**Department of Electronics and Communications Engineering**

# THROUGHPUT ANALYSIS OF VARIOUS FADING PROPAGATION MODELS USED IN 4G LTE SYSTEM


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# Letter of Transmittal

To
Md. Asif Hossain
Assistant Professor
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East West University

**Subject: Submission of Project Report as (ETE-498)**

Dear Sir,

We are pleased to let you know that we have completed our thesis on **"Throughput Analysis of Various Fading Propagation Models used in 4G LTE System"**. The attachment contain of the thesis that has been prepared for your evaluation and consideration. Working on this thesis has given us some new concepts. By applying those concepts we have tried to make something innovative by using our theoretical knowledge which we have acquired since last four years from you and the other honorable faculty members of EWU. This thesis would be a great help for us in future.

We are very grateful to you for your guidance, which helped us a lot to complete my project and acquire practical knowledge.

Thanking You.

Yours Sincerely

Suborna Afrin

ID: 2013-2-55-012

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# Declaration

This is certified that the project is done by us under the course “Thesis (ETE-498)”. The thesis of **“Throughput Analysis of Various Fading Propagation Models used in 4G LTE System”** has not been submitted elsewhere for the requirement of any degree or any other purpose except for publication.


Suborna Afrin

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# Acceptance

This thesis paper is submitted to the **Department of Electronics and Communications Engineering, East West University** is submitted in partial fulfillment of the requirements for the degree of **B.Sc.** in **Electronics &Telecommunications Engineering** under complete supervision of the undersigned.

__________________

**Md. Asif Hossain**
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# Abstract

Development of the 4G Network or the Long Term Evolution (LTE) is working very quickly. LTE exhibits a major advance in wireless communication networks to meet increasing demands for high quality multimedia services. 4G is on its phase in improving the Quality of Service (QOS). This paper shows the throughput analysis of various fading propagation models used in PDSCH (Physical Downlink Shared Channel) of LTE. The fading propagation channel models considered in this paper are: Extended Pedestrian A (EPA), Extended Vehicular A (EVA) and Extended typical urban (ETU) models.

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# CHAPTER 1

# INTRODUCTION

Long Term Evolution (LTE) is a 4G wireless communications standard developed by the 3rd Generation Partnership Project (3GPP) that's designed to provide up to 10x the speeds of 3G networks for mobile devices. LTE is based on the GSM/EDGE and UMTS/HSPA technologies. LTE provides significantly increased peak data rates and increases the capacity and speed.

Fading is a variation of attenuation of a signal with various variables such as time, geographical position and radio frequency. It occurs when the two copies of the signal get combined the resulting signal can be attenuated signal. The attenuated signal is poorer than the original signal.

For simulating the effects of multipath fading, a model can be created that consists of a delay line with several taps. A tap is just a point on the delay line corresponding to a certain delay. When the received signal is subject to multipath fading, the composite signal and summed signals from each tap represents a real radio wave.

In [1], the authors have compared various fading models like EPA, ETU and EVA. They have compared the performances of those parameters under LTE network.

The authors in [2] have presented a throughput analysis on of a LTE System for Static Environment. They have considered various modulation models and fading models.

In [3], there has been given a lot of information about different propagation channel models and their benefits for communication.

In [4], the authors give comparisons among different fading models and their statistical result.

Similar works have been done in [5-10], the authors have discussed about different channel models and different fading models.

The project has been organized as: Chapter 1 has described the introduction, chapter 2 will discuss about the Long Term Evolution (LTE), chapter 3 is the details of the fading channel models, chapter 4 is for the parameters and the simulation results and chapter 5 will conclude the entire project.

# CHAPTER 2

# Long Term Evolution (LTE)

Long Term Evolution (LTE) is an upcoming standard for very high-speed wireless communication for mobile devices and data terminals. LTE is based on the GSM/EDGE and UMTS/HSPA technologies. By using different radio interface together with core network improvements, LTE increases the capacity and speed.

LTE is a 4G wireless communications standard developed by the 3rd Generation Partnership Project (3GPP) that's designed to provide up to 10x the speeds of 3G networks for mobile devices such as smart phones, tablets, notebooks, notebooks and wireless hotspots.

3GPP engineers named the technology "Long Term Evolution" because it represents the next step (4G) in a progression from GSM, a 2G standard, to UMTS, the 3G technologies based upon GSM. LTE provides significantly increased peak data rates, with the potential for 100 Mbps downstream and 30 Mbps upstream, reduced latency, scalable bandwidth capacity, and backwards compatibility with existing GSM and UMTS technology. Future developments to could yield peak throughput on the order of 300 Mbps.

The upper layers of LTE are based upon TCP/IP, which will likely result in an all-IP network similar to the current state of wired communications. LTE will support mixed data, voice, video and messaging traffic. LTE uses OFDM (Orthogonal Frequency Division Multiplexing) and, in later releases, MIMO (Multiple Input Multiple Output) antenna technology similar to that used in the IEEE 802.11n wireless local area network (WLAN) standard. The higher signal to noise ratio (SNR) at the receiver enabled by MIMO, along with OFDM, provides improved coverage and throughput, especially in dense urban areas.

