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Performance Analysis on Throughput in 4G Network in Digital Environment with SISO Technique

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Abstract**—** The development of the 4G or the Long Term Evolution (LTE) is working at a very fast pace. The 4G system invention had very high prospective and goals compared to 3G. It was already thought that the system should be more competitive and secure based. Every wireless connection would be IP oriented. 4G is on its phase in improving the Quality of Service (QOS). This paper shows the comparison of the throughput delivered by the different modulation techniques which have been proposed to be used. Also comparison has been made with the different Extended Channel Models. Figures and graphs have been put forward to show the performance by the throughput delivered in digital environment and RF technology.

Index Terms**—** LTE, EPA, EVA, ETU, RBs

I. Introduction

The first standard invented to access the wireless medium was the 1G technology. This is also called the 1st generation technology. This was solely based on analog technology for its communications. This means that the transmitted signals were analog radio signals. One significant example is the AMPS. Then came the 2G standards where the radio signals were digital. The short messaging text service (SMS) was also started with the 2G. This technology was introduced a decade after the 1G technology. TDMA and CDMA technologies were used. But the bandwidth of CDMA usage was not very wide. Security controls and roaming facilities also showed a significant success. Examples of 2G technology are the GSM and the PDC. The 2.5 Generation technology which included HSCSP, GPRS and the EDGE included some advanced features than the 2G.

The demand for improvement led to the launch of the 3G telecommunications. There was a significant improvement in the standards when 3G was launched. It is also the International Mobile Telecommunications-2000 (IMT-2000). The 3G specifications are the objectives which related to the principles laid down in the International Telecommunications Union (ITU). The works on 3G was already started in early 1992. It had many additional features which were absent in 1G and 2G standards. This technology was completely different and had vast differences with its predecessors. The most competitive feature of 3G compared to the other existing standards was it is backwards compatible with the pre-existing ones. This evolution provided with mobile internet facilities, video conferencing, playing online internet games, live music and digital televisions. Also the CDMA range was broadened and this technology could be used globally. The UMTS, CDMA-2000, WCDMA and the TD-SCDMA standards fall under the 3G technology.

The LTE technology is actually a project under the 3rd Generation Partnership Project (3GPP). The work for this project had already started in November 2004. But the primary work was concerned with the Universal Mobile Telecommunication Systems (3GPP).

Enhancing the UMTS and the 3GPP's RAN (Random Access Network) were the main objectives at that phase of time. Having a greater amount of throughput in Downlink as well as Uplink was one of the main targets.

Some of the factors which were necessary to consider with the works related to LTE release were:

- Better Quality of Service (QOS).
- User Friendly with low complexity mechanism.
- Technology should be available to all areas with reasonably lower cost so that everybody can have the capability to afford it.
- High data rates
- Least interference and disturbances in the network.
- Maintaining the continuity of 3G.

Fading [1] is a term that is closely related to networking. Fading is defined as a disturbance that causes hindrance to the signals sent in the wireless medium. Fading makes a signal suffer deviation when it is transmitted in a medium. Fading is different for different cases. Fading may show different behavior with respect to its medium. Their characterizations vary with the kind of radio frequency, bandwidth, geographical terrain and the medium itself. The real life scenario of the fading environment is shown below with some obstacles that cause the attenuation:

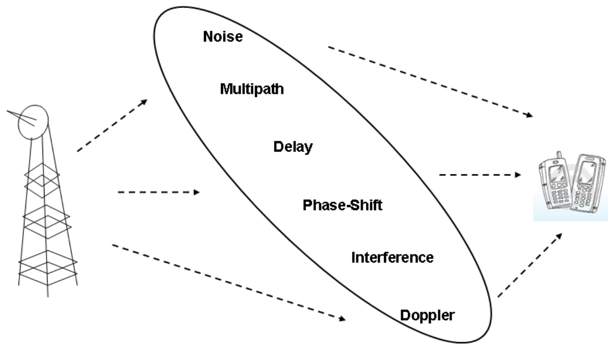

Fig. 1: Fading scenario for small scale fading in real world

Small scale fading may be cause due to multiple factors. Some of the common reasons which cause fading are:

- ♦ Multipath propagation [2]
- ♦ Doppler Shift
- ♦ Noise
- ♦ Delay
- ♦ Phase shift
- ♦ Shadowing

The fading which is caused by multipath is termed 'Multipath Induced Fading' while that caused by shadowing is called 'Shadow Fading'. The fading considered for the simulation comparison is done for small scale fading scenarios.

