Performance Analysis of 3GPP LTE

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Abstract*:*
One of the key concerns in identifying the technological innovation to involve in LTE, is the trade-off between cost of performance and genuine advantages. The 3GPP LTE is a new standard with commendable performance targets, therefore it is necessary and urgent to evaluate the performance and quality of this new system at an initial phase in order to promote its smooth and cost-efficient introduction and implementation. This work therefore aims at evaluating the performance of LTE Downlink with different MIMO antenna configuration and techniques under different channel conditions and this evaluation is based on performance metric such as BER against SNR.
Keywords: 3GPP LTE, BER, MIMO, OFDMA, SCFDMA.

1. Introduction

Long Term Evolution (LTE) of the Universal Mobile Telecommunication System (UMTS) is a clear move in the field of mobile communications. It was necessitated by the constant increase in demand for high speed connections on networks, delay, low error rates and resilience because modern users and network applications have become increasingly dependent on these requirements for efficient functionality and performance. Third Generation Partnership Project Long Term Evolution (3GPP LTE) promises high peak data rates for both downlink and uplink transmission, spectral efficiency, low delay and latency, low bit error rates, to mention but a few. LTE leverages on a number of technologies namely MIMO antennas, Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiplexing Access (OFDMA) at the downlink, Single Carrier Frequency Division Multiple Access (SCFDMA) at the uplink, support for Quadrature Phase Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (16QAM), and 64QAM.

During the last several years along with ongoing development of systems and devices technology and the globalization of 3rd Generation of Mobile Communication Systems, the support for voice and data services have encountered a greater development compared to 2nd Generation Systems. At the same time 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 improved by adopting some advanced technologies. It has been confirmed in both concept and practice that some novel technologies such as orthogonal frequency division multiplexing (OFDM) and multiple input, multiple output (MIMO) systems, can improve the performance of the current wireless communication systems. The high data rates and the high capacity can be attained by using the advantages of the two technologies. From a standardization viewpoint 3G era is now well innovative. While upgrades continue to be made to make use of the highest possible performance from currently implemented systems, there is a limit to the level to which further upgrades will be effective. If the only purpose were to provide excellent performance, then this in itself would be relatively easy to achieve. The added complexity is that such excellent performance must be delivered through systems which are cheaper from installation and maintenance prospect. Users have experienced an amazing reduction in telecoms expenses and they now predict receiving better high quality communication solutions at low prices. Therefore, in determining the following standardization phase, there must be a double approach; in search of significant performance improvement but at a low cost. Long Term Evolution (LTE) is that next phase and will be the basis on which future mobile telecoms systems will be built. LTE is the first cellular communication system enhanced from the beginning to support packet-switched data services, within which packetized voice devices are just one part. The 3rd Generation Partnership Project (3GPP) started work on Long Term Evolution in 2004 with the description of targets and it is defined in its specifications [1].

The specifications associated to LTE are formally identified as the evolved UMTS terrestrial radio access network (E-UTRAN) and the evolved UMTS terrestrial radio access (E-UTRA). These are jointly known as LTE. In December 2008, release of LTE was approved by 3GPP which allowed 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. In addition to the continued advancement in wire line technologies, a similar growth is needed for technological innovation to work with complete confidence with described requirements in the wireless domain. 3GPP technological innovation must match and go beyond the competition with other wireless technologies which guarantee high data capabilities – such as IEEE 802.16. To take maximum advantage of available spectrum, large capacity is an important factor. LTE is needed to offer superior performance compared to High Speed Packet Access (HSPA) technology according to 3GPP specifications. The 3GPP LTE release 8 specification describes the basic performance of a new, high-performance air interface providing high user data rates along with low latency based on MIMO, OFDMA (Orthogonal Frequency Division Multiple Access), and an Enhanced System Architecture Evolution (SAE) as main enablers. The LTE solution provides spectrum flexibility with scalable transmission bandwidth between 1.4 MHz and 20 MHz depending on the available spectrum for flexible radio planning. The 20 MHz bandwidth can provide up to 150 Mbps downlink user data rate and 75 Mbps uplink peak data rate with 2 × 2 MIMO, and 300 Mbps with 4 × 4 MIMO[2].

2. LTE at a Glance

LTE is now being implemented and is the way ahead for high-speed mobile solutions. There has been a fast improvement in the use of information carried by mobile services, and this improvement will only become bigger in what has been known as “data explosion”. To take care of this and the improved requirements for improved information transmission rates and lower latency, further growth of mobile technological innovation have been required.

