Ministry Of Higher Education
And Scientific Research
University Of Diyala
College Of Engineering
Communication Engineering Department

Doppler Fading Channel Simulation

A project

Submitted to the Department of Communication University of Diyala-College of Engineering in Partial Fulfillment of the Requirement for Degree Bachelor in Communication Engineering

BY

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ ۖ وَسَتُرَدُّونَ إِلَىٰ
عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُمْ بِمَا كُنْتُمْ تَعْمَلُونَ (١٠٥)

صدق الله العظيم

سورة التوبة

SUPERVISORS CERTIFICATION

We certify that the preparation of this project entitled “***Doppler Fading Channel Simulation***”, was made under our supervision at Communication Engineering Department/College of Engineering in Diyala university by (**Sarab Hamid Abdallah & Elaph Abdulrazzaq AbdulKareem**) as a partial fulfillment of the requirements for the degree of B.Sc. in Communication Engineering.

Signature:
Name: **Dr. Riyadh Khlf Alazawi**
Title: Lect.Doctor
Date: / / 2016

In view of the available recommendations, I forward this project for debate by the examining committee.

Signature:

Name: **Dr. Montadar Abas Taher**

(Head of the Department)

Title: Lect.Doctor

Date: / / 2016

CERTIFICATION OF THE EXAMINATION COMMITTEE

We certify that we have read this project entitled "***Design Laser Communication System with Repeater***" and as examining committee examined the students (**Sarab Hamid Abdallah & Elaph Abdulrazzaq AbdulKareem**) in its contents and that in our opinion it meets the standards of a project for the degree of B. Sc. in Communication Engineering.

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Name :	Name:
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Date: / /2016	Date: / /2016
(Member)	(Member)

Signature :

Name :

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(chairman)

Approved for Communication Engineering Department.

Signature:
Name: **Dr. Montadar Abas Taher**
(Head of the Department)

Title: Lecturer
Date: / / 2016

Dedication

A kiss on the forehead of my father, who oozes sweat for us,

This great, who painted the wrinkles on his face, a map for a decent life

And to my mother, the first homelands and final exiles.

Acknowledgement

To the people who paved our way of science and knowledge

To all our teachers Distinguished,

And in particular, Dr. Riyadh Khlf Alazawi.

ABSTRACT

Fading is commonly used to describe the properties of the communication channel, so large efforts has been made to describe characteristics of the channel in wireless communication system. The performance of a wireless signal propagation in a conventional environment needs Doppler fading channel schemes by assuming a perfect knowledge about the channel frequency response at the transmitter and receiver. The performance is evaluated by two methods, where the first method consists of two antennas at a given distance (r) to evaluate the Doppler effect for transmission links at relative motion between the transmitter and receiver antennas. The second method is MATLAB simulation model in term of source velocity to illustrate the performance. In This work, we present a MATLAB based approach to multipath Doppler fading channel simulation, which compute the envelope at receiver end taking into account the source velocity over the multipath fading.

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LIST OF ABBREVIATIONS

ACF _ Autocorrelation Function

AR _ Autoregressive

AWGN _ Additive White Gaussian Noise

Bc _ Channel Bandwidth

BEP _ Basic Periodontal Examination

BER _ Bit Error Rate

BPS _ Bhagat Phool Singh

BPSK _ Binary phase-shift keying

Bs _ Signal Bandwidth

BS _ Base Station

C _ Constant Speed

CCI _ Co-Channel Interference

CDMA _ Code Division Multiple Access

COFDM _ Coded Orthogonal Frequency Division Multiplexing

FD _ Doppler Faging

ICI _ Inter Channel Interference

ISI _ Inter-Symbol Interference

MC-CDMA _ Multicarrier Code Division Multiple Access

MIMO _ Multiple-Input Multiple-Output

MMSE _ Minimum Mean-Square Error

MMSE-DFE _ Minimum-Mean-Squared-Error Decision- Feedback Equalizer

MS _ Mobile Station

MUI _ Multilingual User Interface

NTUA _ National Technical University of Athens

OFDM _ Orthogonal Frequency Division Multiplexing

PSAM _ Pilot Symbol Assisted Modulation

QAM _ Quadrature amplitude modulation

QPSK _ Quadrature Phase Shift Keying

RAKE _ Radiophysics and Quantum Electronics

RX _ Receiver

SER _ Symbol-Error Rate

SNR _ Signal-To-Noise Ratio

SOS _ Sum-Of-Sinusoids

TBP _ TATA-Binding Protein

Vs _ Speed Of The Sound Source

WSS _ Wide-Sense Stationary

LIST OF SYMBOLS

an _ Random amplitude of the nth path

αn _ Random phase associated with the nth path

rn _ length of nth path

N _ Large number of scattering structures

σ _ Standard deviation

Vr _ Received voltage

φ _ Latitude of the earth station

A _ Direct path amplitude

Θ _ Elevation angle

fd _ Doppler frequency

φn _ Phase angle

f _ Frequency

Sd _ Doppler power spectrum

Tc _ Coherence Time

Ts _ Symbol period

CHAPTER ONE

INTRODUCTION

1.1 Introduction

An explosive development of the wireless technology has opened several new paths for its implementation, however some unavoidable circumstances attenuate the signal energy and make barriers to achieving the optimum results from the system [1]. The radio link between the transmitter and receiver varies from simple line-of-sight to one that is severely obstructed by the buildings, mountains etc, and hence suffers from severe multipath fading [1-7]. However, the mobile channels are very different from the stationary as well as predictable wired channels, because of their randomness. There are several factors which determine the behavior of a channel such as terrain features between the transmitter and receiver, the speed of transmitter and receiver, weather conditions etc. Over the years, several studies and measurements have been undertaken in different locations for such channels and various models have been proposed for both the indoor and outdoor environments [3, 4]. The instantaneous signal strength at the receiver can be predicted using the traditional large-scale and small-scale models, wherein the large-scale models predict the average received signal strength depending on the transmitter-receiver distance and the small-scale channel models represent local variations of the average signal strengths [8-13].

1.1.1 Channel

A channel is defined as the communication path between transmit and receive antennas. The channel accounts for all possible propagation paths as well as the effects of absorption, spherical spreading attenuation, reflection losses, Faraday rotation, scintillation, polarization dependence, delay spread, angular spread, Doppler spread, dispersion، interference, motion, and fading. It may not be necessary that any one channel has all of the above effects but often channels have multiple influences on communication waveforms. Obviously, the complexity of the channel increases as the number of available propagation paths increases. It also becomes more complex if one or more variables vary with time such as the receiver or transmitter position. Several excellent texts exist which describe channel characteristics [14–22]. Indoor propagation modeling can be a formidable challenge. This is partly due to the regular and periodic location of structures such as windows, doors, wall studs, ceiling tiles, electrical conduits, ducts‘ and plumbing. This is also partly due to the very close proximity of scattering objects relative to the transmitter and/or receiver.

An excellenttreatment of indoor propagation channels can be found in Sarkar et al. [18], Shankar [16], and Rappaport [22].

1.1.2 Fading

Fading is a term used to describe the fluctuations in a received signal as a result of multipath components. Several replicas of the signal arrive at the receiver, having traversed different propagation paths, adding constructively and destructively. The fading can be defined as fast or slow fading. Additionally, fading can be defined as flat or frequency selective fading.

1.1.2.1 Fast fading

Fast fading is propagation which is characterized by rapid fluctuations over very short distances. This fading is due to scattering from nearby objects half-wavelength distances.

1.1.2.2 Slow fading

Slow fading is propagation which is characterized by slow variations in the mean value of the signal. This fading is due to scattering from the more distant and larger objects and thus is termed large-scale fading. Typically slow fading is the trend in signal amplitude as the mobile user travels over large distances relative to a wavelength. The slow fading mean value is generally found by averaging the signal over 10 to 30 wavelengths [23]. A log-normal distribution tends to best fit this fading scenario, thus slow fading is sometimes referred to as lognormal faging.