The paper aims in analyzing the comparison shown by the different types of modulation schemes in the fading environment. Here, the comparison has been done with the performances delivered in the RF and digital background. The performance analysis has been done taking the specifications of LTE with its new features according to the 3GPP specifications. Section 2 of the paper gives an overview about what fading is. Description of the different fading profiles used while throughput analysis has been given. Overview of Doppler shift and the different modulation techniques used to show the performances have been discussed. Section 3 shows the graphs of the different fading profiles in RF and digital environment. Also comparison has been made to analyze the best channel model during fading.

II. Fading Classification

The general classification of fading [1] is shown below fig 2:

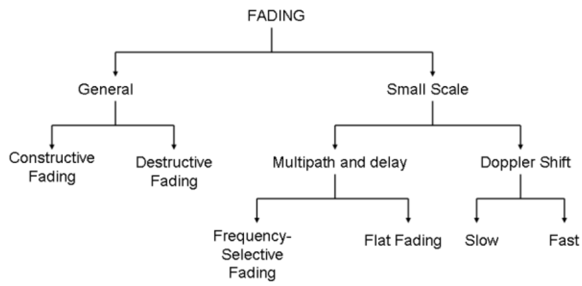

Fig. 2: Classification diagram with small-scale fading

2.1 Constructive and Destructive

The obstacles in the real environment cause the signals to get reflected before they reach the receiver. For this reason, the receiver sees a multiple number of paths for the same signal while transmission. This in turn makes each copy of the superimposed signal to experience different amount of fading. This can prove to be a result of either constructive or destructive fading. The signal can attenuate, amplify or deviate when it reaches its destination. Severe downfall in the Signal-to Noise ratio may prove in deep fading. The dense fading is called the destructive fading. Here the phase shift is π. In constructive fading, the phase shift is completely zero.

2.2 Slow and Fast

In spite of the constructive and destructive fading, there is another class of fading: fast and slow. This kind of fading is categorized on the basis of phase shift and magnitude of the signal which acts upon a particular channel. Fast channel fading is defined as that type of fading which occurs when the time needed for coherence of the channel is smaller than its delay constraint. In this case, the magnitude of the amplitude and the phase change are not constant and they vary greatly over the channel. The opposite phenomenon of fast fading defines the slow fading where the coherence time for the channel is analyzed to be bigger than that of its delay constraint. In this scenario, the amplitude and the phase stays constant over the period of time when the channel is in use. In short, it can be said that slow fading process does not make the channel change its state while in fast fading, the channel states changes during the signal transmission. Also, the fast fading experience high Doppler spread while the slow fading show lower Doppler spread. Channel variations show greater speed than the baseband signal variations. The opposite happens in case of slow fading.

2.3 Frequency-Selective and Flat

This is a class of fading where the fading behaves by selecting some frequencies. The signals propagate in the process of partial cancellation of its own signal. When the signal reaches its destination, it comes in two different routes, of which one or both changes its propagation while arriving. Frequency-Selective fading is a very slow process. This process takes place when the different layers in the atmosphere combine and parts from each other. The cancelling of the signal is very dense only at some part of its frequency. This type of fading can be rectifies by using OFDM or two separate receivers each having a different antenna. These types of schemes help in comparing and analyzing the behavior of the different signals which are sent during transmission.

In frequency-selective fading, the coherence bandwidth of the signal is greater than that of its channel. For this reason, this process of fading is slow and the signal experience almost same amount of fading while propagating through the channel. The whole of the channel effect depends upon its frequency components. Delay spread in this case is seen to be bigger than its symbol period.

The flat fading is defined as that type of fading which is responsible for creating its impact on all the frequency components of the channel through which the signal is transmitted. In short, the signal fluctuation takes place throughout the channel remains. The coherence bandwidth of the signal is seen to be smaller than that of its channel coherence bandwidth. For this factor, this process is a type of fast fading. Here, the frequencies of the signal show unmatched fading compared to each other. The delay spread factor is smaller than its symbol period.

2.4 Fading Scenarios

2.4.1 The Channel Models

The fading profiles which have been taken into consideration for the simulation in digital environment are the Extended Pedestrian A Model (EPA), Extended Vehicular A Model (EVA) and the Extended Typical Urban Model (ETU) [3, 4]. These models and their use in LTE are described in the 3GPP specifications.

