from each antenna and each symbol is only transmitted once unlike STBC where redundant data symbols are sent to give the receiver a fair chance of recovering the transmitted data [9].

3.5.3 ICI and ISI

An orthogonal frequency division multiplexing system suffers performance degradation when the length of the cyclic prefix is less than the channel impulse response. The root cause of this degradation is the inter-carrier interference (ICI) and inter-symbol interference (ISI) introduced by the excessive multipath delay.

Channel variation during an OFDM block leads to the loss of orthogonality among subcarriers, resulting in inter-carrier interference (ICI) in orthogonal frequency division multiplexing (OFDM) systems. Many schemes have been proposed to suppress ICI, but they are computationally complex or at the price of sacrificing bandwidth. In some cases, such as high-density television (HDTV) broadcasting and satellite OFDM systems, the very long delay spreads pose the possibility that the channel length exceeds that of the moderate cyclic prefix (CP), resulting in inter symbol interference (ISI) and inter carrier interference (ICI).

The price for the optimum subcarrier spacing is the sensitivity of OFDM to frequency errors. If the receiver's frequency is some fractions of the subcarrier spacing (subcarrier bandwidth) then we encounter not only interference between adjacent carriers, but in principle between all carriers. This is known as Inter-Carrier Interference (ICI) and sometimes also referred to as Leakage Effect in the theory of discrete Fourier transform. As one can see this strongly depends on the ratio between absolute offset frequency between transmitter and receiver and the subcarrier spacing. To limit the influence of the ICI on OFDM systems completely by hardware is very challenging [7].

3.6 Modulation Techniques [8]

3.6.1 QPSK

- Quadrature phase shift keying
- Quadrature means the signal shifts among phase states that are separated by 90 degrees.
- The signal shifts in increments of 90 degrees from45° to 135°, -45° (315°), or -135° (225°).
- Data into the modulator is separated into two channels called I and Q.
- Two bits are transmitted simultaneously, one per channel.
- Each channel modulates a carrier. The two carrier frequencies are the same, but their phase is offset by 90 degrees (that is, they are "in quadrature")
- The two carriers are combined and transmitted
- Four states because $2^2 = 4$
- Theoretical bandwidth efficiency is two bits/second/Hz

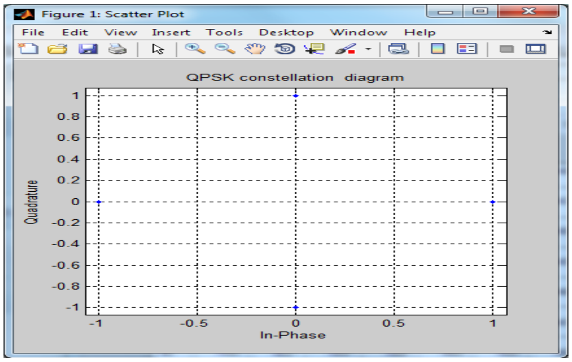

Fig. 5. QPSK modulation.

3.6.2 16-QAM

- 16-state quadrature amplitude modulation.
- Four *I* values and four *Q* values are used, yielding four bits per symbol.
- 16 states because $2^4 = 16$.
- Theoretical bandwidth efficiency is four bits/second/Hz.
- Data is split into two channels, I and Q.
- Two bits are routed to each channel simultaneously.
- The two bits to each channel are added, then applied to the respective channel's modulator.

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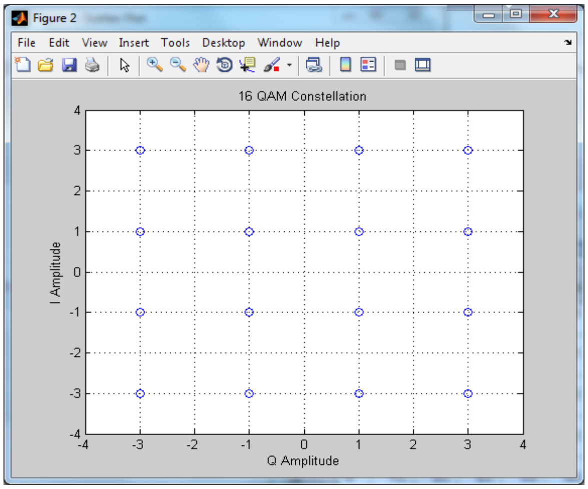

Fig. 6. 16-QAM modulation.