1.1.2.3 Flat fading

Flat fading is when the frequency response of the channel is flat relative to the frequency of the transmit signal, that is, the channel bandwidth Bc is greater than the signal bandwidth Bs(Bc > Bs). Thus,the multipath characteristics of the channel preserve the signal quality at the receiver.

1.1.2.4 Frequency selective fading

Frequency selective fading is when the channel bandwidth Bc is less than the signal bandwidth Bs (Bc < Bs). In this case, the multipath delays start to become a significant portion of the transmit signal time duration and dispersion occurs. Fast fading is of particular interest to the electrical engineer because the resulting rapid fluctuations can cause severe problems in reliably maintaining communication.

1.1.3 Doppler

The Doppler effect (or the Doppler shift) is the change in frequency of a wave (or other periodic event) for an observer moving relative to its source. It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. Compared to the emitted frequency, the received frequency is higher during the approach, identical at the instant of passing by, and lower during the recession.[24]

When the source of the waves is moving toward the observer, each successive wave crest is emitted from a position closer to the observer than the previous wave. Therefore, each wave takes slightly less time to reach the observer than the previous wave. Hence, the time between the arrival of successive wave crests at the observer is reduced, causing an increase in the frequency as in Fig. (1.1) . While they are travelling, the distance between successive wave fronts is reduced, so the waves "bunch together". Conversely, if the source of waves is moving away from the observer, each wave is emitted from a position farther from the observer than the previous wave, so the arrival time between successive waves is increased, reducing the frequency. The distance between successive wave fronts is then increased, so the waves "spread out".

For waves that propagate in a medium, such as sound waves, the velocity of the observer and of the source are relative to the medium in which the waves are transmitted. The total Doppler effect may therefore result from motion of the source, motion of the observer, or motion of the medium. Each of these effects is analyzed separately. For waves which do not require a medium, such as light or gravity in general relativity, only the relative difference in velocity between the observer and the source needs to be considered.

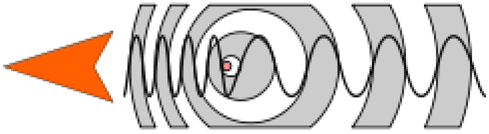

Fig. (1.1) Change of wavelength caused by motion of the source

An interesting effect was predicted by Lord Rayleigh in his classic book on sound: if the source is moving at twice the speed of sound, a musical piece emitted by that source would be heard in correct time and tune, but backwards. [25] The Doppler effect with sound is only clearly heard with objects moving at high speed, as change in frequency of musical tone involves a speed of around 40 meters per second, and smaller changes in frequency can easily be confused by changes in the amplitude of the sounds from moving emitters. Neil A Downie has demonstrated [26] how the Doppler effect can be made much more easily audible by using an ultrasonic (e.g. 40 kHz) emitter on the moving object. The observer then uses a heterodyne frequency converter, as used in many bat detectors, to listen to a band around 40 kHz. In this case, with the bat detector tuned to give frequency for the stationary emitter of 2000 Hz, the observer will perceive a frequency shift of a whole tone, 240 Hz, if the emitter travels at 2 meters per second.

1.1.3.1 Different cases of the source and observer :-

The first case when the sound source fixed produces sound waves at a fixed frequency f, and interfaces wave spread symmetrically away from the source at a constant speed c. The distance between wave fronts is the wavelength , as shown in Fig. (1.2).

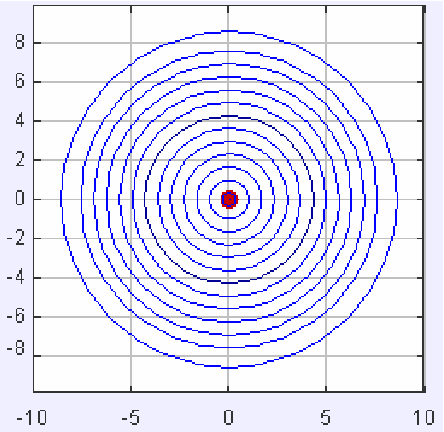

Fig. (1.2) Source at a Cconstant speed c.

In the second case the same sound source is radiating sound waves at a constant frequency in the same medium. However, now the sound source is moving with a speed υs = 0.7 c (Mach 0.7). Since the source is moving, the centre of each new wavefront is now slightly displaced to the right. As a result, the wave-fronts begin to bunch up on the right side (in front of) and spread further apart on the left side (behind) of the source , as shown in Fig. (1.3).

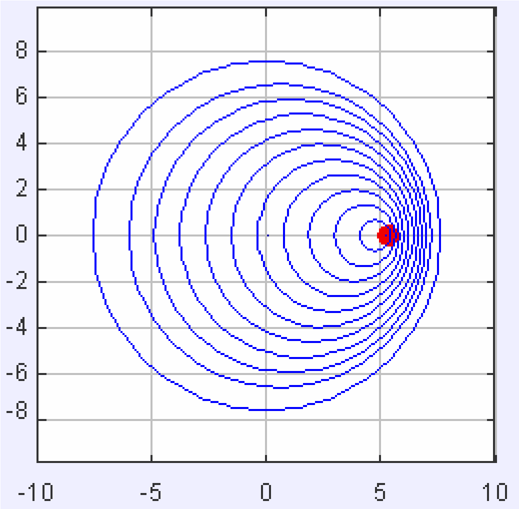

Fig. (1.3) source is moving with a speed $\upsilon_s = 0.7$ c

And the third case is when the source is moving at the speed of sound in the medium ($\upsilon s = c$, or Mach 1). The wave fronts in front of the source are now all bunched up at the same point , as shown in Fig. (1.4).

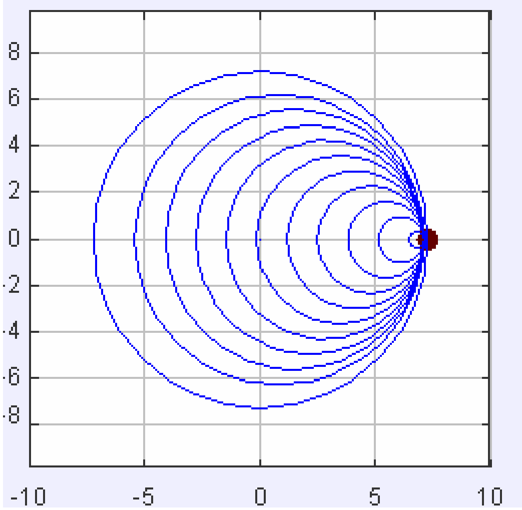

Fig. (1.4) source is moving at the speed of sound($\upsilon_s = c$)

In the fourth case, the sound source has now surpassed the speed of sound in the medium, and is traveling at 1.4 c (Mach 1.4). Since the source is moving faster than the sound waves it creates, it actually leads the advancing wavefront. The sound source will pass by a stationary observer before the observer hears the sound , as shown in Fig. (1.5)

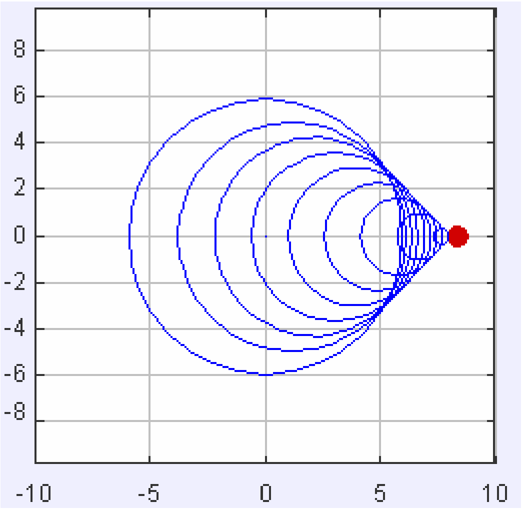

Fig. (1.5) source is moving faster than the sound waves

1.1.3.2 Inverse Doppler effect

Since 1968 scientists such as Victor Veselago have speculated about the possibility of an inverse Doppler effect. The experiment that claimed to have detected this effect was conducted by Nigel Seddon and Trevor Bearpark in Bristol, United Kingdom in 2003.[27]