The UMTS mobile technological innovation update has been known as LTE – Long Term Evolution. The concept is that LTE will allow much greater or higher rates of speed to be obtained along with much reduced packet latency (an increasing need by many users these days), and that 3GPP LTE will allow mobile device services to progress to fulfill the needs for mobile technological innovation to 2017 and well beyond.

Many service providers have not yet improved or updated their basic 3G systems and 3GPP LTE is regarded as the next sensible phase for many service providers, who will jump directly from the primary 3G directly to LTE as this will prevent offering several levels of upgrade. The utilization of LTE will also offer the information abilities that will be needed for many decades and until complete release of the full 4G requirements known as LTE Advanced is achieved [3].

3. 3G LTE Evolution

Although there are significant phase changes between LTE and its 3G forerunners, it is nevertheless seemed upon as a progress of the UMTS/3GPP 3G requirements. Although it uses a different way of radio interface, using OFDMA/SCFDMA instead of CDMA, there are many resemblances with the previous types of 3G architecture and there is chance for a great deal of re-use [4].

LTE can be projected to offer a further development or progress of performance, enhanced rates of speed and general enhanced performance. LTE is an all IP based network, supporting both IPv4 and IPv6. LTE is concentrating on the best possible support of Packet Switched (PS) services. Primary requirements for the design of an LTE system were determined in the beginning of the standardization work on LTE [5]

4. Technologies for LTE:

LTE provided a variety of new technologies when compared to the past mobile systems. They allow LTE to be able to operate more successfully with regards to the use of spectrum and also to offer the much higher data rates that are being required.

Three fundamental technologies have shaped the LTE radio interface design and are: Multicarrier Technology, Multiple Antenna Technology (MIMO) and the application of packet switching to the radio interface. Lastly, we review the blends of abilities that are reinforced by different categories of LTE mobile terminal [3].

4.1 Multicarrier Technology:

Adopting a multicarrier approach for multiple access in LTE was the first significant design choice. After preliminary relief of suggestions, the candidate schemes for the downlink were Orthogonal Frequency-Division Multiple Access (OFDMA) and Multiple WCDMA, while the candidate schemes for the uplink were Single Carrier Frequency-Division Multiple Access (SC-FDMA), OFDMA and Multiple WCDMA. The option of multiple access schemes was created in December 2005, with OFDMA being chosen for the downlink and SC-FDMA for the uplink. Both of these schemes start up the frequency domain as a new dimension of flexibility in the systems [3]. One of the key components is the use of Orthogonal Frequency-Division Multiple (OFDM) as the signal bearer and the associated access schemes, OFDMA and SC-FDMA [3].

4.2 Orthogonal Frequency-Division Multiple (OFDM)

OFDM is used in LTE Downlink by virtue of simple implementation in receiver and high performance. In OFDM, Frequency selective wide band channel is divided into non-frequency selective narrowband sub-channels that are orthogonal to each other [3]. Each subcarrier is modulated based on conventional modulation schemes such as QPSK, 16QAM and 64QAM.
Transmission of a high data rate stream results in an Inter Symbol Interference (ISI) problem. This problem arises from the fact that the channel delay spread is greater than the symbol period when data is transmitted as a serial stream. To avoid this problem in OFDM, the serial data stream is converted to N parallel subcarriers. This conversion guarantees that the symbol duration is now N times larger than the channel delay spread and avoids ISI. The serial-to-parallel block converts serial data to the N parallel subcarrier. Then subcarriers are individually modulated. Subcarriers can carry different data rates since the channel gain can be different between subcarriers due to the channel frequency selectivity. The Inverse Fast Fourier Transform (IFFT) block converts N frequency domain data symbols to N complex time domain. One of the key steps in OFDM signal generation is to add Cyclic Prefix (CP) to avoid ISI. CP is generated by duplicating the last symbols of IFFT output and adding them to the beginning of that symbol. It should be considered that the length must be longer than the longest supported channel response. The final step is to convert the IFFT output symbols to serial data stream to be transferred through the frequency selective channel. At the receiver the inverse process takes place to obtain ISI free symbols [3].
One of the remarkable disadvantages of OFDM is high Peak-to-Average Power Ratio (PAPR). Amplitude variation of OFDM symbols is high due to the fact that the time domain OFDM symbols can be considered as Gaussian waveform. Therefore, the OFDM signal is distorted from nonlinear power amplifiers. To eliminate distortion, power amplifiers need to be operated with larger operating point that lead to expensive transmitters.
Another significant problem of OFDM is that OFDM is sensitive to carrier frequency offset and time- varying channels. Different reference frequencies used in transmitter and receiver cause Inter-Carrier Interference (ICI) that contributes to lose OFDM orthogonality. Components that are used in the user terminal are cost effective, and the local crystal in the receiver may have more intense problems of drifting than the one in the transmitter. This can cause a Carrier Frequency Offset (CFO) that may be greater than subcarrier spacing. Even in cases where transmitter and receiver frequencies are synchronized, the impact of Doppler can cause frequency errors [3].
In OFDM All subcarriers at any given time are received by a single user; however, in OFDMA subcarriers are received by multiple users simultaneously, providing a multiuser scheme. OFDMA can be used with the TDMA (Time Division Multiple Access) technique, meaning that a group of subcarriers is assigned to be transmitted during a specific time period [3]. The main motive for OFDMA in LTE and some other systems go down to its better performance in frequency selective fading channels; low complexity of base-band receiver; better spectral properties and usage of so many bandwidths; link adaptation and frequency domain scheduling; and finally it's usage with advanced receiver and antenna technologies.