EPA: It is a Propagation Channel Model that has been based on the International Telecommunication Union (ITU) Pedestrian ‘A’ model. It has been modified by extending the ITU Pedestrian ‘A’ Model that will have a capacity of a wider bandwidth defining 20 MHz. The pedestrian channel model can represent a UE that has a speed of 3 km/hour.

EVA: It has seven taps which are necessary to define the fading profile. Like the EPA, the EVA is also Propagation Channel Model. This is also based on the International Telecommunication Union (ITU) Pedestrian ‘A’ model. The EVA model has also been defined to a wider bandwidth of 20MHz. the Vehicular Model represents any UE having speed of 30km/hour, 120km/hour or even higher. The taps defined for EVA is nine.

ETU: Like the EPA and the EVA, the ETU is another Propagation Channel Model. But this Model is based on the GSM Typical Urban Model. Bandwidth has been limited to 20 MHz. It models such environments which are typical and valid for urban areas. One of the scenes is that it can create a scattering environment. Like the EVA, the taps defined for this fading profile is also nine.

2.4.2 FDD

This is the Frequency Division Duplex Mode [5]**.** The mode provided in this case is bidirectional. Here, the transmission and the receiving process happen at the same time but on different carrier frequencies. An operator tries to establish a connection to a station. The station must have the ability to accept and send a signal simultaneously at the same time. The station does this task by altering its frequency when it has to transmit or receive data. This mode of working is termed as the ‘Duplex Mode’.

The separation of the uplink and the downlink bands are done by the Frequency Offset. The FDD performs really when the medium has symmetric traffic. The radio planning also becomes much easier when FDD is employed. This is because the base stations do not listen to each other in normal cases. The bandwidth has been kept at 10 MHz.

2.4.3 Doppler

The Doppler Effect or the Doppler Shift can be defined as the changes that can be analyzed in the frequency of a wave in two conditions:

- When the source and the observer are moving towards each other.

- When the source and the observer moves away from each other.

If the source moves towards the observer though a medium with a wavelength having a frequency of f_s, then the observer which has a frequency of f_o, is given by the following equation:

$$f_o = \left(\frac{V + V_o}{V} \right) f_s \quad (1)$$

Where v is the velocity of the waves which travel through a medium and v_o is the velocity of the observer or the receiver.

For the second case, when the source and the observer moves away from one another than the frequency of the observer f_o is given by the following formula:

$$f_o = \left(\frac{V}{V + V_s} \right) f_s \quad (2)$$

where v_s is the source velocity.

The generalized equation concluded for both the cases taking the scenario that the source as well as the observer is moving, the equation is defined as:

$$f_o = \left(\frac{V + V_o}{V + V_s} \right) f_s \quad (3)$$

Three types of Doppler Effect have been tested for fading. The figures are given below:

- 5 Hz Doppler for which the relative velocity has been defined to be 25 deci kilometer/hour
- 70 Hz Doppler for which the relative velocity has been taken to be 353 deci kilometer/hour
- 300 Hz Doppler for which the relative velocity has been calculated to be 1514 deci kilometer/hour.

As per the 3rd Generation Partnership Project (3GPP) specifications, The 5 Hz Doppler is used for the EPA fading profile. The EVA uses 5 Hz as well as the 70 Hz Doppler Effect in fading. ETU is concerned with &0 HZ and 300 Hz only. The Doppler Effect and its use for different profiles for the LTE have been specified in 3GPP LTE specifications. It is noticeable to say that with the Doppler increase, fading is also incremented.

2.4.4 Modulation Techniques used for fading in the faders

Modulation is defined as a process where the carrier signal properties differ when compared to a general modulating signal. Modulation actually means conveying or passing a message from one point to another in telecommunications. The message conveying may take place in the form of an analog signal or as a stream of bits in digital systems. The properties which vary to carry information are of three types:

- Amplitude - The message passing is done by changing the amplitude of the transmitted signal keeping the frequency and the phase shift constant. This process is called Amplitude Shift Keying (ASK).
- Phase - In this case, the message is transmitted by varying the phase of the signal. Amplitude and frequency remains constant. This modulation technique is called the Phase Shift Keying (PSK).
- Frequency – Here, the frequency parameter is changed while transmitting the message. Amplitude and the phase shift stay fixed. The modulation technique in this case is called Frequency Shift Keying (FSK).