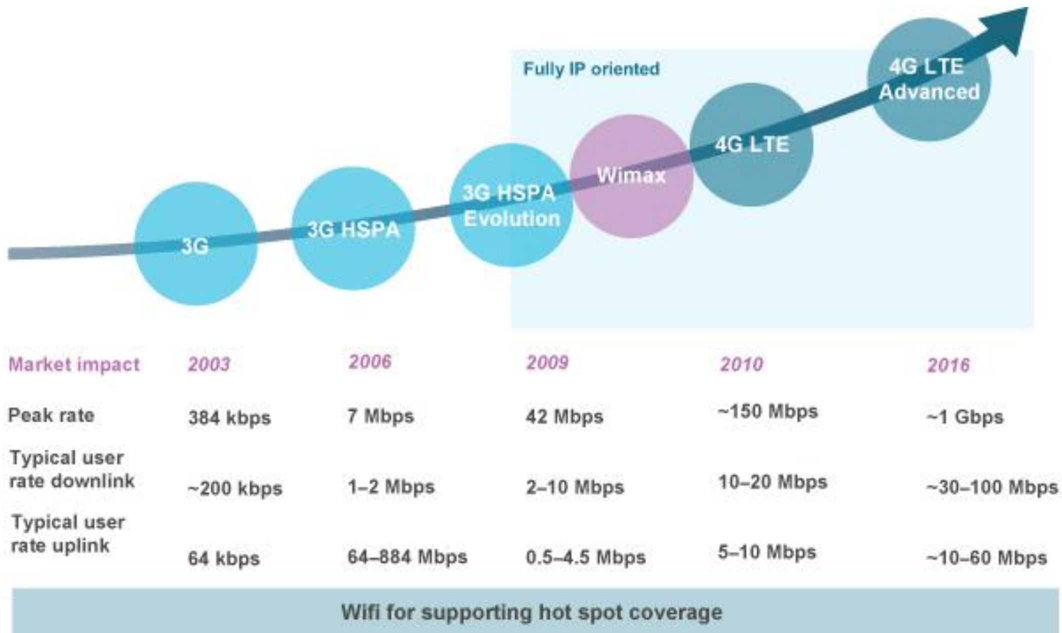



Fig. 1 The Evolution of LTE

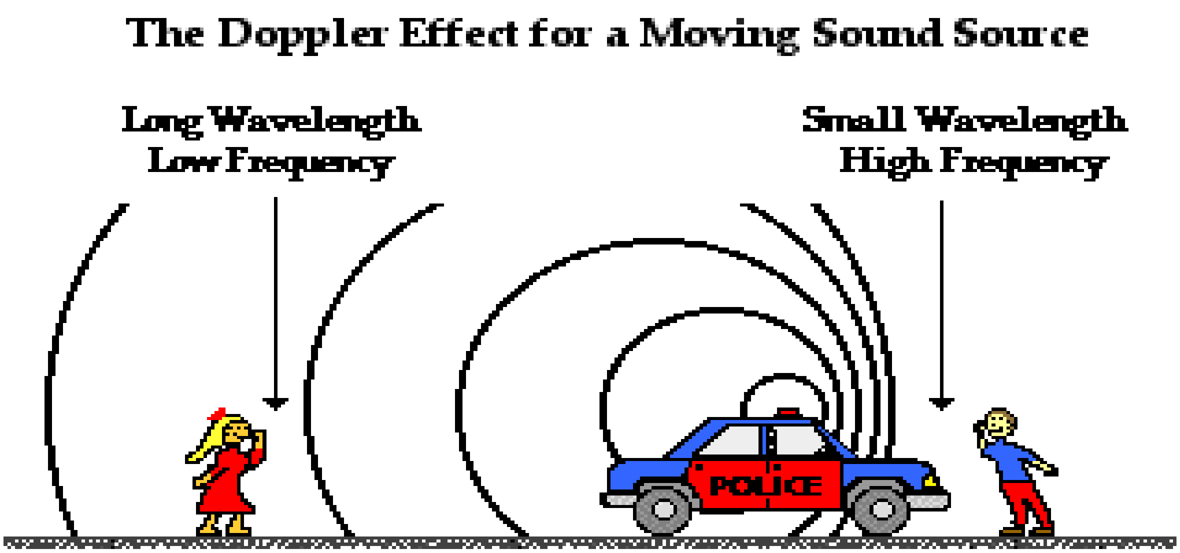
LTE is scheduled to be launched commercially in 2010 by Verizon Wireless and AT&T Wireless. T-Mobile and Alltel have also announced plans to roll out 4G capabilities based on LTE. These networks will compete with Clearwire's WiMAX for both enterprise and consumer broadband wireless customers. Outside of the US telecommunications market, GSM is the dominant mobile standard, with more than 80% of the world's cellular phone users. As a result, HSDPA and then LTE are the likely wireless broadband technologies of choice for most users. Nortel and other infrastructure vendors are focusing significant research and development efforts on the creation of LTE base stations to meet the expected demand. When implemented, LTE has the potential to bring pervasive computing to a global audience, with a wire-like experience for mobile users everywhere.

# CHAPTER 3

# Doppler Effect

The frequency of a wave like signal such as sound or light depends on the movement of the sender and the receiver. This is known as Doppler Effect. The Austrian physicist Christian Doppler proposed it in 1842 in Prague.

The relative motion difference between the source and observer is called Doppler Effect. The relative speed of an object and the shift of the frequency of wave can be measured by using the Doppler Effect. The Doppler Effect is also known as Doppler shift. If a receiver is moving toward the source, then the zero crossing of the signal appear faster, and consequently, the received frequency is higher. The opposite effect if the receiver is moving away from the source. The resulting change in frequency is known as Doppler shift.



# CHAPTER 4

# Fading

In wireless communications, Fading is defined as a variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading is often modeled as a random process. A fading channel is defined as a communication channel which experiences fading.

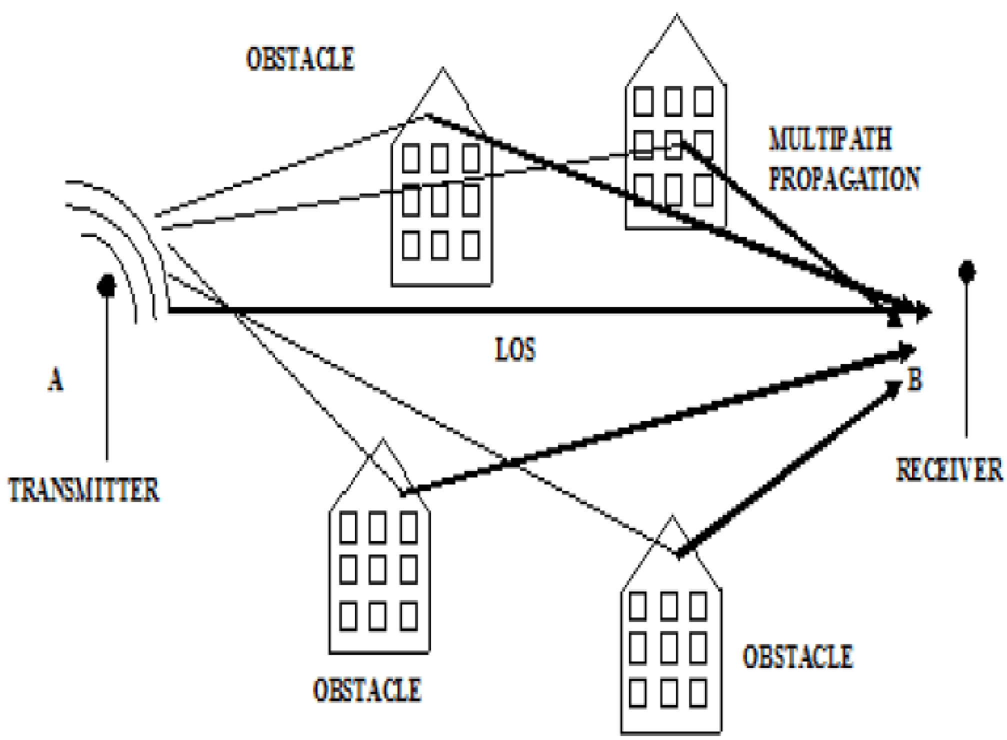



Fig.1 Mobile user in the presence of multipath and interference

## Types of fading:

There are various types of fading.