3.6.3 64-QAM

- 64-state quadrature amplitude modulation.
- Four *I* values and four *Q* values are used, yielding four bits per symbol.
- 64 states because $2^8 = 16$.
- Theoretical bandwidth efficiency is six bits/second/Hz.

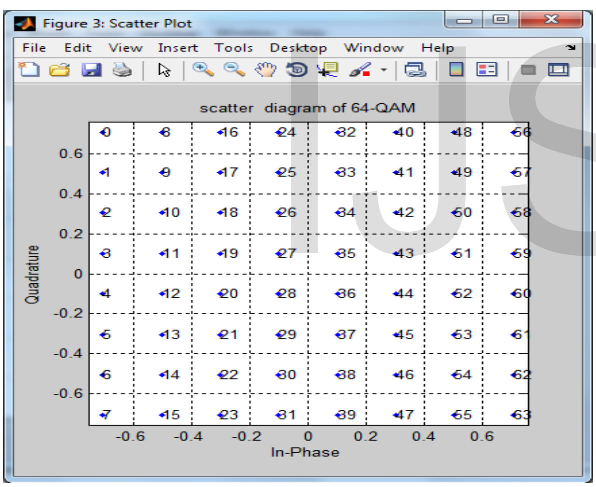

Fig. 7. 64-QAM modulation

4 SIMULATIONS AND ANALYSIS

In this section we look about implementation plan: a plan that provides output-specific segmentation. The process consists of

- OFDM transmission symbol generation.
- OFDM reception.
- Check Orthogonality in OFDM.
- Path loss in OFDM.
- BER vs. SNR in OFDM using 16-QAM.
- Capacity using MIMO

4.1 OFDM transmission symbol generation

A detailed description of OFDM can be found in [7] where we can find the expression for one OFDM symbol starting at $t = t_s$ as follows.

$$s(t)=\mathrm{Re}\left\{\sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i+N_s/2}\exp\left(j2\pi\left(f_c-\frac{i+0.5}{T}\right)(t-t_s)\right)\right\},\ t_s\le t\le t_s+T \qquad (1)$$

$$s(t)=0,\ t<t_s \ \wedge\ t>t_s+T$$

Where d_i are complex modulation symbols, N_s is the number of subcarriers, T the symbol duration and f_c the carrier frequency. A particular version of above equation is given in the DVB-T standard as the emitted signal. The expression is

$$s(t)=\mathrm{Re}\left\{e^{j2\pi f_c t}\sum_{m=0}^{\infty}\sum_{l=0}^{67}\sum_{k=K_{min}}^{K_{max}} c_{m,l,k}\cdot\Psi_{m,l,k}(t)\right\} \qquad (2)$$

Where,

$$\Psi_{m,l,k}(t)=\begin{cases} e^{j2\pi\frac{k'}{T_U}(t-\Delta-l\cdot T_S-68\cdot m\cdot T_S)} & (l+68\cdot m)\cdot T_S\le t\le(l+68\cdot m+1)\cdot T_S \\ 0 & \text{else}\end{cases} \qquad (3)$$

Where:

k denotes the carrier number;

l denotes the OFDM symbol number;
m denotes the transmission frame number;
K is the number of transmitted carriers;
T_S is the symbol duration;
T_u is the inverse of the carrier spacing;
Δ is the duration of the guard interval;
f_c is the central frequency of the radio frequency (RF) signal;
k′ is the carrier index relative to the center frequency, $k' = K-(K_{max}+K_{min})/2$;
$c_{m,0,k}$ complex symbol for carrier k of the Data symbol no.1 in frame number m;
$c_{m,1,k}$ complex symbol for carrier k of the Data symbol no.2 in frame number m;
$c_{m,67,k}$ complex symbol for carrier k of the Data symbol no.68 in frame number m;

4.1.1 FFT Implementation

The first task to consider is that the OFDM spectrum is centered on f_c ; i.e. subcarrier 1 is 7.61/2 MHz to the left of the carrier and subcarrier 1,705 is 7.61/2 MHz to the right. One simple way to achieve the centering is to use a 2N-IFFT and T/2 as the elementary period. As we can see in Table **1**, the OFDM symbol duration, TU, is specified considering a 2,048-IFFT (N=2,048); therefore, we shall use a 4,096-IFFT [7]. A block diagram of the generation of one OFDM symbol is shown in Figure 8, where we have indicated the variables used in the MATLAB code. The next task to consider is the appropriate simulation period. T is defined as the elementary period for a baseband signal, but since we are simulating a pass band signal, we have to relate it to a time-period, 1/Rs, that consider at least twice the carrier frequency. For simplicity, we use an integer relation, Rs=40/T. This relation gives a carrier frequency close to 90 MHz, which is in the range of a VHF channel five, a common TV channel in any city. We can now proceed to describe each of the steps specified by the encircled letters in figure below.