Till date, many modulation techniques are being invented and the previous ones are also in used. The BPSK is the simplest of all modulation techniques and also the most robust of all the techniques invented up till now.

2.4.4.1 QPSK

The QPSK which is the Quadrature Phase Shift Keying is also called 4-PSK (4- Phase Shift Keying). Quadrature in modulation terms means the shifting of a signal with respect to its phase state parameter which is apart from each by a factor of 90^o. The data which is fed into the modulator is separated in two different channels. Each of these channels is responsible for carrier modulation. The carriers in both the channels are the same, but they are separated by a 90^o phase shift. As already mentioned, for this reason, the carriers are said to be in Quadrature with each other. During transmission of both the carriers, they are combined and sent together. The QPSK can display itself in a constellation diagram of four states. So, it has the capability to encode two bits for each symbol. Theoretically, the efficient bandwidth of QPSK is found to be 2 bit/sec/Hz. The QPSK mapping with its constellation diagram is shown below:

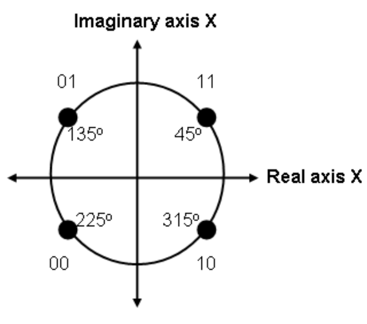

Fig. 3: The constellation diagram for QPSK

The figure 6.4.1.1 shows that the constellation diagram of QPSK has four points, each in a single quadrant and all of them are equidistant from each other. The QPSK modulation can generate twice as much data rate than the BPSK with the same amount of bandwidth in both the cases. At the same time, it tries to maintain the same amount of BER as the BPSK. The only complication in both the cases is that the receivers and the transmitters in case of QPSK becomes complex. Hence, the equipments become more expensive.

2.4.4.2 16-QAM

The 16-QAM defines the QAM in a 16-state scenario. This means that this modulation technique can encode four bits per symbol. Just like the QPSK, the 16-QAM data is also divided into two different channels. So, two bits are transmitted with each channel. These bits are later combined and added and fed into the channel modulators. Since the 16-QAM signifies 4 bits per symbol. Thus, its symbol rate is ¼.

The digital television receives its signal from the source in groups of 16 symbols. The forward error correction bitrates in this case is around 18 Mb/sec. the ratio has been found to be 1/3. The 16-QAM technology has the power to carry a maximum of five television channels at the same time. The 16-QAM has 16 constellation points in total with each quadrant displaying 4 points.

The 16-QAM constellation diagram is given below:

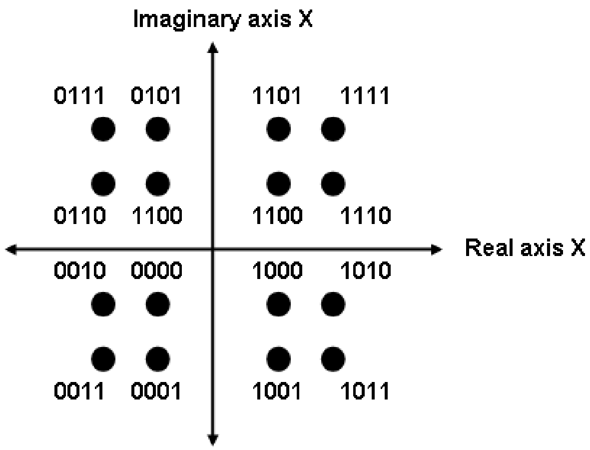

Fig. 4: The constellation diagram for 16-QAM

2.4.4.3 64-QAM

Like the 16-QAM, the 64-QAM is also a modulation technique. Its advantage over 16-QAM is that it can deliver higher throughput and thus show better performance. The state of 64-QAM is defined in a 64 state. In this case, encoding is done taking 16 symbols at once for each symbol. When the data is divided into two different channels, the information sent through the channels is later combined and then they are received by the receiver. This modulation technique sends 6 bits per symbol. Hence the symbol has been found to be 1/6 bit rate.