(a) Slow fading

(b) Fast fading

(c) Block fading

(d) Selective fading or frequency selective fading

## (a)Slow fading:

Slow fading occurs when the coherence time of the channel is larger than the relative the delay requirement of the application. The amplitude and phase change imposed by the channel. Over the period of use, this channel can be considered roughly constant. Slow fading can be caused by events such as shadowing. Shadowing occurs where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver. Shadowing changes the received power. With a standard deviation according to the long-distance path loss model, Shadowing is often modeled using a log- normal distribution.

## (b) Fast fading:

Fast fading occurs when the coherence time of the channel is smaller than the relative to the delay requirement of the application. Over the period of use, the amplitude and phase change imposed by the channel varies considerably.

## (c) Block fading:

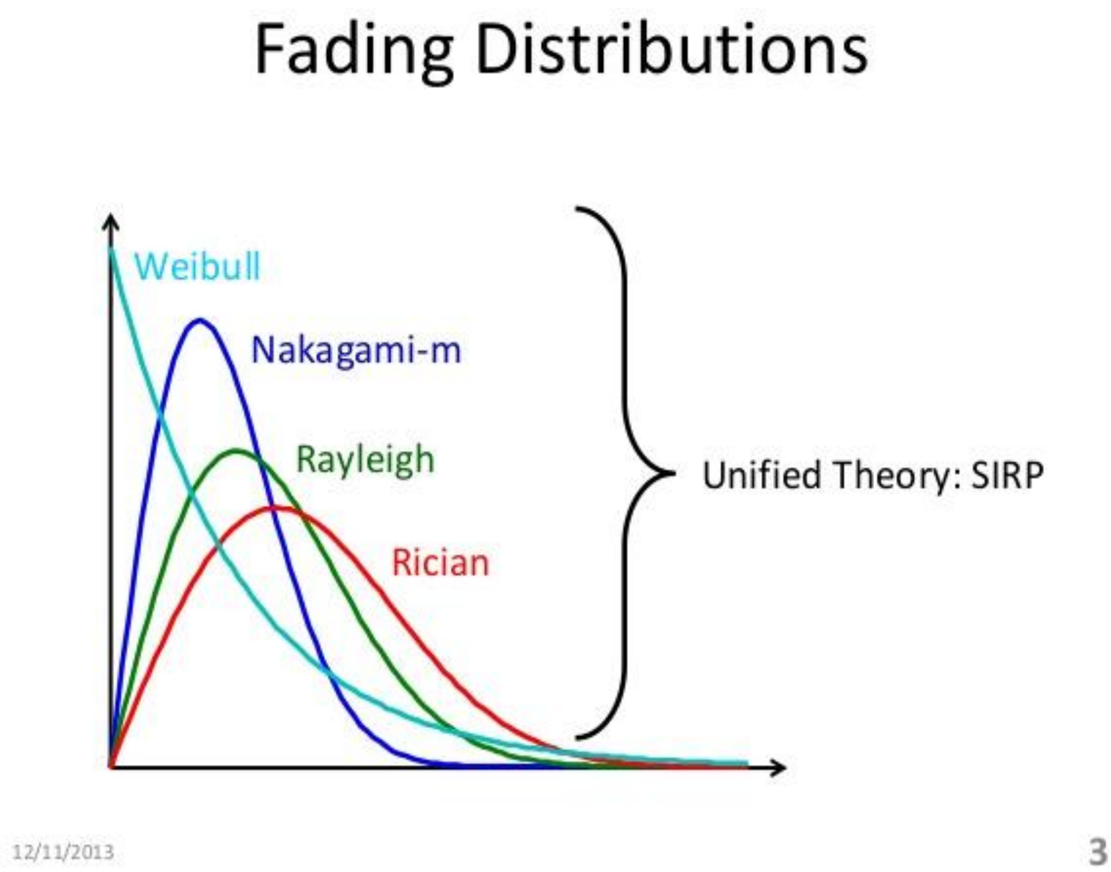
For a number of symbol intervals, the fading process is approximately constant in block fading. When it is block fading in both the time and frequency domains then the channel is ‘doubly block-fading’.

## (d) Selective fading or frequency selective fading:

Selective fading or frequency selective fading is radio propagation. It is caused by partial cancellation of a radio signal by itself .The signal arrives at the receiver by two different paths. At least one of the paths is changing it may be as lengthening or shortening.

## Fading models:

- Nakagami fading
- log- normal shadow fading
- Rayleigh fading
- Rician fading
- Two-wave with diffuse power(TWDP)fading
- Weibull



# CHAPTER 5

# The Fading Models (EPA, EVA & ETU)

## EPA:

EPA stands for Extended pedestrian A model. It is a model which is used to generate channel models for wireless applications. This model has been based on International Telecommunication Union (ITU) Pedestrian A model and has been modified by extending the ITU Pedestrian A model. It has maximum Doppler frequency of 5 Hz. This model has number of seven channel taps and the maximum delay is 410ns. The pedestrian channel model has wider bandwidth of 20 MHz. The UE of this channel model has a speed of 3 Km/hour.