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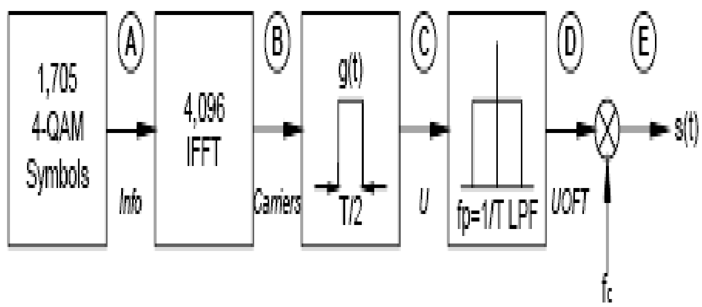

Fig. 8. OFDM symbol generation.

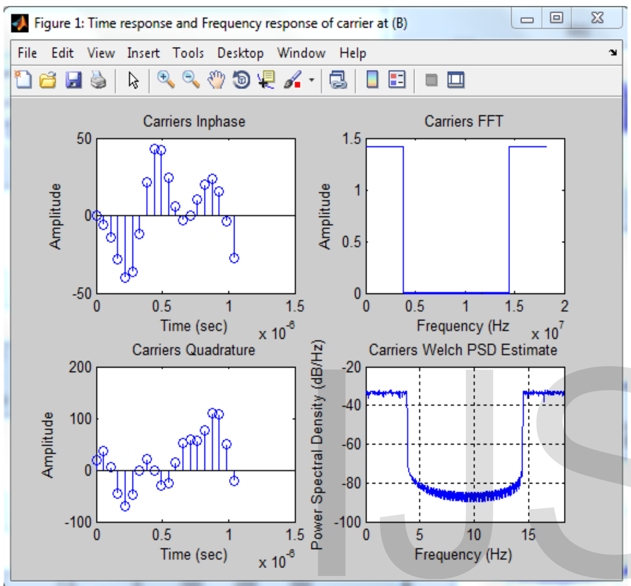

Fig. 9. Time response and Frequency response of carrier at(B).

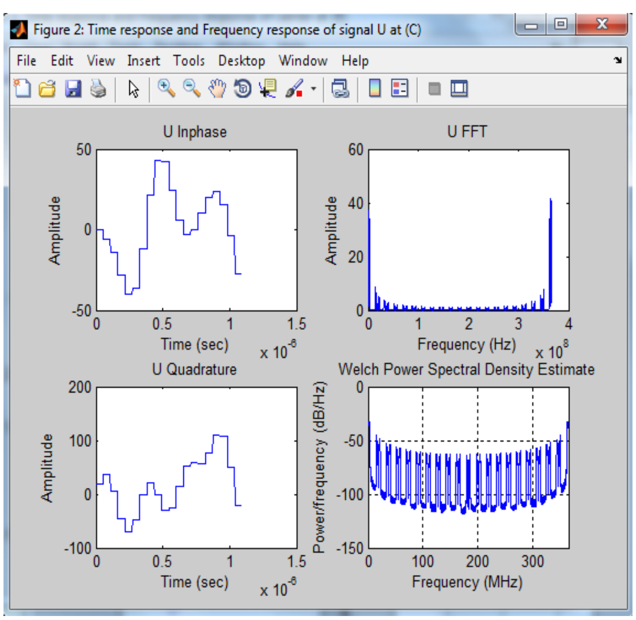

Fig. 10. Time response and Frequency response of signal U.