4.3 Orthogonal Frequency-Division Multiple Access (OFDMA) basics

The transmitter concept in any OFDMA system is to use narrow, mutually orthogonal subcarriers. In LTE the sub-carrier spacing is 15 kHz regardless of the total transmission bandwidth. Different sub-carriers are orthogonal to each other, as at the sampling instant of only one subcarrier the other sub-carriers have a zero value. The transmitter of an OFDMA system uses IFFT block to create the signal. The data source feeds to the serial-to-parallel conversion and further to the IFFT block. Each input for the IFFT block tallies to the input representing a particular sub-carrier (or particular frequency component of the time domain signal) and can be modulated independently of the other subcarriers.

Each sub channels can completely be separated by the FFT at the receiver when there are no ISI and ICI introduced by channel distortion. Practically these conditions cannot be obtained. Since the spectra of an OFDM signal is not strictly band limited, linear distortion such as multipath fading cause sub channel to spread energy in the adjacent channels [4]. This problem can be solved by increasing symbol duration. One way to prevent ISI is to create a cyclically extended guard interval, where each symbol is preceded by a periodic extension of the signal itself. The main reasons to use a cyclic prefix for the guard band interval are [4]:

1. To maintain the receiver carrier synchronization.
2. Cyclic convolution can still be applied between the OFDM signal and the channel response to model the transmission systems.

The use of OFDMA in a base station transmitter is that users can be assigned generally to any of the subcarriers in the frequency domain. The possibility of having different subcarriers to assigned users allows the scheduler to benefit from the differences in the frequency domain, this differences being due to the temporary interference and fading differences in different parts of the system bandwidth as allocation is not done on a single subcarrier but on resource blocks, each made up of 12 subcarriers, resulting in the minimum bandwidth allocation being 180 kHz. When the respective allocation resolution in the time domain is 1 ms, the downlink transmission resource allocation means filling the resource shared with 180 kHz blocks at 1 ms resolution.
Due to the use of extra back-off by the signal in time domain in the amplifier, results in the reduction of the amplifier power performance or smaller output power and this causes the uplink range to be smaller and it consumes the battery energy quicker due to high amplifier power consumption. Though it is not an issue for the base station where the devices are connected to the mains but for the mobile devices running on their own battery power, it makes it difficult and consumes the battery power quick. For this reason, 3GPP made the decision to use OFDMA in the downlink direction and use the power efficient SC-FDMA in the uplink direction [6].

4.4 Single-Carrier Frequency-Division Multiple Access (SC-FDMA)

For the LTE uplink, a different idea is used for the access technique. Although still using a form of OFDMA technology, the implementation is known as Single Carrier Frequency Division Multiple Access (SC-FDMA) [9]. The high Peak-to-Average Power Ratio (PAPR) associated with OFDM led 3GPP to look for a different modulation scheme for the LTE uplink. SC-FDMA was chosen since it combines the low PAPR techniques of single-carrier transmission systems, such as GSM and CDMA, with the multipath resistance and flexible frequency allocation of OFDMA [7]. Data symbols in the time domain are converted to the frequency domain using a Discrete Fourier Transform (DFT), once in the frequency domain; they are mapped to the desired location in the overall channel bandwidth before being converted back to the time domain using an Inverse FFT (IFFT). Finally, Cyclic Prefix (CP) is inserted. SC-FDMA is sometimes called Discrete Fourier Transform Spread OFDM (DFT S-OFDM) because of this process [7].