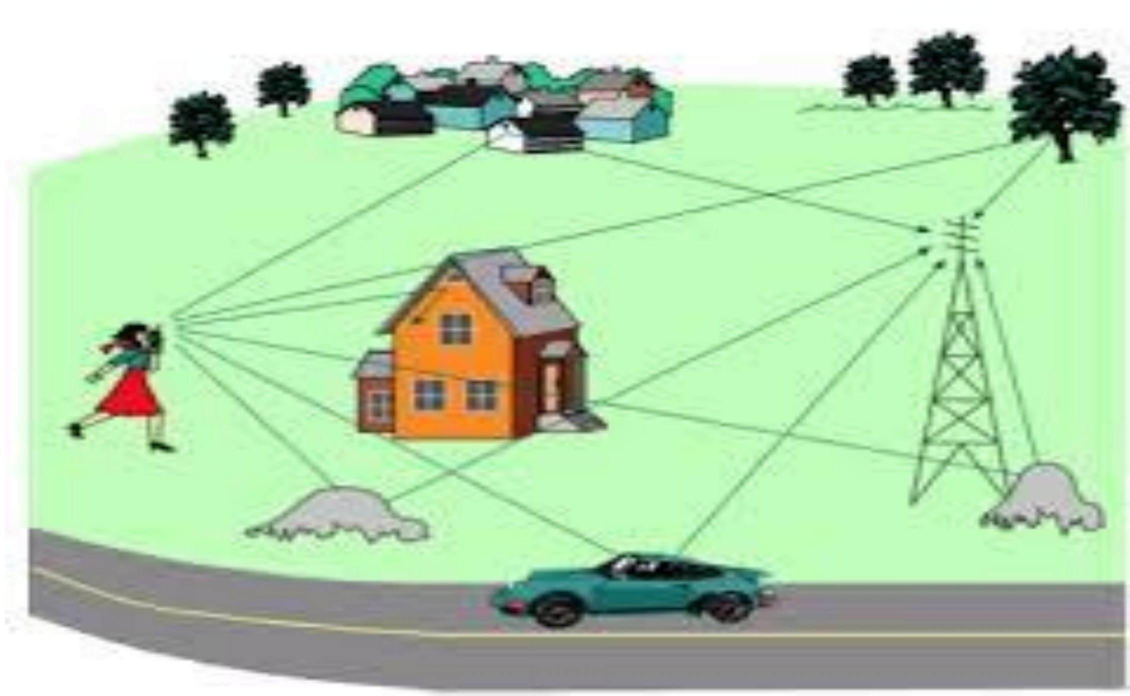


Fig. 2 The concept of the fading channel EPA

**EPA Delay Profile**

| Excess tap delay (ns) | Relative power (dB) |
|---|---|
| 0 | 0.0 |
| 30 | –1.0 |
| 70 | –2.0 |
| 90 | –3.0 |
| 110 | –8.0 |
| 190 | –17.2 |
| 410 | –20.8 |

## EVA:

Extended vehicular A model (EVA) is a propagation channel model. This model has also been based on International Telecommunication Union (ITU) Pedestrian A model. It has maximum Doppler frequency of 70 Hz. This model has number of nine channel taps and the maximum delay is 2510ns. The pedestrian channel model has wider bandwidth of 20 MHz. The UE of this channel model has a speed of 30 Km/hour, 120Km/hour or even higher than this.

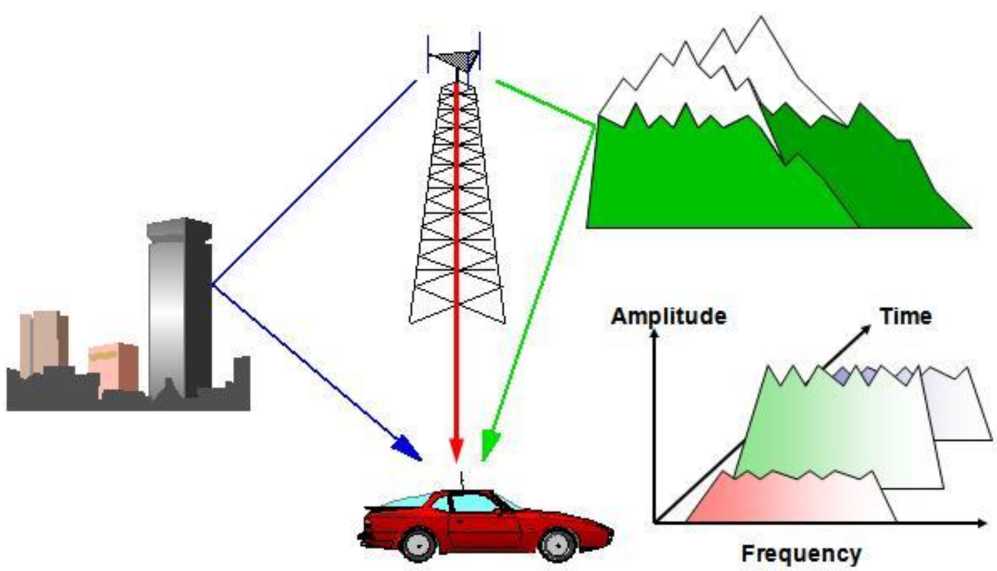



Fig. 3 The concept EVA

### EVA Delay Profile

| Excess tap delay (ns) | Relative power (dB) |
|---|---|
| 0 | 0.0 |
| 30 | −1.5 |
| 150 | −1.4 |
| 310 | −3.6 |
| 370 | −0.6 |
| 710 | −9.1 |
| 1090 | −7.0 |
| 1730 | −12.0 |
| 2510 | −16.9 |

## **ETU:**

Extended typical urban model (ETU) is used to generate channel models for wireless applications like EPA and EVA. This is based on the GSM Typical Urban Model. It has maximum Doppler frequency of 300 Hz. This model has number of nine channel taps and the maximum delay is 5000ns. This channel model has limited bandwidth of 20 MHz. The UE of this channel model has a speed of 120Km/hour or 350 Km/hour. This model is applicable for typical urban areas.