Researchers from many Universities like Swinburne University of Technology and the University of Shanghai for Science and Technology showed that this effect can be observed in optical frequencies as well. This was made possible by growing a photonic crystal and projecting a laser beam into the crystal. This made the crystal act like a super prism and the inverse Doppler effect could be observed.[28]

1.2 Problem Statement

The transmitted signal from transmitter to the receiver through wireless channel suffer from several effects like small scale fading , dispersion and attenution. In our work we experiminate and simulate the Doppler fading channel performance. The signal is received by different paths as aconsequence of reflection, diffraction and scattering from building, structures and other obstacles exciting in the propagation environment when the received signals are out of phase, high reductioon will be occured.This causes significant fluctuations in received signal amplitude**.**

1.3 Objectives

The objectives and goals of this research can be in brief summarized in the following :

1.Make simulation of Doppler performance by change the terms of source velocity, frequency and phase angels.

2. Build a special set up to measure the Doppler frequency

1.4 Organization of research

At the start, chapter one shows the introduction of the Fading Channel, and shows how several factors which determine the behavior of a channel such as terrain features between the transmitter and receiver. and then define channel as the communication path between transmit and receive antennas. Then describe the fluctuations in a received signal as a result of multipath components as Fading, and explain the types of fading, to start the main matter of Doppler fading.

In chapter two , after the introduction, it will have explain the beginning of Doppler channel and the previous published studies of Doppler fading channel. Later, it will give a brief description about Rayleigh, Rician, and Doppler Fading Channel Models.

Chapter three speak about the methodology of the research and shows the different mechanisms of multipath propagation such as diffraction, scattering, reflection and refraction which play as important factor to create multiple propagation paths, and clarify the equations for each types of fading. Then it will study how the research had been organized, the Doppler fading will Illustrates by a practical experiment using Gun oscillator, Horn antenna, and other resource, to create a data bank for how to take out the parameters of the simulation work.

Chapter four include the results and the discussion of the results which had obtained by using MATLAB software, moreover, the effect of changing the Doppler frequency and number of paths will affects on the simulation behavior.

Chapter five will talk about the conclusion of the research according to the result which had been obtained.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Doppler fading channel first proposed this effect in 1842 in the treatise of Christian Doppler (During the colored light of the double stars and some other stars from the sky).The hypothesis was tested for sound waves by Buys Ballot in 1845, He confirmed that the sound's pitch was higher than the emitted frequency when the sound source approached him, and lower than the emitted frequency when the sound source receded from him. Hippolyte Fizeau discovered independently the same phenomenon on electromagnetic waves in 1848.In this chapter we will list some previous published studies of Doppler Fading Channel.

2.2. Simulation on Effect of Doppler shift in Fading channel and Imperfect Channel Estimation for OFDM in Wireless Communication

Manita Baral Kharel, Institute of Engineering, Tribhuvan University.

Sarbagy Ratna Shakya, Institute of Engineering, Tribhuvan University.

The abstract of this research was that " In wireless communication system, the transmitted signal is distorted by various phenomena that are intrinsic to the structure and contents of the wireless channel. Among these fading and interference are the main dominant sources of distortion that are responsible for the degradation of performance. Fading as is the fluctuation in amplitude phase and multipath delays over very short travels distance or very short time duration. To increase high data rate in wireless communication Multiple-input multiple-output (MIMO) and orthogonal frequency division multiplexing (OFDM) techniques have been considered best as it has high frequency spectrum efficiency [29]. In this study, the performance over fading channel on the wireless communication is explained, simulation and compared for maximum likelihood receivers in different modulation structure in the presence of Gaussian Channel estimation error, based on different Doppler shift".

The conclusion of research was that " The increase in the Doppler shift in the different channel models for OFDM signal increases the BER rate for the constant SNR, whereas the BER decreases with the increase in SNR for the same Doppler Shift [30]. Also due to the Doppler fading caused by the Doppler shift it can be observe that the signal at the receiver side varies**".**

2.3 Performance Analysis of Rayleigh and Rician Fading Channel Models using MATLAB Simulation

Sanjiv Kumar , Computer Engineering, BPS Mahila Vishwavidyalaya,, India **.**

Prabhat K. Gupta, Computer Science and Engineering, Jaypee University of Information Technology, India

Ghan Singh, Electronics and Communication Engineering, Jaypee University of Information Technology, India

D. S. Chauhan, Uttarakhand Technical University, India

The abstract of this research was that " The performance comparison of the Rayleigh and Rician fading channel models by using MATLAB simulation in terms of source velocity and outage probability. The Rayleigh and Rician fading channels algorithms have developed, which computes the envelop and outage probability [31]. The parameters such as source velocity and outage probability play very important role in the performance analysis and design of the digital communication systems over the multipath fading environment".

The conclusion of research was that " As the vehicle speed of user is increased, the amount of fading is increased in the signal envelope. Therefore, as we increase the speed, more of the signal goes below the threshold and the amount of fading increased. He also simulated the Rayleigh and Rician fading channels in terms of the outage probability by using Matlab simulation for different thresholds of the received signal and compare these values to those calculated analytically [32] . However, the results from both the simulation and analysis are comparable. As he have observed from the comparison table, the outage probability in the Rician fading channel is lower than that of the Rayleigh fading channel, which is due to the presence of line-of-sight path in the Rician channel. He also concluded that the outage probability increases as the mobile velocity or Doppler shift increases. Dynamically changed multipath and Doppler effects are the main causes behind the degradation of the channel capacity".

2.4 An Analysis of Pilot Symbol Assisted Modulation for Rayleigh Fading Channels

James K. Cavers, Electrical engineering, University of British.

The abstract of this research was that " Proposals have appeared recently for the use of pilot symbols to mitigate the effects of rapid fading in mobile communications. Unlike the more familiar pilot tone systems [33], pilot symbol assisted modulation (PSAM) does not affect the transmitted pulse shape or the peak-to-average power ratio, and implementation is straightforward. This paper puts PSAM on a solid analytical basis, a feature missing from previous work. It presents closed form expressions for the BER in BPSK and QPSK, for a tight upper bound on SER in 16 QAM, and for the optimized receiver coefficients. The error rates obtained are lower than for differential detection for any combination of SNR and Doppler spread, and the performance is within 1 dB of a perfect reference system under slow fading conditions, and within 3 dB when the Doppler spread is 5% of the symbol rate".

The conclusion of research was that " Pilot symbol assisted modulation is relatively simple to implement. The transmitter just inserts known symbols periodically, so there is no change in pulse shape or peak to average power ratio [34]. The receiver interpolates the channel measurements provided by the pilot symbols to obtain an amplitude and phase reference for detection. The pilot symbols lower the effective bit rate by about 14% if the Doppler spread is *5%* of the symbol rate. For smaller Doppler values, though, the loss of capacity is much less: about *5* % for a 1 % Doppler spread. Minor drawbacks include the delay and buffer space required at the receiver for interpolation. However, the good error performance, the removal of the error floor, and the enabling of multilevel signal formats outweigh these deficiencies".

2.5 Joint Multipath-Doppler Diversity in Mobile Wireless Communications

Akbar M. Sayeed, Electrical and computer Engineering, University of Wisconsin

Behnaam Aazhang, Electrical and computer Engineering, Rice University

The abstract of this research was that " Introduce a new approach for achieving diversity in spread-spectrum communications over fast-fading multipath channels [35]. The RAKE receiver used in existing systems suffers from significant performance degradation due to the rapid channel variations encountered under fast fading. We show that the Doppler spread induced by temporal channel variations in fact provides another means for diversity that can be further exploited to combat fading. We develop the concept of Doppler diversity and propose a framework that exploits joint multipath- Doppler diversity in an optimal fashion. Performance analysis shows that even the relatively small Doppler spreads encountered in practice can be leveraged into significant diversity gains via our approach. The framework is applicable in several mobile wireless multiple access systems and can provide substantial performance improvement over existing systems".