4.5 Multiple Antenna Technology (MIMO)

MIMO antenna technology is one of the key technologies leveraged on by LTE. It is a technology in which multiple antennas are used at both the transmitter and at the receiver for enhanced communication: The use of additional antenna elements at either the base station (eNodeB) or User Equipment side (on the uplink and/or downlink) opens an extra spatial dimension to signal precoding and detection. Based on the options and availability of these antennas at the transmitter and/or receiver, the following classifications exist [5]:

4.5.1 Single-Input Multiple-Output (SIMO)

A simple scenario of this is an uplink transmission whereby a multi-antenna base station (eNodeB) communicates with a single antenna User Equipment (UE).

4.5.2 Multiple-Input Single-Output (MISO)

A downlink transmission whereby a multi-antenna base station communicates with a single antenna User Equipment (UE) is a scenario.

4.5.3 Single-User MIMO (SU-MIMO)

This is a point-to-point multiple antenna link between a base station and one UE.

4.5.4 Multi-User MIMO (MU-MIMO)

This features several UE"s communicating simultaneously with a common base station using the same frequency- and time-domain resources.
MIMO is only used for the shared channel and only to transmit those resource blocks assigned to users that experience very good signal conditions. For other channels, only a single stream operation with

a robust modulation and coding is used as the eNodeB has to ensure that the data transmitted over those channels can reach all mobile devices independent of their location and current signal conditions. Transmitting simultaneous data sources over the same channel is possible only if the sources stay mostly separate of each other on the way from the transmitter to the receiver. This can be carried out if two simple specifications are met. On the transmitter side, two or four independent hardware transmit chains are required to create the simultaneous data streams. In addition, each data stream requires its own antenna. For two streams, two antennas are required. This is done within a single antenna casing by having one internal antenna that transmits a vertically polarized signal while the other antenna is positioned in such a way as to transmit its signal with a horizontal polarization. It should be noted at this point that polarized signals are already used today in other radio technologies such as UMTS to create diversity, that is, to improve the reception of a single signal stream. A MIMO receiver also requires two or four antennas and two or four independent reception chains. For small mobile devices, such as smart phones, this is challenging because of their limited size. For other mobile devices, such as notebooks or net books, antennas for MIMO operation with good performance are much easier to design and integrate. Here, antennas do not have to be printed on the circuit board but can, for example, be placed around the screen or through the casing of the device. The matter is further complicated because each radio interface has to support more than one frequency band and possibly other radio technologies such as GSM, UMTS and CDMA, which have their own frequencies and bandwidths. The second requirement that has to be fulfilled for MIMO transmission is that the signals have to remain as independent as possible on the transmission path between the transmitter and the receiver. This can be achieved if simultaneous transmissions reach the mobile device via several independent paths. This is possible even in environments where no direct line of sight exists between the transmitter and the receiver [8].

5. LTE Network Architecture

System Architecture Evolution (SAE) is the evolution associated with the core network along with the radio access technology, indicated as LTE. SAE was developed to satisfy the requirements of LTE and provide improved data capacity, reduced latency and cost (capital expenditure and operational expenditure), and support for packet switch configuration. Hence LTE architecture consists of two main parts: EUTRAN (EUTRA Node) and EPC (Evolved Packet Core). These two nodes together comprise an Evolved Packet System (EPS). EPS routes the IP packet with a given Quality of Service (QoS), called an EPS bearer, from the Packet Data Network Gateway (P-GW) to User Equipment (UE) [9].

6. Multiple Antenna Techniques

Generally, multiple antenna techniques utilize multiple antennas at the transmitter or/and receiver in combination with adaptive signal processing to provide smart array processing, diversity combining or spatial multiplexing capability of wireless system [10, 11]. Previously, in conventional signal antenna systems the exploited dimensions are only time and frequency whereas multiple antenna systems exploit an additional spatial dimension. The utilization of spatial dimension with multiple antenna techniques fulfils the requirements of LTE; improved coverage (possibility for larger cells), improved system capacity (more user/cell), QoS and targeted date rates are attained by using multiple antenna techniques as described in [12]. Multiple antenna techniques are the integrated part of LTE specifications because some requirements such as user peak data rates cannot be achieved without the utilization of multiple antenna schemes.