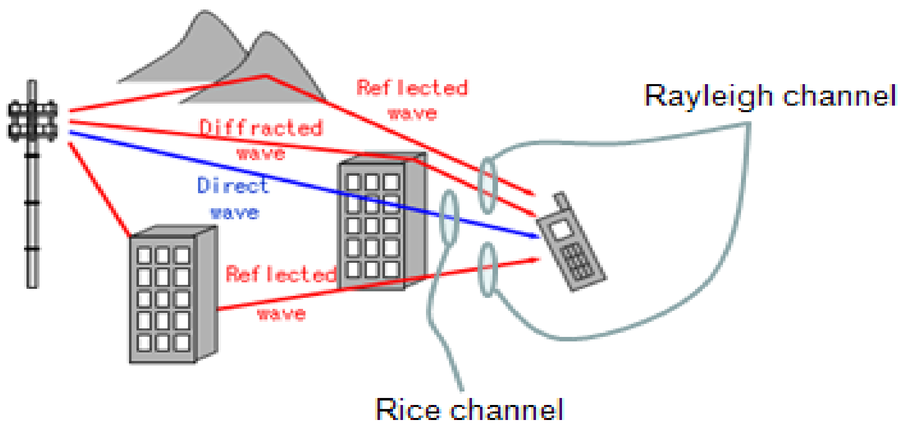



Fig. 4 The concept ETU

**ETU Delay Profile**

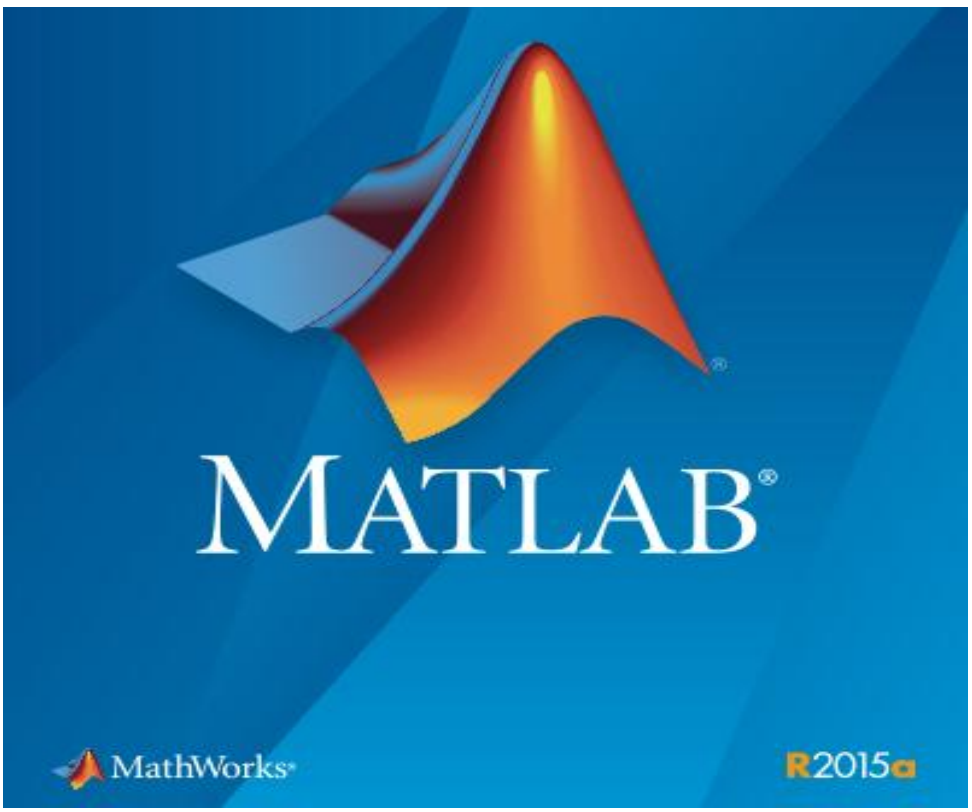
| Excess tap delay (ns) | Relative power (dB) |
|---|---|
| 0 | –1.0 |
| 50 | –1.0 |
| 120 | –1.0 |
| 200 | 0.0 |
| 230 | 0.0 |
| 500 | 0.0 |
| 1600 | –3.0 |
| 2300 | –5.0 |
| 5000 | –7.0 |

# CHAPTER 6

# MATLAB

MATrix LABoratory is known as MATLAB.

MATLAB is a programming package which is designed for solving quick and east scientific calculations. It has hundreds of build-in functions for a wide variety of computations. Specific research disciplines, including statistics, optimization, solution of partial differential equations, data analysis can be solved easily by using special toolboxes of MATLAB. Two dimensional graphs and three dimensional graphs can be plotted in MATLAB. User can get solutions of algebraic equation, differential equations, matrices and linear system of equations.




## Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows user to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

## Features of MATLAB:

- High-level language for scientific and engineering computing
- Desktop environment tuned for iterative exploration, design, and problem-solving
- Graphics for visualizing data and tools for creating custom plots
- Apps for curve fitting, data classification, signal analysis, and many other domain-specific tasks
- Add-on toolboxes for a wide range of engineering and scientific applications
- Tools for building applications with custom user interfaces
- Interfaces to C/C++, Java, .NET, Python, SQL, Hardtop, and Microsoft, Excel
- Royalty-free deployment options for sharing MATLAB programs with end users

## The MATLAB System:

The MATLAB system consists of five main parts:

### The MATLAB language:

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

### The MATLAB working environment.

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

**Handle Graphics:**

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

**The MATLAB mathematical function library:**

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transforms.

**The MATLAB Application Program Interface (API):**

This is a library that allows you to write C and Fortran programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

## Advantages of MATLAB:

- Easiest and most productive software for engineers and scientists
- Essential for analyzing data, developing algorithms, or creating models
- an environment that invites exploration and discovery

- Combines a high-level language with a desktop environment tuned for iterative engineering and scientific workflows.

# CHAPTER 7

# Simulations & Results

## Parameters:

The parameters used here to simulate the LTE PDSCH have been given below:

| Parameters | Value |
|---|---|
| Reference channel | R.12 |
| Duplex mode | FDD |
| Transmission scheme | TxDiversity |
| PDSCH Rho (dB) | -3 |
| Propagation model | EPA, EVA, ETU |
| Doppler (Hz) | 5, 70, 300 |
| Antenna correlation | Medium |
| No. of receive antennas | 2 |
| SNR | [-2.0, -1.0, 1.0, 2.0] |

**Throughput** is sometimes normalized and measured in percentage, but normalization may cause confusion regarding what the percentage is related to. *Channel utilization*, *channel efficiency* and *packet drop rate* in percentage are less ambiguous terms.

The channel efficiency, also known as bandwidth utilization efficiency, is the percentage of the net bitrate (in bit/s) of a digital communication channel that goes to the actually achieved throughput. For example, if the throughput is 70 Mbit/s in a 100 Mbit/s Ethernet connection, the channel efficiency is 70%. In this example, effective 70 Mbit of data are transmitted every second.

In a point-to-point or point-to-multipoint communication link, where only one terminal is transmitting, the maximum throughput is often equivalent to or very near the physical data rate (the channel capacity), since the channel utilization can be almost 100% in such a network, except for a small inter-frame gap.

**Signal-to-noise ratio (abbreviated SNR or S/N)** is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. The signal-to-noise ratio, the bandwidth, and the channel capacity of a communication channel are connected by the Shannon–Hartley theorem.

Signal-to-noise ratio is defined as the ratio of the power of a signal (meaningful information) and the power of background noise (unwanted signal):

$$SNR = \frac{P_{signal}}{P_{noise}}$$

where, P is average power. Both signal and noise power must be measured at the same and equivalent points in a system, and within the same system bandwidth.