The conclusion of research was that " Signal fading produced by the wireless channel is one of most significant factors limiting the performance of mobile communication systems. The mobile wireless channel inherently affords diversity that can be exploited via the use of large-TBP signaling waveforms to combat fading. In this context, spread-spectrum CDMA systems have a distinct advantage over other systems, such as time-division or frequency-division multiple-access systems. However, existing CDMA systems based on the RAKE receiver only partly exploit channel diversity: they are optimal for slow fading scenarios and achieve multipath diversity. Consequently, existing systems perform poorly under fast fading and exhibit BEP floors due to mismatch with channel characteristics [36]".

2.6 Fading Models

Fabio Belloni, Communication Systems, Helsinki University of Technology

The abstract of this research was that " Most mobile communication systems are used in and around center of population. The transmitting antenna or Base Station (BS) are located on top of a tall building or tower and they radiate at the maximum allowed power. In the other hand, the mobile antenna or Mobile Station (MS) is well below the surrounding buildings. Consequently, the radio channel is influenced by the surrounding structures such as cars, buildings,...

The wireless channel can be described as a function of time and space and the received signal is the combination of many replicas of the original signal impinging at receiver (RX) from many different paths. The signal on these different paths can constructively or destructively interfere with each other. This is referred as multipath .

The conclusion of research was that " The Fading Models and divided the it into three classes by separating the received signal in three scale of spatial variation, such as fast fading, slow fading (shadowing) and path loss. Moreover, several models for small scale fading are considered such as Rayleigh, Ricean, Nakagami and Weibull distributions. Slow fading is also investigated as well as serial and siteto-site correlations are compared [37] "

2.7 Autoregressive Modeling for Fading Channel Simulation

Kareem E. Baddour, Electrical engineering, University of Newfoundland

Norman C. Beaulieu, Electrical engineering, University of British Columbia

The abstract of this research was that " Autoregressive stochastic models for the computer simulation of correlated Rayleigh fading processes are investigated. The unavoidable numerical difficulties inherent in this method are elucidated and a simple heuristic approach is adopted to enable the synthesis of accurately correlated, band limited Rayleigh variants. Startup procedures are presented, which allow autoregressive simulators to produce stationary channel gain samples from the first output sample. Performance comparisons are then made with popular fading generation techniques to demonstrate the merits of the approach [38]. The general applicability of the method is demonstrated by examples involving the accurate synthesis of non isotropic fading channel models.
The conclusion of research was that " Autoregressive (AR) stochastic models were considered for the computer simulation of correlated Rayleigh fading channels.

The numerical difficulties faced by this approach were resolved by approximating the deterministic band limited Doppler processes with regular processes. Two procedures for eliminating the need to discard, possibly many, initial generated samples due to transient distortion were presented. The proposed methods enable the synthesis of stationary and statistically accurate Rayleigh channel gain samples as they are needed. Furthermore, the fading channel ACF is easily specified, which makes the simulator especially suited for the emulation of generalized flat Rayleigh fading channels. To demonstrate the general applicability of the method, an AR simulator for generating non isotropic fading channel variants was derived. This non isotropic simulator will be useful for emulating directional fading scenarios encountered in practical mobile communication systems".

2.8 Multi-Input Multi-Output Fading Channel Tracking and Equalization Using Kalman Estimation

Christos Komninakis, Electrical and Computer Engineering, National Technical University of Athens (NTUA)

Christina Fragouli, Wireless Networks, National Technical University of Athens (NTUA)

Ali H. Sayed, Electrical Engineering, Stanford University

Richard D. Wesel, Electrical Engineering**,** Massachusetts Institute of Technology, Cambridge

The abstract of this research was that "This paper addresses the problem of channel tracking and equalization for multi-input multi-output (MIMO) time-varying frequency-selective channels. These channels model the effects of inter-symbol interference (ISI), co-channel interference (CCI), and noise. A low-order autoregressive model approximates the MIMO channel variation and facilitates tracking via a Kalman filter. Hard decisions to aid Kalman tracking come from a MIMO finite-length minimum-mean-squared-error decision- feedback equalizer (MMSE-DFE), which performs the equalization task. Since the optimum DFE for a wide range of channels produces decisions with a delay, the Kalman filter tracks the channel with a delay. A channel prediction module bridges the time gap between the channel estimates produced by the Kalman filter and those needed for the DFE adaptation. The proposed algorithm offers good tracking behavior for multiuser fading ISI channels at the expense of higher complexity than conventional adaptive algorithms [39]. Applications include synchronous multiuser detection of independent transmitters, as well as coordinated transmission through many transmitter/receiver antennas, for increased data rate"**.**

The conclusion of research was that "This paper proposed a receiver structure to track and equalize a MIMO frequency-selective fading channel. A Kalman filter was used for tracking the channel, employing a low-order autoregressive model to best fit the true statistics of the channel variation. An MMSE DFE optimized for decision delay [40]"**.**

2.9 Limitations of Sum-of-Sinusoids Fading Channel Simulators

Marius F. Pop, Electrical engineering, Queen’s University, Canada

Norman C. Beaulieu, Electrical engineering, University of British Columbia

The abstract of this research was that " Rayleigh signal fading due to multipath propagation in wireless channels is widely modeled using sum-of-sinusoids simulators. In particular, Jakes’ simulator and derivatives of Jakes’ simulator have gained widespread acceptance. Despite this, few in-depth studies of the simulators’ statistical behaviors have been reported in the literature. Here, the extent to which Jakes’ simulator adequately models the multipath Rayleigh fading propagation environment is examined [41]. The results show that Jakes’ simulator does not reproduce some important properties of the physical fading channel. Some possible improvements to Jakes’ simulator are examined. The significances of the number and the symmetries of the Doppler frequency shifts on the validity of the simulator’s reproduction of the physical fading channel are elucidated".

The conclusion of research was that " This mathematical model has led to various simulator designs. One method of simulating the multipath fading encountered on Rayleigh flat fading wireless channels is based upon the SOS model. It is generally desired to have an efficient method for generating fading signals. Viewed in this light, Jakes' approach presents an interesting point. That is, if we are able to reduce the complexity of the model, i.e., the number of low-frequency oscillators, then the generation of the signal is more efficient. On the other hand, this reduction was shown to lead to the generation of a no stationary signal [42]. Also shown here is that introduction of random phase shifts in the low-frequency oscillators removes the stationary problems; that is, the resulting signal is WSS. Finally, it has been shown that the smallest number of low-frequency oscillators required is equal to the number of distinct Doppler frequency shifts, counting positive and negative shifts as one. However, care must be taken in determining the gain of each branch for each low-frequency oscillator, i.e., all phase shifts corresponding to a particular Doppler frequency shift must be included in the simulator design".

2.10 Performance Analysis of Synchronous MC-CDMA in Mobile Rayleigh Channel With Both Delay and Doppler Spreads

Jean-Paul M. G. Linnartz, Electrical engineering, Eindhoven University of Technology

The abstract of this research was that " Rapid time variations of the mobile communication channel have a dramatic effect on the performance of multicarrier modulation. This paper models the Doppler spread and computes its effect on the bit error rate (BER) for multicarrier code division multiple access (MC-CDMA) transmission and compares it to orthogonal frequency division multiplexing (OFDM). Also, we evaluate the transmission capacity per subcarrier to quantify the potential of MC-CDMA and (coded-) OFDM [43]. We focus on linear receivers, in particular those using the minimum mean-square error (MMSE) criterion. Our channel and system models allow the computation of analytical performance results. Simulations verify some commonly used, yet critical assumptions".