The radio link is influenced by the multipath fading phenomena due to constructive and destructive interferences at the receiver. By applying multiple antennas at the transmitter or at the receiver, multiple radio paths are established between each transmitting and receiving antenna. In this way dissimilar paths will experience uncorrelated fading. To have uncorrelated fading paths, the relative location of antennas in the multiple antenna configurations should be distant from each other. Alternatively, for correlated fading (instantaneous fading) antenna arrays are closely separated. Whether uncorrelated fading or correlated fading is required depends on what is to be attained with the multiple antenna configurations (diversity, beam-forming, or spatial multiplexing) [10]. Generally, multiple antenna techniques can be divided into three categories (schemes) depending on their different benefits; spatial diversity, beam-forming and spatial multiplexing which will be discussed further in the following sections.

7. Simulation Design: LTE Downlink

The 3GPP LTE simulates the Downlink communication from one Evolved Universal Terrestrial Radio Access Network (E-UTRAN) also known as eNodeB, to one User Equipment

(UE) using a Channel and the Uplink communication from the UE to the eNodeB [13]. There are four main parts of the simulator: Transmitter (eNodeB), Channel, Receiver (UE) and finally the Outputs are calculated in one part. The LTE simulator is mainly modeled in the physical layer. In terms of physical channel, the simulator focuses on the Physical Downlink Shared Channel (PDSCH) and Uplink (PUSCH). Moreover, the simulator operates in terms of sub-frames, i.e. the generation and transmission of signals are in the form of sub-frames [13].

7.1 MIMO Transmission

MIMO technology involves the use of multiple antennas at the transmitter, receiver or both as in the case of 1x1, 1x2, 2x2, 4x2 and 4x4 which are currently supported in LTE but 2x2, 4x2 and 4x4 are used in this thesis. MIMO has different antenna techniques and two (2) of them are also used in this work and are currently supported by LTE simulator namely: Transmit Diversity and Spatial Multiplexing [14].

7.2 Transmit Diversity

Transmit Diversity is common in Downlink of Cellular Systems, because it is cheaper and easy to install multiple antennas at the base station than to install or put multiple antennas in every handheld device. In Transmit Diversity, to tackle or scrap fast fading and to achieve reasonable gain in fast signal-to-noise-ratio (SNR), the receiver is being provided with multiple copies of the transmitted signal. Therefore, TD is applied to have extended converge and better link quality when the users experience terrible channel conditions, in other words, this explains that TD has to do with improving system performance [14].

7.3 Spatial Multiplexing

Spatial Multiplexing is the use of multiple antennas at both the transmitter and the receiver and can benefit from multipath fading to provide additional diversity and to improve SNR compared to SISO systems. This advantage of multiple antennas can be used to provide higher data rates by efficient utilisation of SNR over the air interface. Spatial Multiplexing can provide substantial increase in data rates by transmitting different data streams over different parallel channels provided by the multiple transmit and receive antennas, while using the same bandwidth and with no additional power expenditure. In MIMO systems, increase in capacity is linearly related to the number of the transmit/receive antenna pair. In other words, SM has to do with improving capacity as in more users per cell [14].

8. Analysis of Results

The performance metric under consideration is the Bit Error Rate (BER). The Signal Noise to Ratio (SNR) is swept from 0dB to 21dB in eight (8) steps. The Multiple Input Multiple Output (MIMO) Techniques used in thıs simulation are Transmit Diversity (TD) and Spatial Multiplexing (SM). The BER simulations are performed for three different modulation types which are: QPSK, 16QAM and 64QAM in ITU channel environment which is ITU Extended Vehicular A (EVA) with delay and power values.

8.1 ITU Extended Vehicular A (EVA)

The Simulation Results are shown for 2x2, 4x2 and 4x4 MIMO using 10MHz bandwidth and MIMO techniques; Transmit Diversity and Spatial Multiplexing in ITU Extended Vehicular-A (EVA) with modulation schemes of QPSK, 16QAM and 64QAM. The parameters adopted are from 3GPP specifications.