**<u>Results:</u>**

This section will discuss the results obtained after the simulation in Matlab 2016a with various parameters that have been discussed in the previous section. In all the simulations, 70% throughput ratio has been considered as the target throughput.

In Fig. 2, throughput vs SNR for EPA with 5 Hz Doppler Effect has been plotted. Here, it has been observed that when the value of SNR is -2dB then the throughput is 45%, for -1dB it is 65%, for 1dB it crosses the target throughput which is 80%. Same result has been obtained for 2dB SNR.

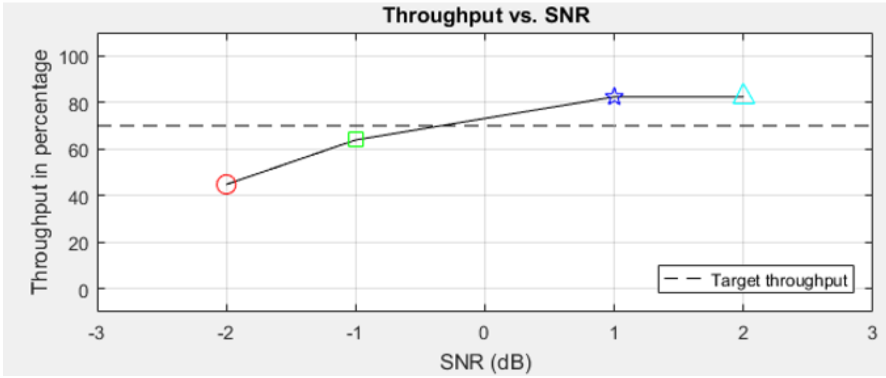



Fig. 2 Throughput vs SNR for EPA with 5 Hz Doppler Effect

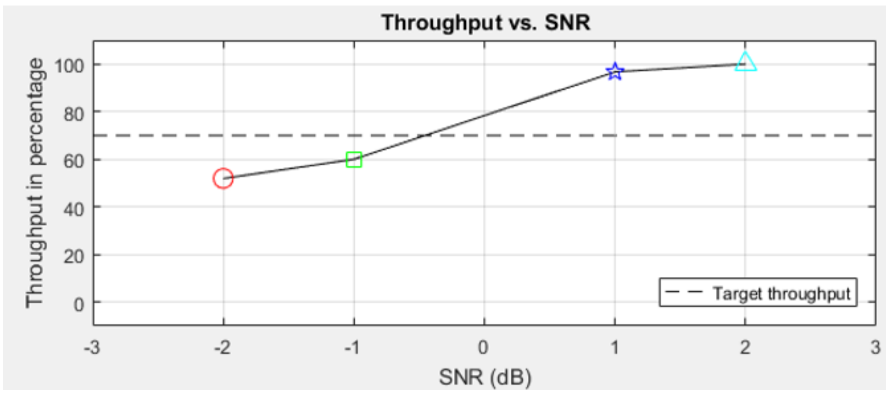



Fig. 3 Throughput vs SNR for EVA with 5 Hz Doppler Effect

The plot of the throughput vs SNR for EVA with same Doppler Effect has been found in Fig. 3. Here, for 1 dB SNR, around 98% throughput has been achieved while for 2 dB it touches 100%. Now, in Fig. 4, the poor throughput has been found. For -2 dB & -1 dB SNR, throughput is 47%, for 1 dB, it is 75% and for 2 dB it reaches 100%.

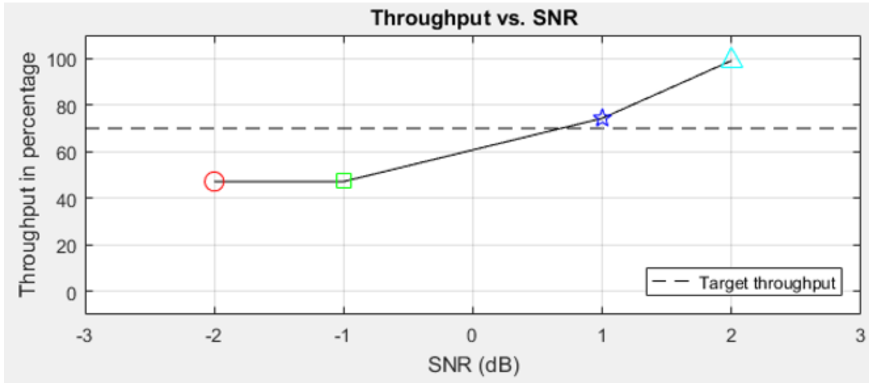



Fig. 4 Throughput vs SNR for ETU with 5 Hz Doppler Effect

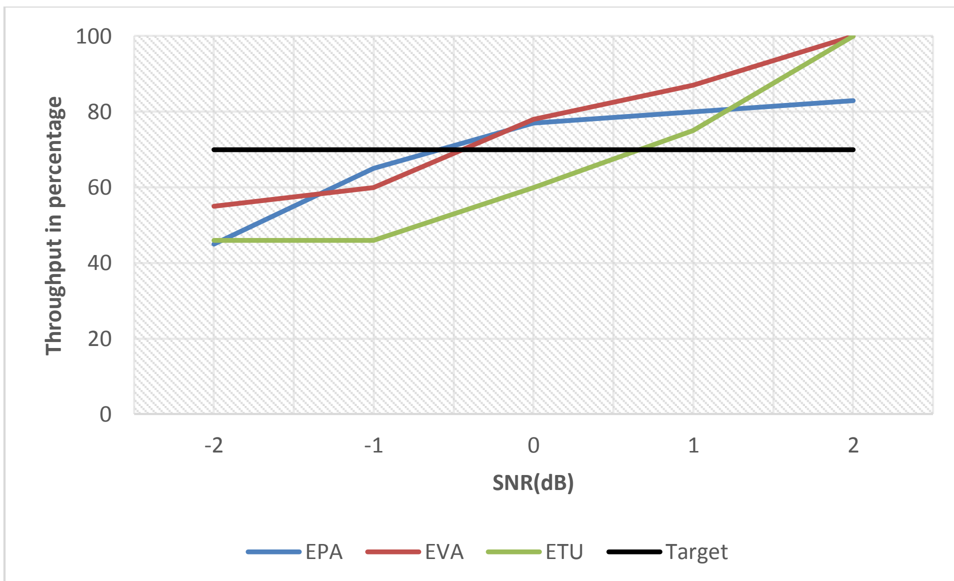



Fig. 5 Combined Throughput vs SNR for EPA, EVA &ETU with 5 Hz Doppler Effect

The throughputs for 5 Hz Doppler Effect for the all the models have been plotted in Fig. 5. From this figure, it has been observed that EVA gives the better results compare to others while ETU gives the worst.