The conclusion of research was that " presented a framework that allows a theoretical estimation of the BER of MC-CDMA with a linear receiver. It includes analytical expressions for the variance of MUI and ICI in an MMSE receiver. Using this method, we found expressions for the performance of MC-CDMA, and we compared these to OFDM. We proposed a pseudo-MMSE receiver for MC-CDMA over channels with Doppler, and analyzed its performance. BERs are better for MC-CDMA than for uncoded OFDM, though OFDM can achieve a higher performance gain from coding than MC-CDMA. A rapid deterioration of the BER is seen when antenna speeds increase, but less dramatic than reported for OFDM. Improvement is possible by implementing the true MMSE receiver settings. This appears to be computationally intensive as it requires channel estimation of many parameters and matrix inversions, but current research addresses such receivers, e.g., [44]. We have also compared OFDM and MC-CDMA using Information Theoretic arguments. If we allow the constellation of the modulation to be optimized for SNR and if the number of subcarriers is very large (infinity), we found that MC-CDMA does not have an advantage over C-OFDM in terms of the theoretical channel capacity. The use of a linear receiver structure in MMSE MC-CDMA leads to a performance penalty. We concluded that for a system with many subcarriers and a channel with sufficiently large delay spread, MC-CDMA symbols see a non fading channel. Hence, we found expressions for the performance of MC-CDMA over Rayleigh channel relative to a classic non fading AWGN channel [45] ".

2.11 Robust Doppler Spread Estimation in Non isotropic Fading Channels

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Norman C. Beaulieu, Electrical engineering, University of British Columbia

The abstract of this research was that " A new parametric approach is proposed for estimation of the maximum Doppler frequency, or equivalently the mobile speed, in narrowband mobile radio channels. In this work, simple and efficient Doppler frequency estimators are formulated based on using a small number of samples of the channel autocorrelation function. Unlike previous approaches, the chosen parameterization is shown to be robust in a microcellular propagation environment, which may be characterized by non isotropic scattering and/or a secular component of unknown strength. Simulation results are described to illustrate the effects of additive noise and the finite data record performance**".**

The conclusion of research was that " we have demonstrated that the first few lags of the channel autocorrelation function contain information that can be exploited to obtain parametric Doppler spread estimators that are robust in the presence of no isotropic scattering. Such a parameterization is essential if reliable estimates of the fading rate are to be achieved in practical propagation scenarios [46]. The effect of additive Gaussian noise on the proposed method was considered and a simple noise compensation approach was shown to result in accurate fd estimates in a pilot symbol-based channel estimation framework **".**

CHAPTER THREE

METHODOLOGY

3.1 Introduction

Relative motion between the transmitter and receiver introduce Doppler shift which affect on the received signal frequency and causes frequency broadening. The transmission radio link between the transmitter source and destination receiver varies from flat earth model to multipath propagation mechanisms which the electromagnetic waves are severely obstructed by the mountains, high buildings and skyscrapers [47][48].The different mechanisms of multipath propagation such as diffraction, scattering, reflection and refraction [49] play as important factor to create multiple propagation paths.

Fading can defined as the fluctuations in received electromagnetic wave as a consequence of multipath signal components. Many different replicas of the received electromagnetic waves can be arrived to the receiving end. These replicas came from different paths and interference constructively or destructively according to their amplitude, phase and time delay.

Fading can be classified as fast or slow fading. In addition, fading can be classified as flat or frequency selective. However, the fast fading is more draw attention to the communication engineers because the fluctuations may affect dramatic problems in communication system reliability.

3.1.1 Fast fading modeling

The Fast fading is of particular interest to the electrical engineer because the resulting rapid fluctuations can cause severe problems in reliably maintaining communication.

3.1.1.1 Multipath with no direct path

Based upon the scenario in fig. (3.1), we will assume that no direct path exists but that the entire received electric field is based upon multipath propagation.

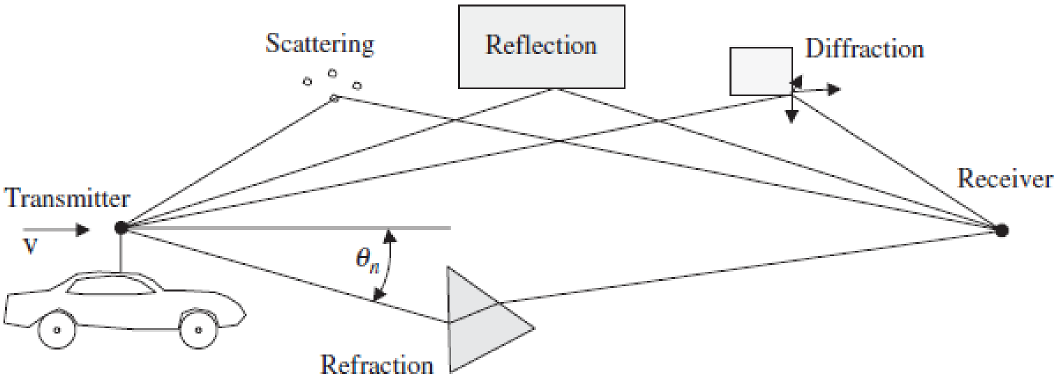

Fig. (3.1) A multipath channel with no direct path.

We can express the received voltage phasor as the sum of all the possible multipath component voltages within the receiver

$$vrs = \sum_{n=1}^{N} an\, e^{-j(krn-\alpha n)} = \sum_{n=1}^{N} an\, e^{j\phi n} \qquad (3.1)$$

where an = random amplitude of the nth path

αn = random phase associated with the nth path

rn = length of nth path

φn=−krn + αn

If we assume a large number of scattering structures N, which are randomly distributed, we can assume that the phases φn are uniformly distributed. We can express the time-domain version of the received voltage as

$$vr = \sum_{n=1}^{N} an\ cos(\omega 0t + \phi n)$$

$$= \sum_{n=1}^{N} an\ cos(\phi n)\cos(\omega 0t - \sum_{n=1}^{N} an\ sin(\varphi n) sin(\omega 0t) \qquad (3.2)$$

We may further simplify Eq. (3.2) using a simple trigonometric identity.

$$Vr = X\cos(\omega 0t) - Y\ \sin(\omega 0t) = r\ \cos(\omega 0t + \varphi) \qquad (3.3)$$

$$\text{Where } X = \sum\nolimits_{n=1}^{N} an\ \cos(\varphi n)$$

$$Y = \sum\nolimits_{n=1}^{N} an\ \sin(\varphi n)$$

$$r = \sqrt{X^2 + Y^2} = \text{envelope}$$

$$\emptyset = \tan^{-1}\frac{y}{x}$$

In the limit, as N→∞, the Central Limit Theorem dictates that the random variables X and Y will follow a Gaussian distribution with zero mean and standard deviation σ. The phase φ can also be modeled as a uniform distribution such that $p(\varphi) = 12\pi$ for $0 \leq \varphi \leq 2\pi$. The envelope r is the result of a transformation of the random variables X and Y and can be shown to follow a Rayleigh distribution as given by Schwarz [50] or Papoulis [51].