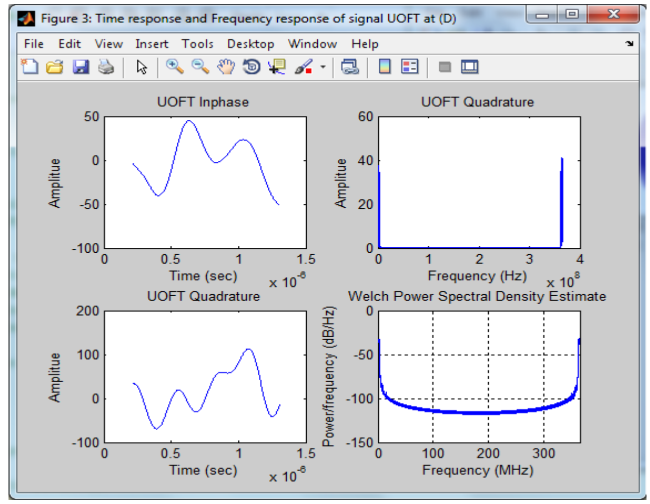

Fig. 11. Time response and Frequency response of signal UFOT at (D).

The next step is to perform the quadrature multiplex double-sideband amplitude modulation of *uoft(t)*. In this modulation, an in-phase signal $m_I(t)$ and a quadrature signal $m_Q(t)$ are modulated using the formula:

$$s(t) = m_I(t)\cos(2\pi f_c t) + m_Q(t)\sin(2\pi f_c t) \qquad (4)$$

$$s(t) = \sum_{k=K_{min}}^{K_{max}} \mathrm{Re}\left(c_{0,0,k}\right)\cos\left[2\pi\left(\left(\frac{k-\frac{K_{max}+K_{min}}{2}}{T_U}\right)+f_c\right)t-\frac{\Delta}{T_U}\right] - \sum_{k=K_{min}}^{K_{max}} \mathrm{Im}\left(c_{0,0,k}\right)\sin\left[2\pi\left(\left(\frac{k-\frac{K_{max}+K_{min}}{2}}{T_U}\right)+f_c\right)t-\frac{\Delta}{T_U}\right] \qquad (5)$$

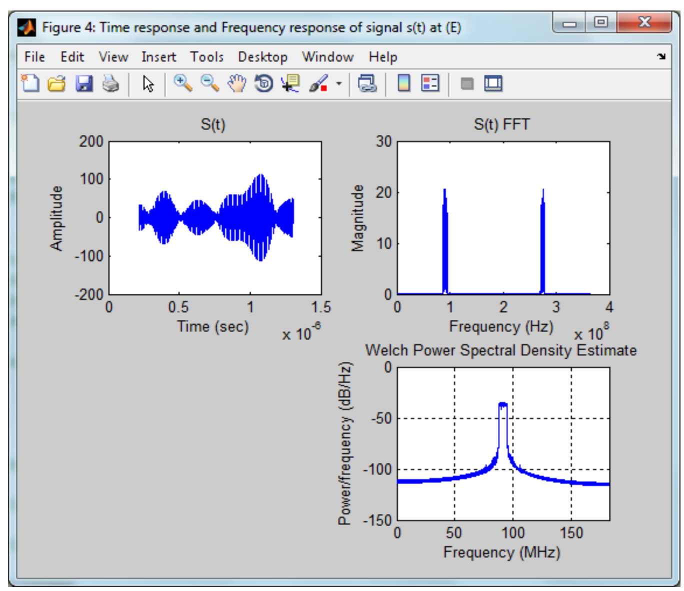

Fig. 12. Time response and Frequency of the signal s(t) at E.

The corresponding operation for the IFFT process is

$$s(t) = uoft_I(t)\cos(2\pi f_c t) - uoft_Q(t)\sin(2\pi f_c t). \qquad (6)$$

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The time and frequency responses for the complete signal, s(t), is shown in Figure 12. We can observe the large value of the aforementioned PAR in the time response of Figure 12.

4.2 OFDM Reception

As we mentioned before, the design of an OFDM receiver is open; i.e., there are only transmission standards. With an open receiver design, most of the research and innovations are done in the receiver. For example, the frequency sensitivity drawback is mainly a transmission channel prediction issue, something that is done at the receiver; therefore, we shall only present a basic receiver structure in this report. A basic OFDM Receiver that just follows the inverse of the transmission process is shown in Figure 13.