Individual plots of the throughput vs SNR for EPA, EVA and ETU with 70 Hz Doppler Effect have been shown in Fig.6-8.

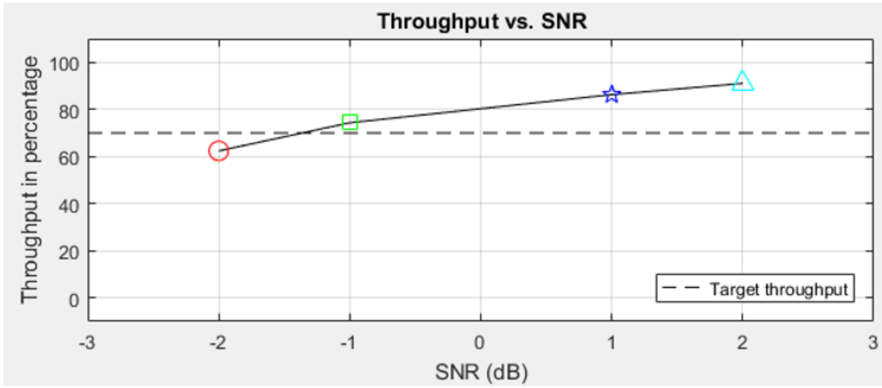



Fig. 6 Throughput vs SNR for EPA with 70 Hz Doppler Effect

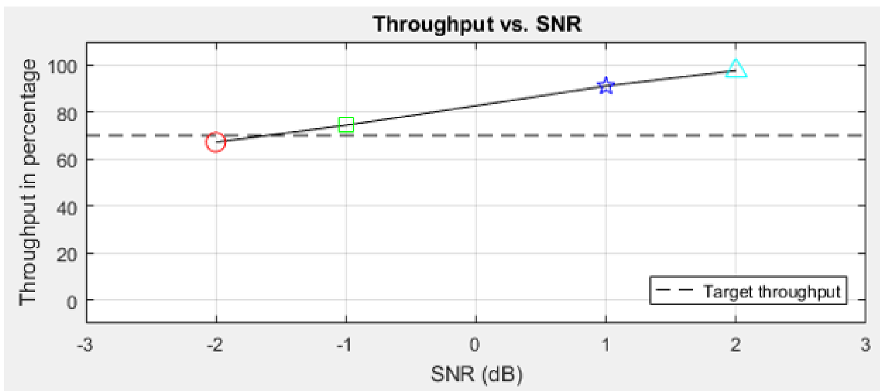



Fig. 7 Throughput vs SNR for EVA with 70 Hz Doppler Effect

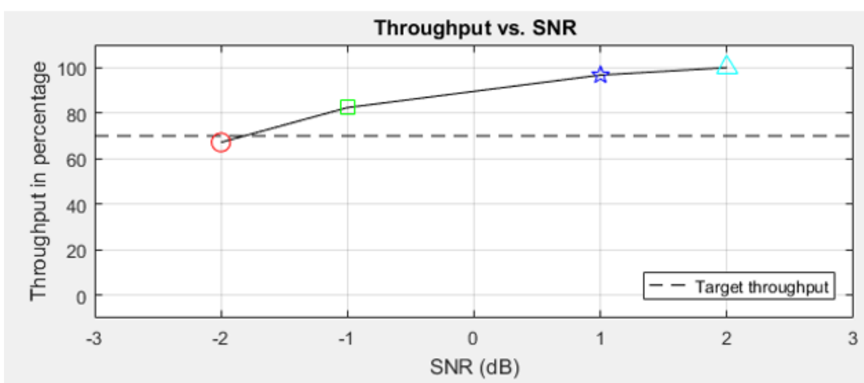



Fig. 8 Throughput vs SNR for ETU with 70 Hz Doppler Effect

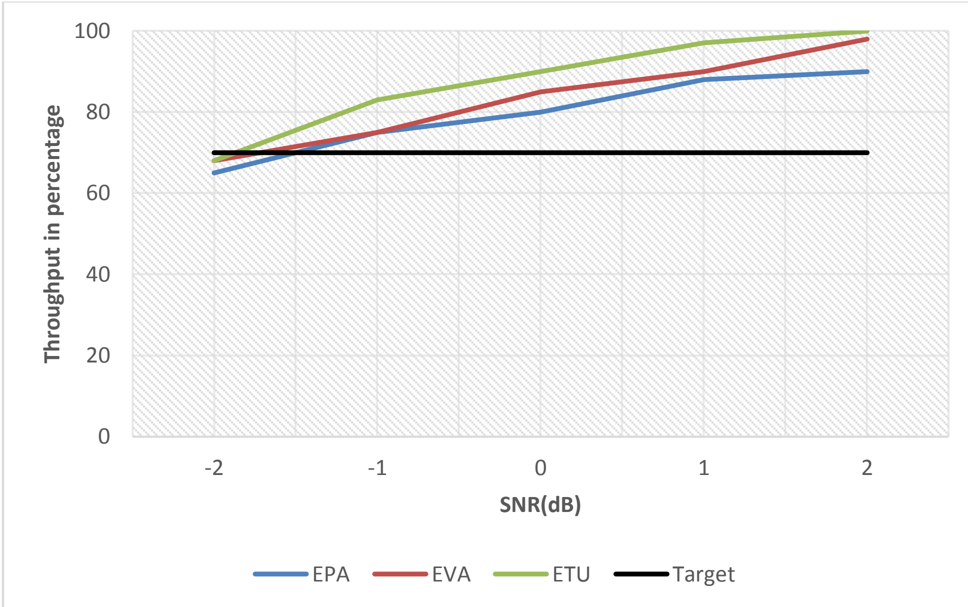



Fig. 9Combined Throughput vs SNR for EPA, EVA &ETU with 70 Hz Doppler Effect

From Fig.9, it is found that ETU gives the best result while EPA gives the worst. So, 70 Hz Doppler Effect, the performance of ETU is the best though it was worst for the case of 5Hz.