8.1.1 Spatial Multiplexing QPSK 10MHz 2x2, 4 x2 &4 x4 EVA.

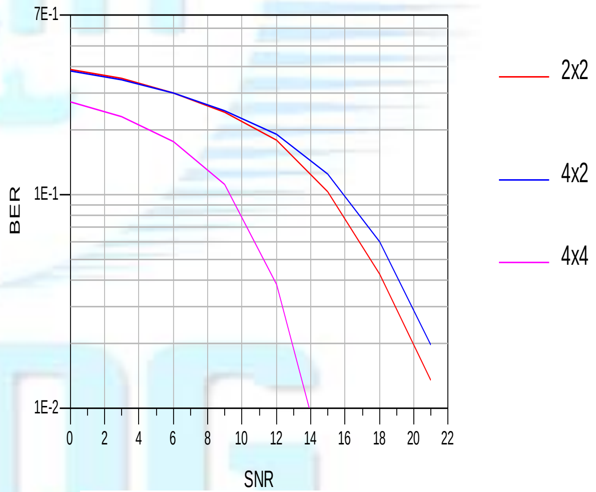

Fig 1: 2x2, 4x2 and 4x4 using QPSK with SM.

In Fig 1, the performance metric under consideration is the Bit Error Rate (BER) and from the results shown are for 2x2, 4x2 and 4x4 MIMO and it can be observe that 4x4 outperforms 4x2 and 2x2 at low BER value of 2.72 x 10^{-1} as compared to 3.79 x 10^{-1} and 3.88 x 10^{-1} for 4x2 and 2x2 respectively, though 2x2 and 4x2 will experience low error rates at high SNR. It is important to take note of the typical performance of 4x4 by observing the relatively wide gap between the 4x4 curve and that of 4x2 and 2x2. It is suggested that 4x4 be used when channel conditions deteriorates or in a scenario where the signal is bound to experience fading and distortions and 2x2 and 4x2 be used when channel conditions are normal and stable

8.1.2 Spatial Multiplexing 16QAM 10MHz 2x2, 4x2 & 4x4 EVA

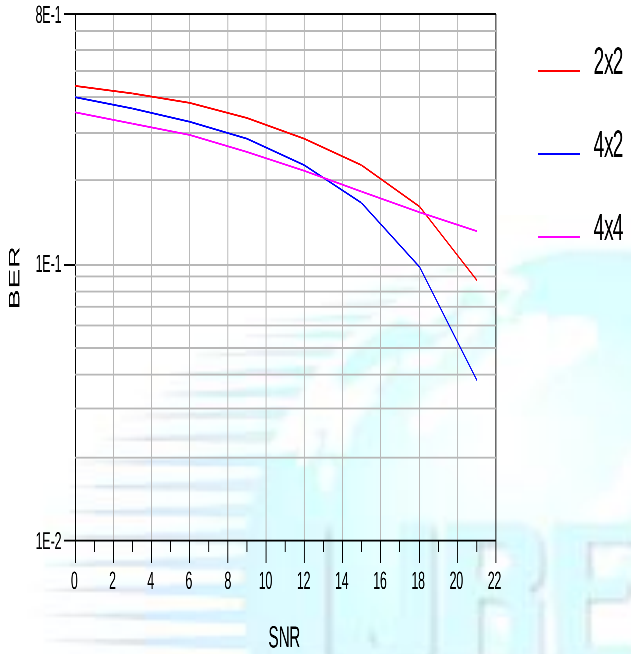

Fig 2: 2x2, 4x2 and 4x4 using 16QAM with SM.

As shown in Fig 2, with same parameters adopted and as shown in Table 4.3, 4x4 performs best at low BER of 3.54 x 10^{-1} up until the 13dB SNR mark where 4x2 exhibits gradually a better and lower BER value of 1.67 x 10^{-1} compared to 1.83 x 10^{-1} and 2.28 x 10^{-1} for 4x4 and 2x2 respectively and also at SNR 20 – 21dB, 4x4 shows a high BER value of 1.32 x 10^{-1} as compared to 8.8 x 10^{-2} and 3.8 x 10^{-2} for 2x2 and 4x2 respectively. It is also required that higher SNR and BER values are obtained in 16QAM than in the preceding QPSK and this can be attributed to the additional modulation i.e. 4 bits per symbol which helps increase data rate.