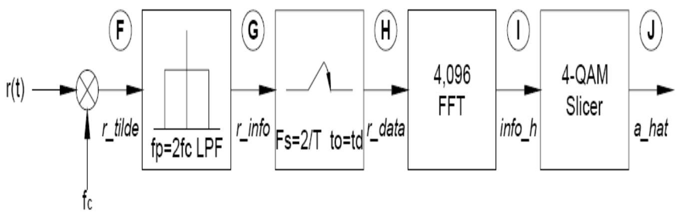

Fig. 13. OFDM reception simulation.

4.3 How ICI & ISI is solved using our symbol generation for MIMO-OFDM system?

ISI is introduced due to the delay spread of the channel wherein one OFDM symbol spreads in time and interferes with the succeeding OFDM symbol. ISI is tackled using Cyclic Prefix (CP) where the CP length is kept slightly more than the channel delay spread. ICI can be introduced by the Doppler spread of the channel wherein the OFDM sub-carriers no longer remain orthogonal to each other. ICI can be mitigated by estimating the Doppler and adjusting the sub-carrier spacing accordingly.

A time-domain equalizer (TEQ) with spectral symbol generation is used in the transmitter and receiver to reduce the duration of the overall response of the transmission system, and therefore minimize the ISI and ICI.

4.4 Check orthogonality in OFDM

Consider the time-limited complex exponential signals $\{e^{j2\pi f_k t}\}_{k=0}^{N-1}$ which represent the different subcarriers at $f_k = k/T_{sys}$ in the OFDM signal, where $0 \le t \le T_{sym}$. These signals are defined to be orthogonal if the integral of the products for their common (fundamental) period is zero which is shown below [9].

$$\frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi f_k t} e^{-j2\pi f_i t}\,dt = \frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi\frac{k}{T_{sym}}t} e^{-j2\pi\frac{i}{T_{sym}}t}\,dt = \frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi\frac{(k-i)}{T_{sym}}t}\,dt = \begin{cases} 1, & \forall \text{integer } k = i \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

Taking the discrete samples with the sampling instances at t = nT_s = nTsym/N,

n = 0, 1, 2, …, N-1. Equation (6) can be written in the discrete time domain as

$$\frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi\frac{k}{T_{sym}}\cdot nT_s} e^{-j2\pi\frac{i}{T}\cdot nT_s} = \frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi\frac{k}{T_{sym}}\cdot\frac{nT}{N}} e^{-j2\pi\frac{i}{T_{sym}}\cdot\frac{nT_{sym}}{N}} = \frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi\frac{(k-i)}{N}n} = \begin{cases} 1, & \forall \text{integer } k = i \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

The above orthogonality is an essential condition for the OFDM signal to be ICI-free.

```
>> test_orthogonality
 ans =
 1.00         -0.00+0.00i  0.00-0.00i  -0.00-0.00i  -0.02-0.03i  0.06-0.08i
-0.00-0.00i   1.00        -0.00-0.00i  -0.00+0.00i  -0.04-0.03i -0.01-0.11i
 0.00+0.00i  -0.00+0.00i   1.00         0.00+0.00i  -0.08+0.07i -0.11+0.03i
-0.00+0.00i  -0.00-0.00i   0.00-0.00i   1.00         0.29-0.94i -0.76-0.58i
 0.02+0.03i  -0.04+0.03i  -0.08-0.07i   0.29+0.94i   1.00        0.33-0.85i
 0.06+0.08i  -0.01+0.11i  -0.11-0.03i  -0.76+0.58i   0.33+0.85i  1.00
```

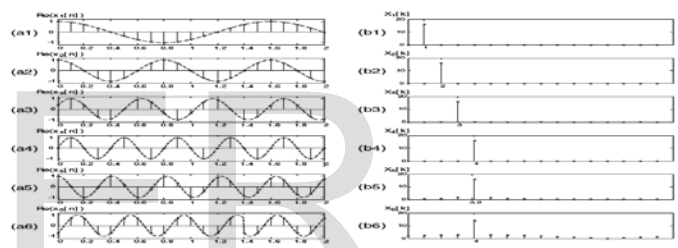

Fig. 14. Sinusoidal signals with different frequencies/phases and their DFTs.