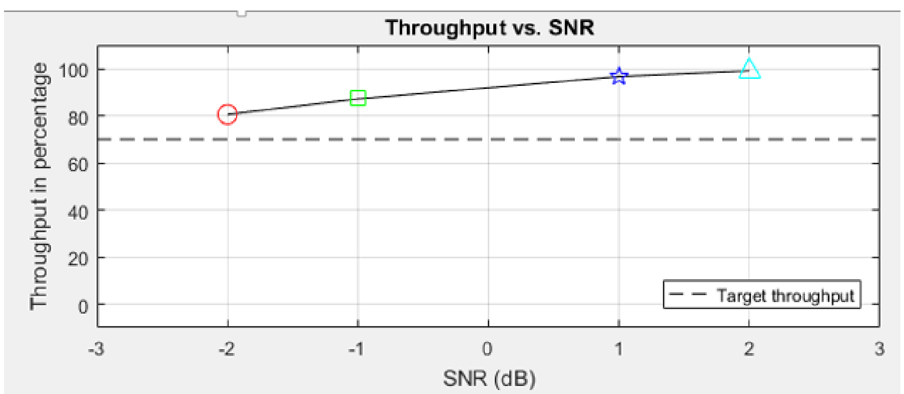



Fig. 10 Throughput vs SNR for EPA with 300 Hz Doppler Effect

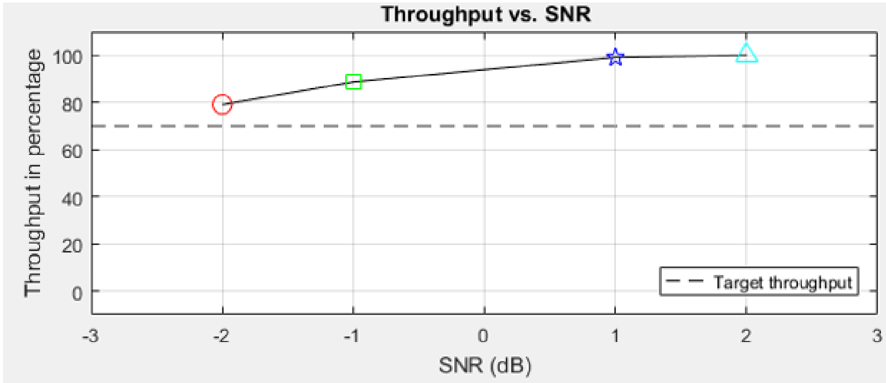



Fig. 11 Throughput vs SNR for EVA with 300 Hz Doppler Effect

Individual plots of the throughput vs SNR for EPA, EVA and ETU with 300 Hz Doppler Effect have been shown in Fig.10-12. In all the cases, the for all the SNR values, throughput has been crossed the target.

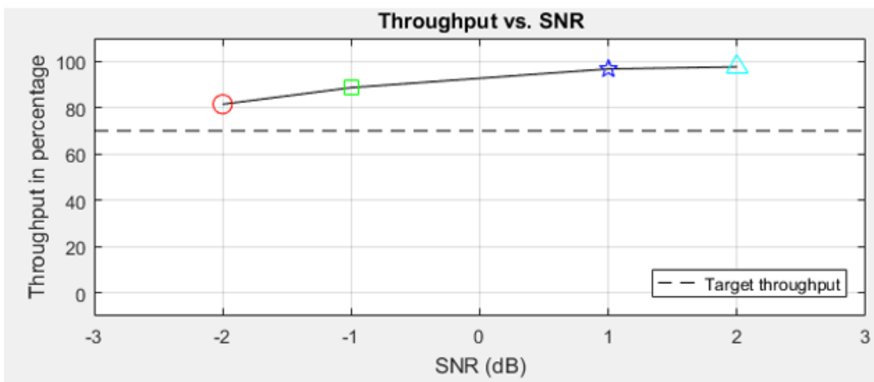



Fig. 12 Throughput vs SNR for ETU with 300 Hz Doppler Effect

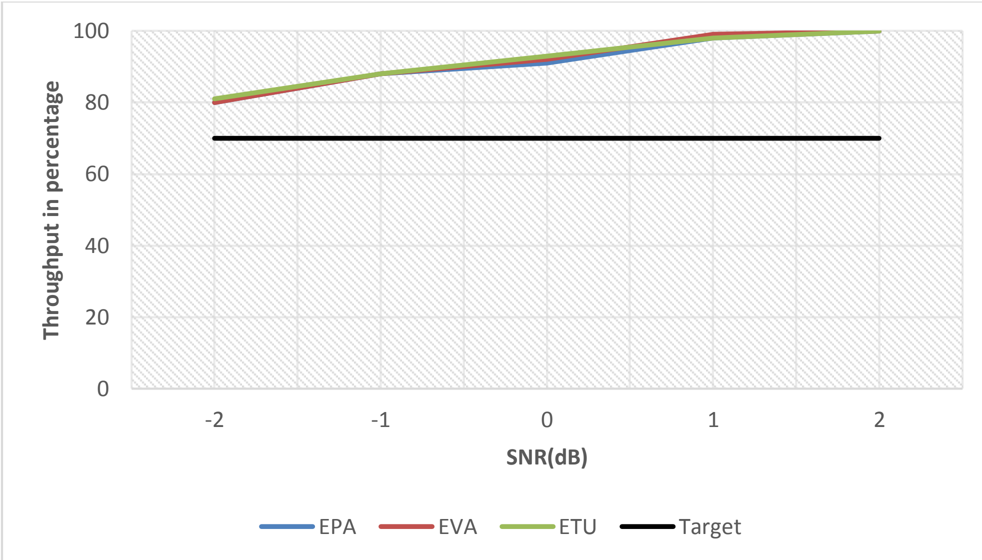



Fig. 13 Combined Throughput vs SNR for EPA, EVA &ETU with 300 Hz Doppler Effect

From Fig.13, it has been observed that all the models give the same results. That means in case of 300 Hz Doppler Effect, the results of the entire propagation model is quite identical.

So from all the figures, it can be summarized that the higher SNR value gives the higher throughput and higher Doppler Effect will result the higher throughput. For 5Hz, EVA gives the best result, for 70 Hz, ETU gives the best and for 300 Hz all the models are same.

# CHAPTER 8

# Conclusion

In this project, the performances of three propagation models of LTE (EPA, EVA & ETU) have been analyzed. In the analysis, throughputs for various SNR's value in several Doppler effects have been considered. It has been found that for 5 Hz Doppler Effect, EVA shows the best performance and ETU shows the worst. In case of 70 Hz, ETU is the best and EPA is the worst. But in case of 300 Hz, all the models are identical. It has been also found that increasing the value of SNR increases the value of throughput. In future, the analysis will be done with real life values instead of the simulation values with considering some other parameters.

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