Since, it is a 16-State representation, the digital television send its information in groups of 64 symbols. The 'Forward Error Correction' for in this state scenario is 2/3. For this reason, its bit rate is 24 megabits per second. So, it has the capability to transfer a maximum of 8 television channels at the same time simultaneously. The constellation diagram for the 64-QAM is shown below with its gray mapping:

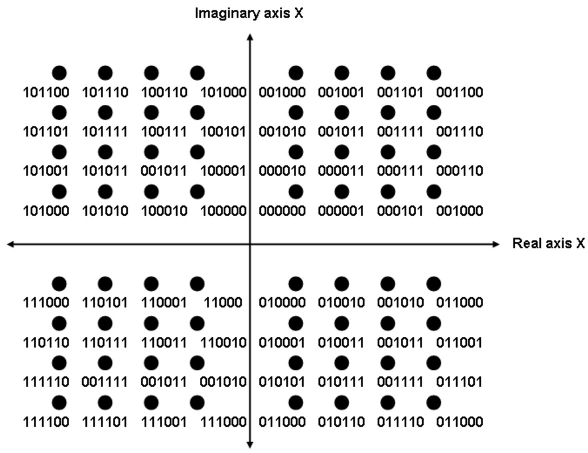

Fig. 5: The constellation diagram for 16-QAM

2.4.5 ACM

This is a coding scheme which is called Adaptive Coding and Modulation. It is also called Link Adaptation. This process is used for directing any code or modulation techniques depending upon the factors associated with the radio frequencies. The factors linked to the radio waves may be several like path loss, delay, power gain and multipath propagations. The ACM technique has the power to keep changing its modulation and coding technique depending upon the conditions that is prevalent with the current signal.

The channel conditions should be known at the transmitter before any modulation or coding is used for the radio links. The current state channel data can be obtained by the TDD systems. Also the channel information can be collected from the receiver which can then be set in the transmitter. Precisely, it can be said that the ACM targets in ensuring high data rates. Also, it has the capability to perform well with fading channels.

III. The Simulation of Throughput:

The fading simulations between the environments of RF and digital have been calculated for the throughput delivered. Matlab has been used for the plotting of the graphs to show a vivid comparison of the performances achieved by both the faders. A total of four graphs have been plotted for the SISO fading [6]. The first three curves of each graph depict the amount of throughput performance delivered. Each of the three scenarios shows the behavior given by the three different modulation techniques – QPSK, 16-QAM and the 64-QAM. The graphs show the different fading profiles with the three kinds of Doppler Frequencies.

The first performance comparison shown is of the EPA profile with 5Hz Doppler. According to 3GPP specifications, LTE network [7] can support the EPA fading with only 5 Hz Doppler frequency. The bandwidth defined for this graph plot is 10 MHz. With these parameters, the throughput delivered by both the faders is shown:

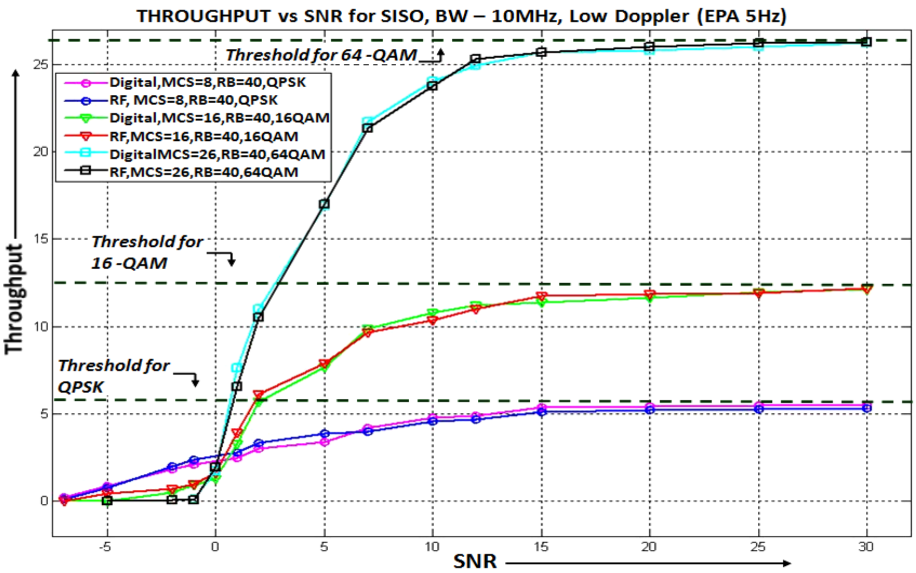

Fig. 6: Throughput vs SNR for EPA with 5Hz Doppler Frequency

In Figure 6, the throughput delivered by the QPSK modulation technique (RF and digital) are shown by the lower portion of the figure. The middle section graphs shows the throughput delivered by the 16-QAM while the top sections shows the performance of the highest modulation technique i.e., the 64-QAM.