4.5 Path Loss in OFDM

The free-space propagation model is used for predicting the received signal strength in the line of-sight (LOS) environment where there is no obstacle between the transmitter and receiver

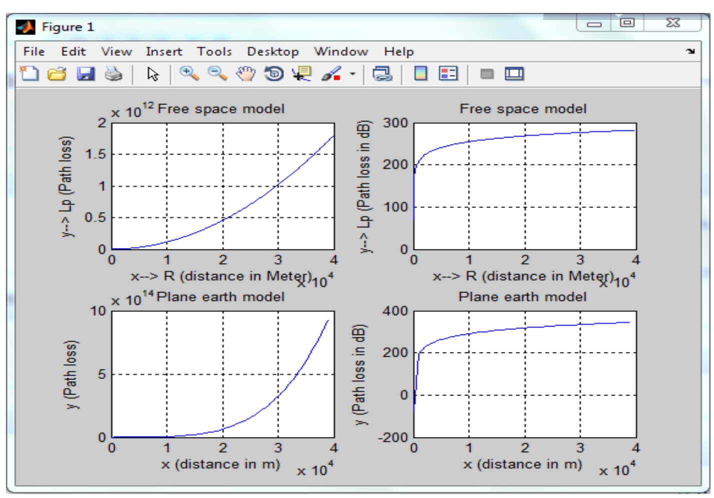

Fig. 15. Free space path loss model and plane earth model.

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Figure 15 shows the free-space path loss and plane earth path loss for different antenna gains as the distance varies. It is obvious that the path loss increases by reducing the antenna gains. As in the aforementioned free-space model, the average received signal in all the other actual environments decreases with the distance between the transmitter and receiver, R, in a logarithmic manner.

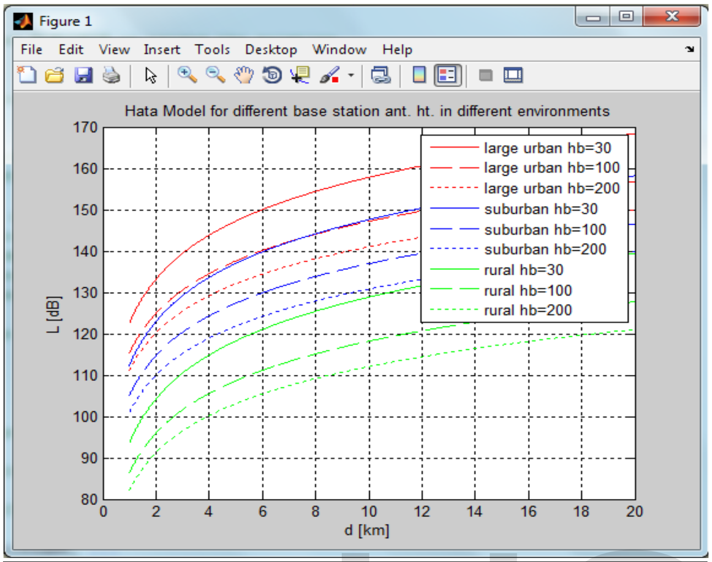

Fig. 16. Okumura/Hata path loss model.

Figure 16 shows Okumura/Hata path loss model.

4.6 BER vs. SNR in OFDM using 16-QAM

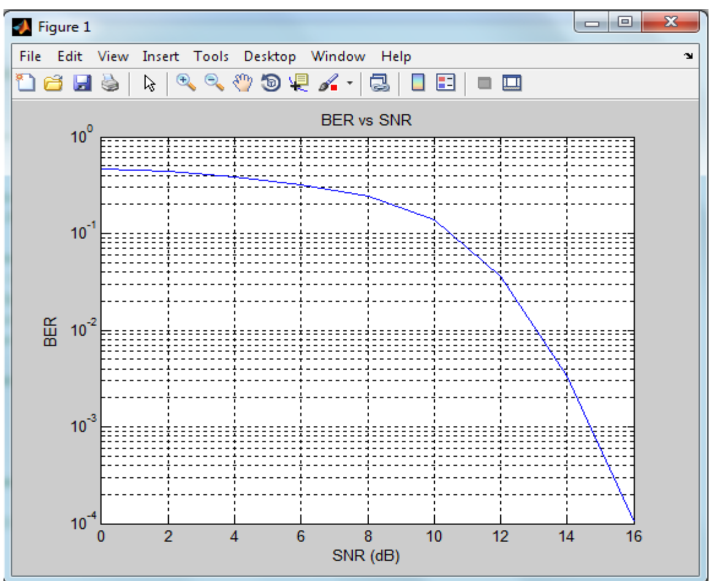

Fig. 17. BER vs. SNR for 16-QAM.