3.1.1.2 Multipath with direct path.

Let us now consider that a direct path is present as indicated in fig.(3.2) If a direct path is allowed in the received voltage, we must modify Eq. (3.2) and (3.3) by adding the direct path term with the direct path amplitude A (volts).

$$vr = A\cos(\omega 0t) + \sum_{n=1}^{N} an\cos(\omega 0t + \phi n)$$

$$= A + \left[\sum_{n=1}^{N} an\cos(\phi n)\right]\cos(\omega 0t - \sum_{n=1}^{N} an\sin(\varphi n)\sin(\omega 0t) \qquad (3.4)$$

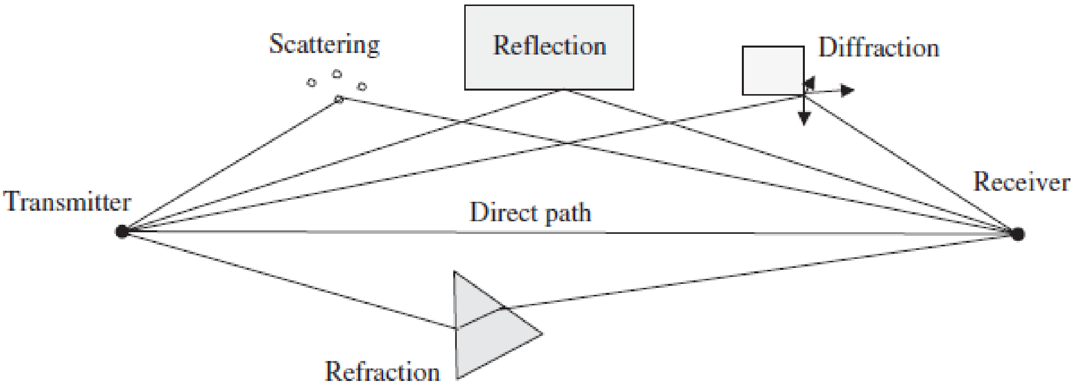

Fig. (3.2) A multipath channel with a direct path.

3.2 Methodology strategy

The following steps indicate the strategy that had been used in the methodology to complete the work, as shown in fig. (3.3).

- microwave function generator (Gunn Oscillator) (1)
- horn antenna (2), and E- field probe (3).
- 2 coaxial cables (4) with BNC/BNC connectors (5).
- Oscilloscope (6).
- metal plate (7) with moving parts (8) and stand bases (9).
- Simulation by using MATLAB program.

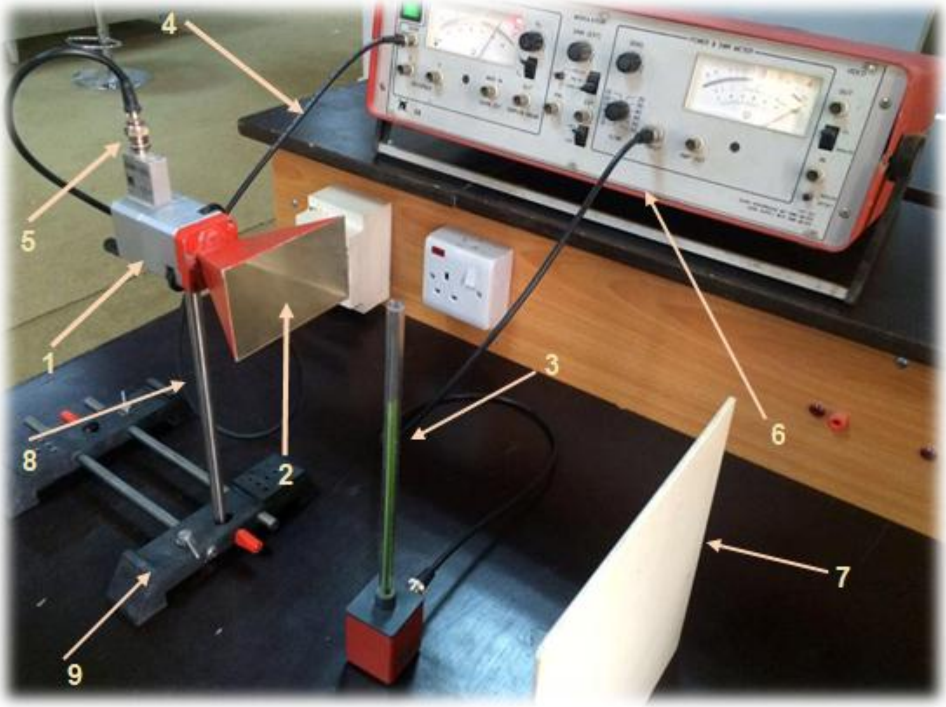

Fig. (3.3) The practical experiment

3.3 Experimental Setup details

The Experimental Setup is shown in Fig. (3.4).

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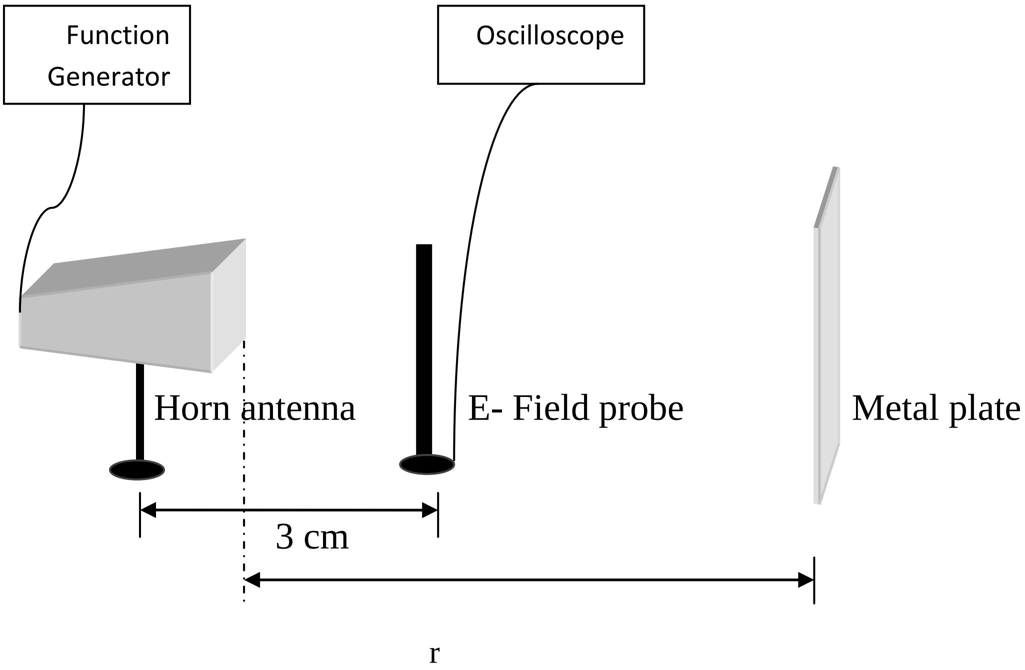

Fig. (3.4) The set of experimental work

As shown in fig. (3.4), The horn antenna is connected to the Gun Oscillator by 2m coaxial cable. The function of E field probes as separate mixer and positioned at distance of 3 cm approximately in front of horn antenna. The metal plate will be moved in the range of 20 cm to the 23 cm in the steps of 2 mm. The oscilloscope corresponding received voltage in each step will be stored in data file.

3.4 General view about MATLAB

MATLAB or (matrix laboratory), It is a numerical computing environment and Fourth-generation programming language. Advanced by Math Works, MATLAB Permits matrix manipulations, plotting of functions and data, implementation of

Algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran [52].