The second graph is for the throughput delivered by the EVA with 70Hz Doppler. The bandwidth is constant at 10 MHz.

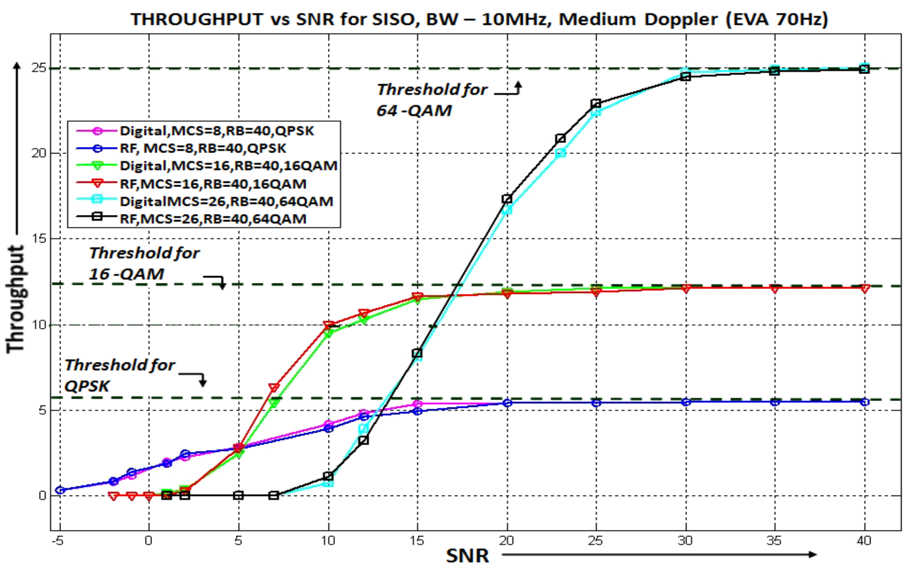

Fig. 7: Throughput vs SNR for EVA with 70Hz Doppler Frequency

The difference in Figure 6 and Figure 7 is that here the Doppler is kept at 70Hz while the Doppler in the previous figure was at 5Hz only. Rests of the parameters are same in both the graphs plotted.

The last graph plotted to show the throughput performance is of the ETU profile which has a Doppler of 300 Hz.

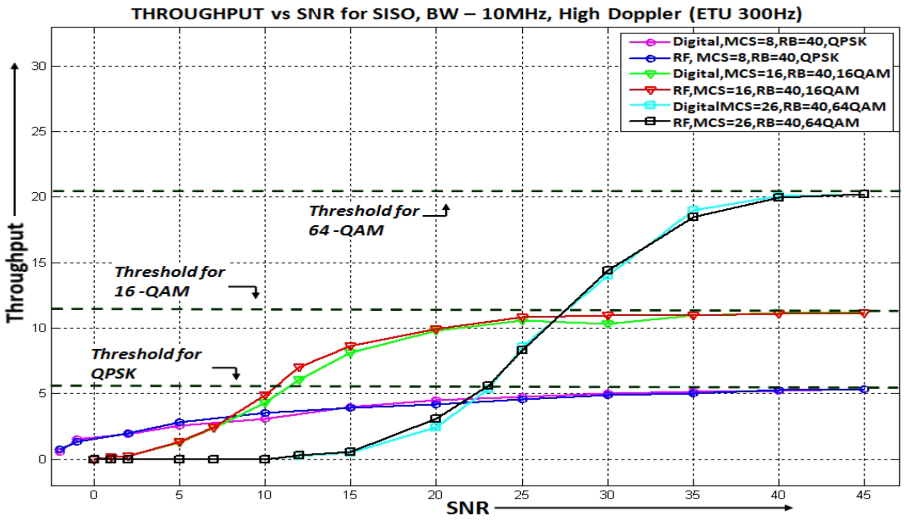

Fig. 8: Throughput vs SNR for ETU with 300Hz Doppler Frequency

IV. Observations

From all the three graphs, the common conclusion that can be drawn is that as the higher type of modulation is used, the throughput delivered is of high data rate.