8.1.3 Spatial Multiplexing 64QAM 10MHz 2x2, 4x2 & 4 x4 EVA

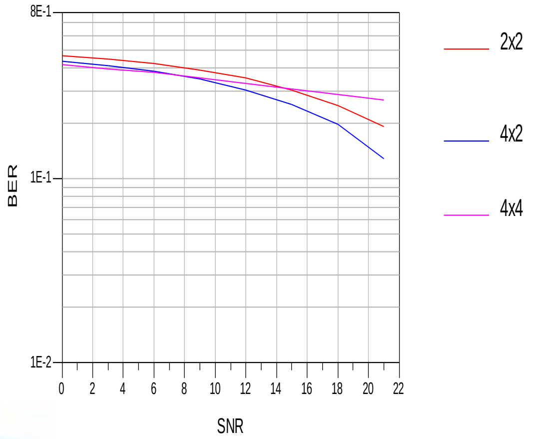

Fig 3: 2x2, 4x2 and 4x4 using 64QAM with SM.

This result is expected using 64QAM, as noise tolerance increases when higher modulation is used as 64QAM has 6 bits per symbol. It is clearly obvious that when there is need for transmitting more bits, extra SNR is required and 4x4 shows this where at 6dB SNR the BER value is 3.76 x 10^{-1} compared to 4x4 in QPSK and 16QAM where at 6dB the BER value is 1.78 x 10^{-1} and 2.94 x 10^{-1} respectively. It can be observed that at 7 – 8dB and 15dB, 4x4 has BER values of 3.54 x 10^{-1} and 3.06 x 10^{-1} as compared to 4x2 at 7 – 8dB which has a BER of 3.47 x 10^{-1} and 2x2 at 15dB which has a BER of 3.04 x 10^{-1}. In this case, 4x4 tends to perform better both in bad and stable channel conditions.

8.1.4 Transmit Diversity QPSK 10MHz 2x2, 4x2 & 4 x4 EVA

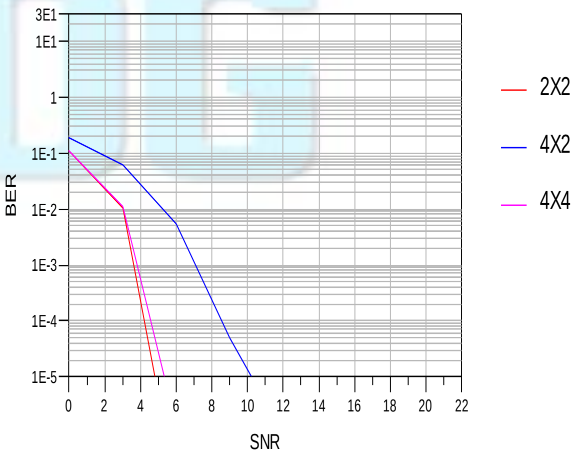

Fig 4: 2x2, 4x2 and 4x4 using QPSK with TD.

In Transmit Diversity (TD), it is always required to have low BER values as the SNR value increases compared to Spatial Multiplexing. It can be observed that 2x2 and 4x4 tends to overlap because of the antenna configuration as compared to 4x2 which has so much load because of the 4 transmit antenna sending to just 2 receive antennas. At 0dB, 2x2 has a ber value of $1.1x10^{-1}$, 1.09×10^{-1} and 1.89×10^{-1} for 4x4 and 4x2 respectively but at 3dB changes were observed with 2x2 having BER values of 1×10^{-2}, 1.1×10^{-2} and 6.3×10^{-2} for 4x4 and 4x2 respectively.

8.1.5 Transmit Diversity 16QAM 10MHz 2x2, 4x2 & 4 x4 EVA

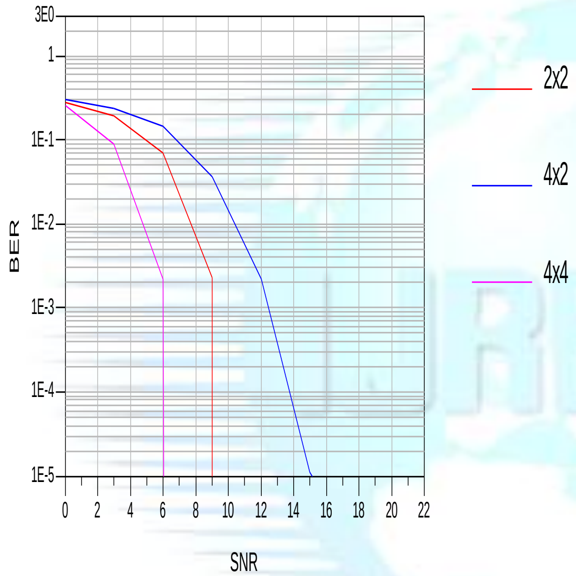

Fig 5: 2x2, 4x2 and 4x4 using 16QAM with TD.