3.5 Simulation Parameters

The representative of Doppler fading makes assumptions that are not realistic. In the following example, the scattering from objects is angularly dependent. Thus, the coefficients an will be a function of time. Additionally, the phase angles φn and θn change with time as shown in fig. (3.5). The Clarke model can be modified to reflect the time dependence of an, φn, and θn. If we assume a large number of paths, the uniform distribution of angles θn results in a sinusoidal variation in the Doppler frequencies fd **.**

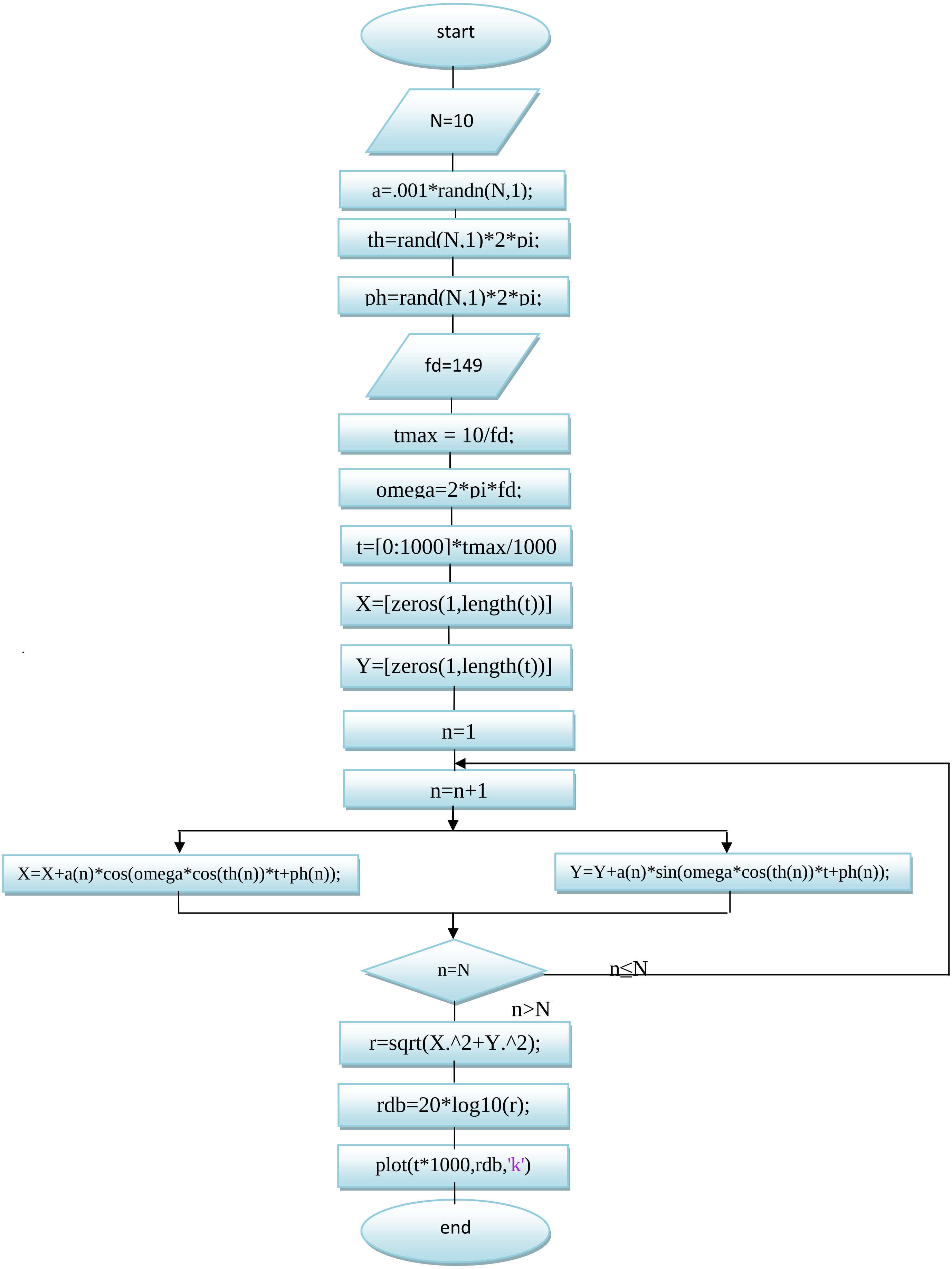

Fig. (3.5) Algorithm

Where

N= Number of scatters
A= Gaussian amplitude coefficients
th= Uniform phase angles
fd= Doppler frequency Hz
tmax = Maximum time in a second
t= Timeline in a second
n= the sums for X and Y
r= The Rayleigh envelope
rdb= The envelope in dB **.**

(The programe is illustrative in the appendix) .

CHAPTER FOUR

RESULTS & DISCUSSION

4.1 Introduction

All parameters were specified, components were connected as shown in previous chapter, MATLAB software code will be executed, results will be tabulated. Two methods are used to calculate the Doppler frequency. First is experimental set up and second is simulation using MATLAB.

4.1.1 Experimental setup

We set up the experiment by connect the Gunn oscillator to the basic unit. Set the supply voltage to UG = 8V.There is no amplitude modulation. The E-field prop is used here as a "separate mixer" and positioned for this purpose approx. 3 cm in front of the horn antenna aperture (approx. 3 cm next to the middle axis) and connected to the oscilloscope in space is not critical for the E-field probe. Move the metal plate functioning as the "radar target" (=back scattering object) in the range from approx. z=20 cm up to 23 cm in step of 2 mm. Read the voltage from the oscilloscope and record the voltages into Table(4.1).

Table (4.1). The corresponding reflected voltage to the change of distance

Distance (mm)	Reflected voltage(mv)
200	139
202	60
204	50
206	64
208	130
210	162
212	150
214	122
216	83
218	50
220	54
222	100
224	143
226	156
228	144
230	120

Fig. (4.1) shows the relationship between the received voltage and distance change from 195 mm to 235 mm

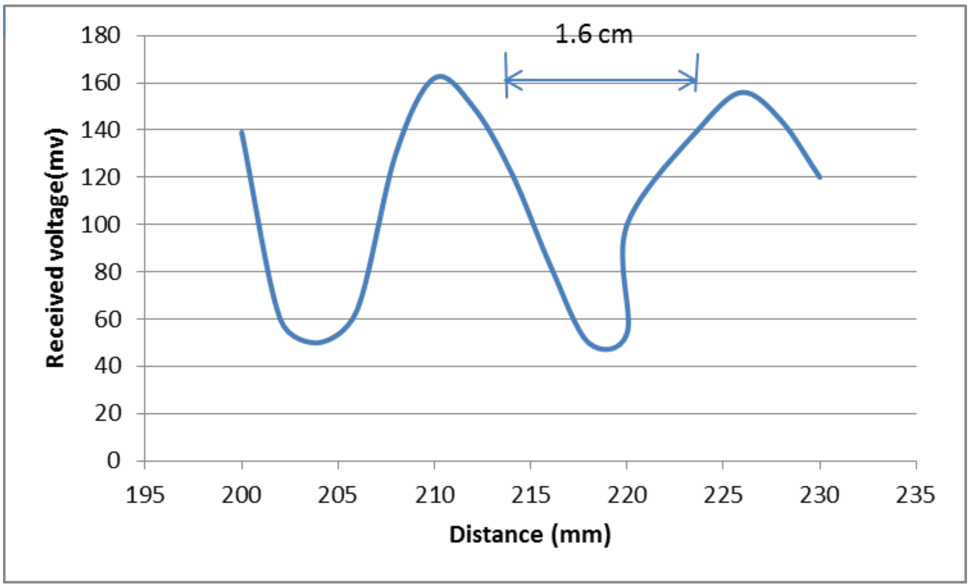

Fig. (4.1) The relationship between the received voltage and distance

4.2 Simulated result using MATLAB

Use MATLAB to plot the reflected voltage where the vehicle velocity is 100 cm/s, the phase angles φn and θn are uniformly distributed, the coefficient *an* has a Gaussian distribution with zero mean and standard deviation of $\sigma = .001$. Let N = 20.

$$T = \frac{\frac{\lambda o}{2}}{Vr} \qquad (4.1)$$

$$= \frac{1.6cm}{\frac{100cm}{s}}$$

$$= \frac{1}{\mathrm{fd}}$$

$$fd = 62.5\ Hz$$

we can plot the results as demonstrate in Figure (4.2).