The above Figure 17 shows comparison of BER at the three different channels. For small SNR values the calculated BER is quite large due to relative high power of noise. As SNR is increased the BER decreases as shown.

4.7 Capacity Using MIMO

In general, however, MIMO channels change randomly. Therefore, H is a random matrix, which means that its channel capacity is also randomly time-varying.

In other words, the MIMO channel capacity can be given by its time average. In practice, we assume that the random channel is an ergodic[2] process.

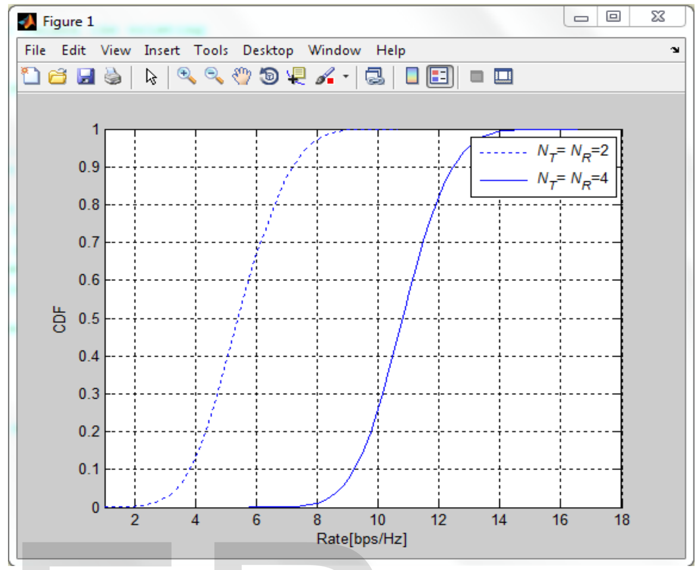

Fig. 18. Distribution of MIMO channel capacity.

Figure 18 shows the CDFs of the random 2 × 2 and 4 × 4 MIMO channel capacities when SNR is 10dB. It is clear from Figure 18 that the MIMO channel capacity improves with increasing the number of transmit and receive antennas.

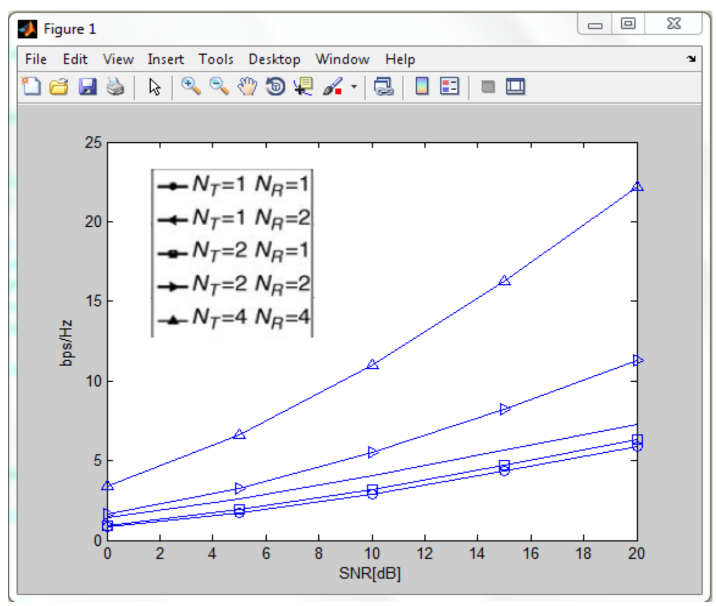

Fig. 19. Ergodic MIMO channel capacity when CSI is not available at the transmitter.

In Figure 19, we have shown that the ergodic channel capacity as varying the number of antennas, under the same conditions as for figure 18.