Higher SNR and BER values are obtained in 16QAM than in the preceding QPSK due to the additional modulation. It is shown here as 4x4 has the BER value and 4x2 has the highest. At 6dB, 2x2 has a BER value of 6.9×10^{-2}, 4x2 has BER value of 1.44×10^{-1} while 4x4 is 2×10^{-3}.

8.1.6 Transmit Diversity 64QAM 10MHz 2x2, 4x2 & 4 x4 EVA.

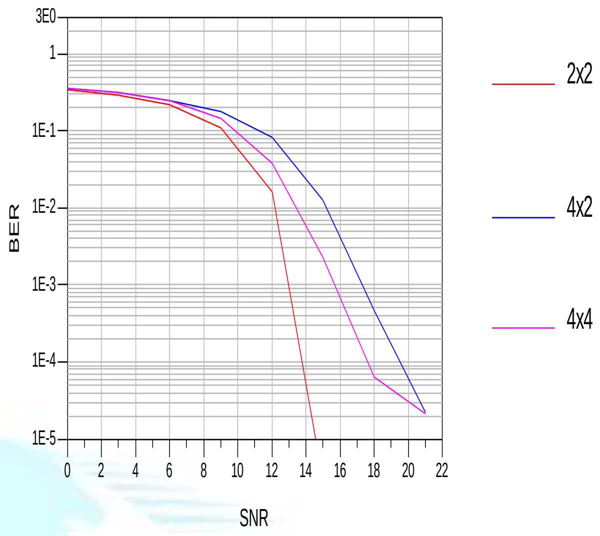

Fig 6: 2x2, 4x2 and 4x4 using 64QAM with TD.

It is expected using 64QAM, as noise tolerance is lower when higher modulation is used because of the increase in bits per symbol which is 6 bits in this case. Here at 0dB, 2x2 slightly surpass 4x2 and 4x4 with BER values of 3.47×10^{-1}, 3.63×10^{-1} and 3.59×10^{-1} respectively but at 14 = 15dB the gap tends to widen with 2x2 having a BER of 2.711×10^{-6} compared to 1.3×10^{-2} and 2×10^{-3} for 4x2 and 4x4 respectively.

According to the results shown, it can be observed that 4x4 has the lowest BER values at the initial stage in TD and SM and tends to increase at a later stage as the SNR increases while 4x2 has low BER values at higher SNR in most cases like in 16QAM and 64QAM SM EVA and 2x2 is always in between in all cases.

9. Conclusion

In this work, an effective study, analysis and evaluation of the LTE downlink performance with MIMO techniques: Spatial Multiplexing and Transmit Diversity in 2x2, 4x2 and 4x4 antenna configurations was carried out. The performance is evaluated using the Bit-Error-Rate (BER) metric, considering the use of ITU channel model environment: Extended Vehicular-A (EVA). In both receivers, for higher order of modulation (16QAM and 64QAM), the EVA channel performed better for the low SNR regions, though in some scenarios and antennas like in 4x2, and also in terms of performance, transmit diversity performed better while in terms of capacity, spatial multiplexing performed better. In rich multipath environments, performance for users far away from the base station is low due to losses caused by the presence of many scatters, but for the EVA channel, performance is better in these low SNR areas, however, additional SNR is required in the higher order of modulation. Analysis of the results obtained reveal that the performance of MIMO is excellent in the channel model. Spatial multiplexing is ideal for achieving very high peak rates, while transmit diversity is a valuable scheme to minimize the rate of bit error occurrence thereby improving signal quality. The vision of LTE is therefore nothing less than an actual possibility for now as the simulation carried out is not concluding, though this evaluation has demonstrated that the design goals and targets of LTE can be met with some degree of reliability. This performance evaluation also provides useful information on LTE downlink planning, design and optimization for deployment. This study was performed for single user MIMO scenario. However, the real traffic is a mix of different users in a cell, therefore, it is essential to undertake studies with multi user MIMO as well.

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