The three fading profiles, the FDD scenario, constant bandwidth of 10 MHz for all the cases, different noise levels specified are all a part of the LTE 3GPP specifications. While taking the readings for the different scenarios, it was to be noted that every modulation technique maintains its limit. In this case, the number of Reserve Blocks (RBs) taken is 40. The QPSK modulation used for fading is defined for 8 Modulation and Coding Scheme (MCS). In the same way, the 16-QAM is defined for 16 MCS while the 64-QAM is used with 26 MCS. The RBs have taken to be 40 for all the fading profiles and modulation schemes. With these figures, the limit defined for the throughput in case of the QPSK is 5.54 Mbps. while that of the 16-QAM modulation is 12.960Mbps. The maximum throughput delivered by 64-QAM limits at 36.696Mbps. These limits are being stated in the Release 8 of the 3GPP specifications. It is to be noticed that the figures which define the limit for each fading profile is only valid for SISO. Beyond these limit, throughput cannot be increased even if the SNR goes on increasing. This limit is called the threshold.

If we take a close look at the first three graphs and compare them together, it will be seen that for the same modulation technique, the throughput achieved by EPA fading profile is the best. This is clearly evident from the throughput shown by the 64-QAM for all the fading profiles. The differences in the graph for all the fading profiles in case of the throughput are shown below:

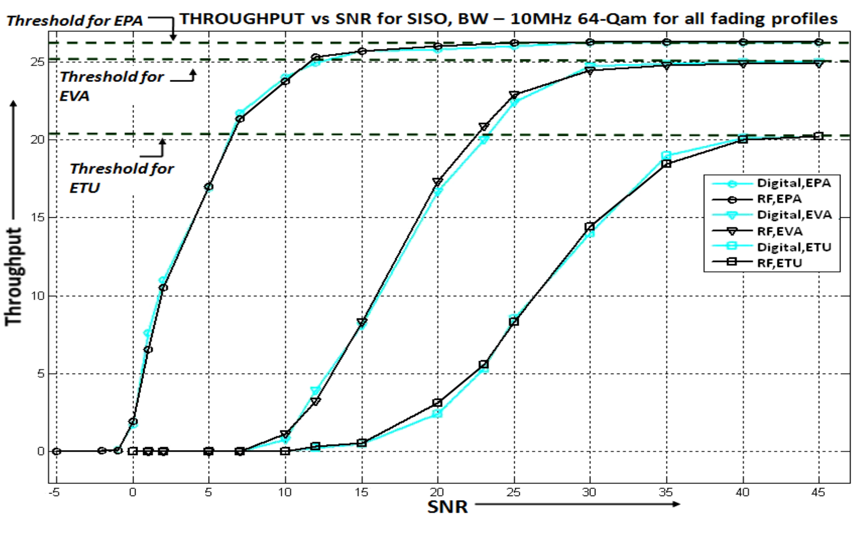

Fig. 9: Throughput performance for all the fading profiles

From these performances, it is evident that the EPA is the best channel model for fading. On the contrary, the ETU has proved to show worst performance.

There is one important thing that is to be kept with respect to the graphs plotted. The QPSK [8] modulation has the capability to withstand high noise. So, even if the SNR is kept increasing, the throughput will keep on increasing but will be limited within its threshold. On the other hand, the 64-QAM modulation technique cannot survive for long. It does not have the capability to withstand higher noise levels. So, the signal with high AWGN becomes out of synchronization and gradually dies away. It cannot keep on displaying its stability even if the SNR [9] is kept increasing. The signal may even die before reaching its threshold. Thus, the throughput cannot withstand higher AWGN [10] as the use of the modulation techniques increases and with the changing of the fading models. But it is definite that the EPA model delivers better performance than the ETU even if the same modulation scheme is being used.

V. Conclusion

In this paper, comparison has been shown in the performances delivered the different modulation schemes QPSK, 16-QAM and 64-QAM for different fading profiles keeping the bandwidth at 10MHz for all the cases. The fading profiles have different Doppler which is specified by the 3GPP organization. The performances have been shown using the SISO technique. Also, the fading comparison the different modulation techniques have been compared for the 4G technology.

Another aim of this paper is to compare the performance displayed in the RF and the Digital environment. By looking and evaluating the plots delivered in both the environments, it can be concluded that the performance delivered by the RF is almost the same as delivered by the Digital one.

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