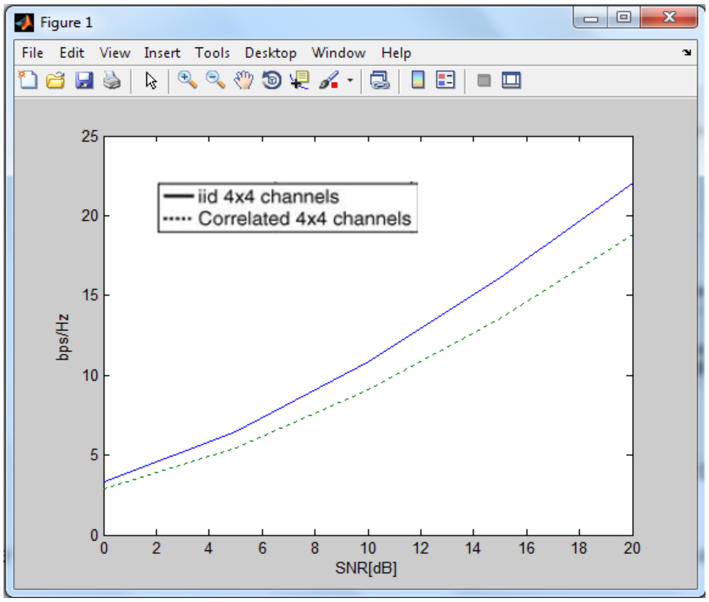

Fig. 20. Capacity reduction due to the channel correlation.

Figure 20 shows that a capacity of 3.3 bps/Hz is lost due to the channel correlation when SNR is 18dB.

4.8 Applications of simulated technologies

LTE-A is a new technology in the world and obviously in Bangladesh. In the development of technology, every new item comes with greater opportunities to the world. How the paper's concept can be used and which are the field are pointed below:

- Higher spectral efficiency allows the operators to support the large number of users within their existing networks and future's spectrum allocation with the low cost of delivery per bit.
- Reduced round trip time (RTT) to 10msec or even less than that. This offers better quality for interactive real time services like high quality audio/video conferencing and multi-player gaming.
- LTE-A can offer the optimum performance in the cell size of up to 5km. it is still capable of delivering the much effective performance in cell having the cell sizes of up to 30km.In addition LTE also enables to deliver the limited services in cell sizes up to 100km.
- One of the main features of LTE-A is its transition to a flat i.e. all-IP based core network has a very simplified architecture and open interfaces.
- The subscribers of LTE-A can be able to make the voice calls from their terminals and access basic data services even when they are present in location without the LTE coverage.
- LTE-A breaks the boundaries between the home and outside, meaning that many advance application can be shared between the home computer and outside the home.
- The introduction of the above features in the LTE-A environment should be able to reduce the cost per bit.

5 CONCLUSIONS AND FUTURE WORK

5.1 Conclusion

LTE Advanced offers high speed access to internet, with high speed internet connection on mobile, where users can enjoy voice calls, video calls, and high speed downloads or uploads of any data and watch internet TV in live or on demand services. The main targets for this evolution are increased data rates, improved spectrum efficiency, improved coverage, reduced latency and packet optimized system that support multiple Radio Access Technologies.

The paper has presented toward LTE-Advanced technologies (Orthogonal Frequency Division Multiplexing (OFDM), also focused on LTE Advanced technologies (MIMO enhancements for LTE-Advanced, carrier aggregation, peak data rate, mobility and co-ordinated multi-point transmission (CoMP). LTE-Advanced is a very flexible and advanced system, further enhancements to exploit spectrum availability and advanced multi-antenna techniques.

In addition to relaying and repeater solution to enhance coverage and cell edge data rates, an evolution of the inter-cell interference coordination in the form of coordinated multipoint transmission/reception is yet another technology to enhance performance.

We want to mention that, in our country, the complete 4G technologies can be implemented using MIMO-OFDM technique. And this would be far more effective and can make a revolutionary step to cope with the modern wireless world as well as the user demand.

Generally, multiple-input multiple-output (MIMO) beam forming is helpful in mitigating such interference because it can spatially suppress some of the multipath. However, the effectiveness of this suppression is very limited. In this paper, we propose an ICI/ISI-aware orthogonal symbol generation techniques which explicitly takes into account the multipath characteristic of the channel. Carrier and user data's are spread spectrum with time and frequency respect to the exact corresponding domains are derived to maximize the signal-to-interference-plus-noise ratio by decreasing BER. In this paper, via simulations, that the proposed techniques those can dramatically reduce the ISI, ICI, block error rate, permitting good performance for channel delay profiles that would break conventional links. This is vitally important for the extension of indoor wireless LAN designs to outdoor uses.

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5.2 Future work

Only the architectural configurations and possibilities of LTE-A using MIMO-OFDM are discussed in this paper with respect to developing countries. If the proposal is implemented, we keep our hope; it will surely encourage further research to build a real wireless world wide web with all-IP based network.

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