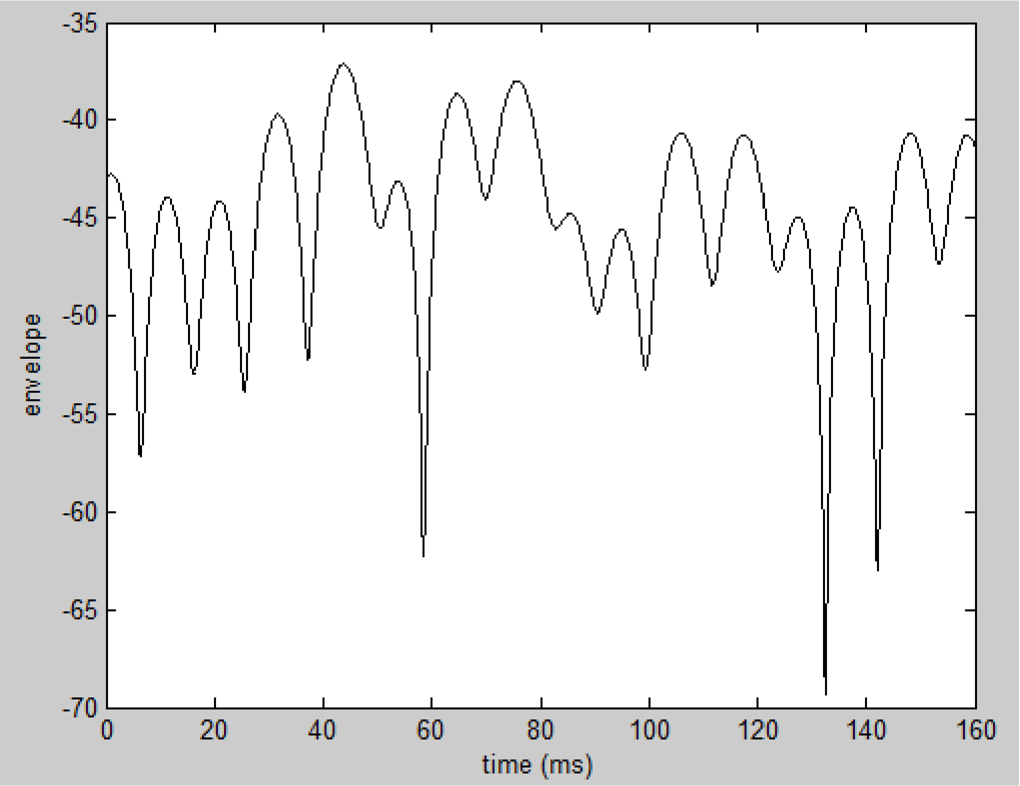

Fig. (4.2) Doppler fading channel with N= 20 and *fd* = 62.5 Hz

Now, we can rerun the program of the previous example by increasing and decreasing the number of scatters, and padding the amplitude *X* with zeros, with the same value of *fd* =62.5 Hz

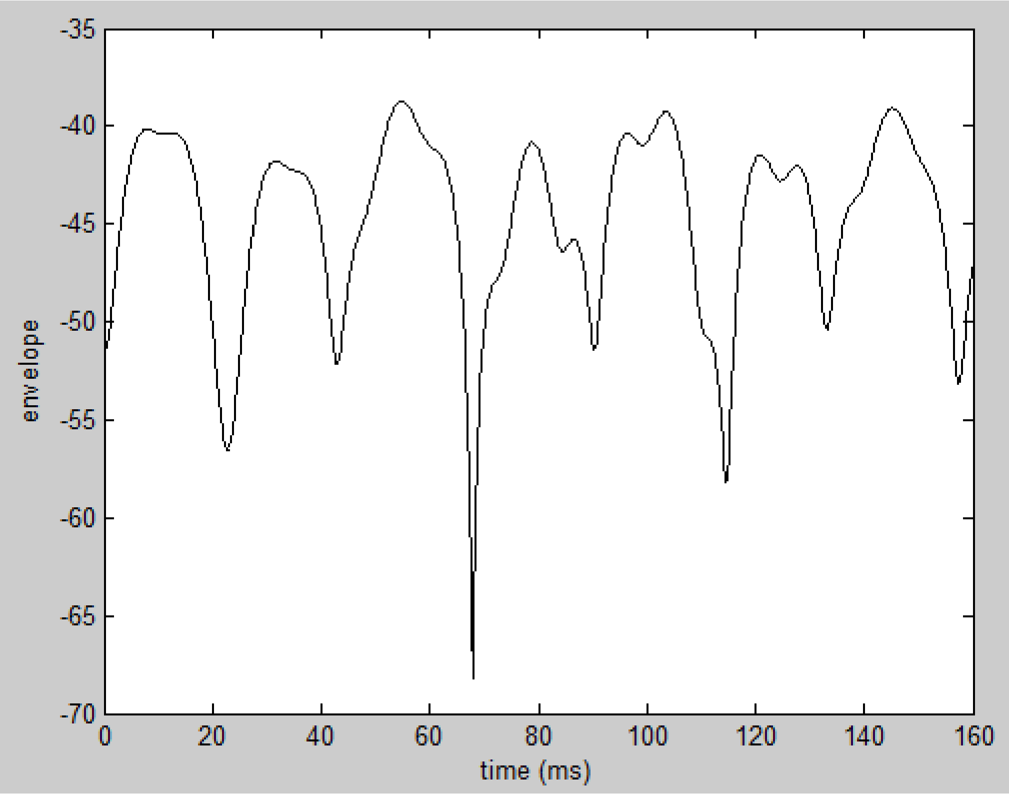

Fig. (4.3) Doppler fading channel with N=10 *fd* =62.5 Hz

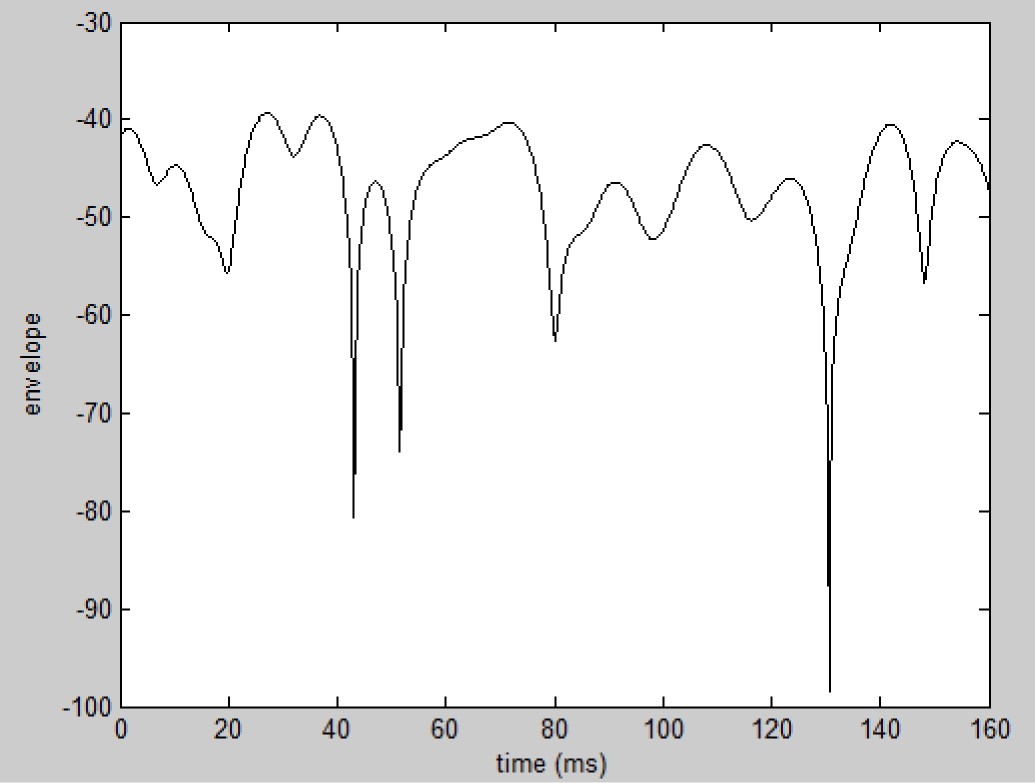

fig.(4.4) Doppler fading channel with N=15, *fd* =62.5 Hz

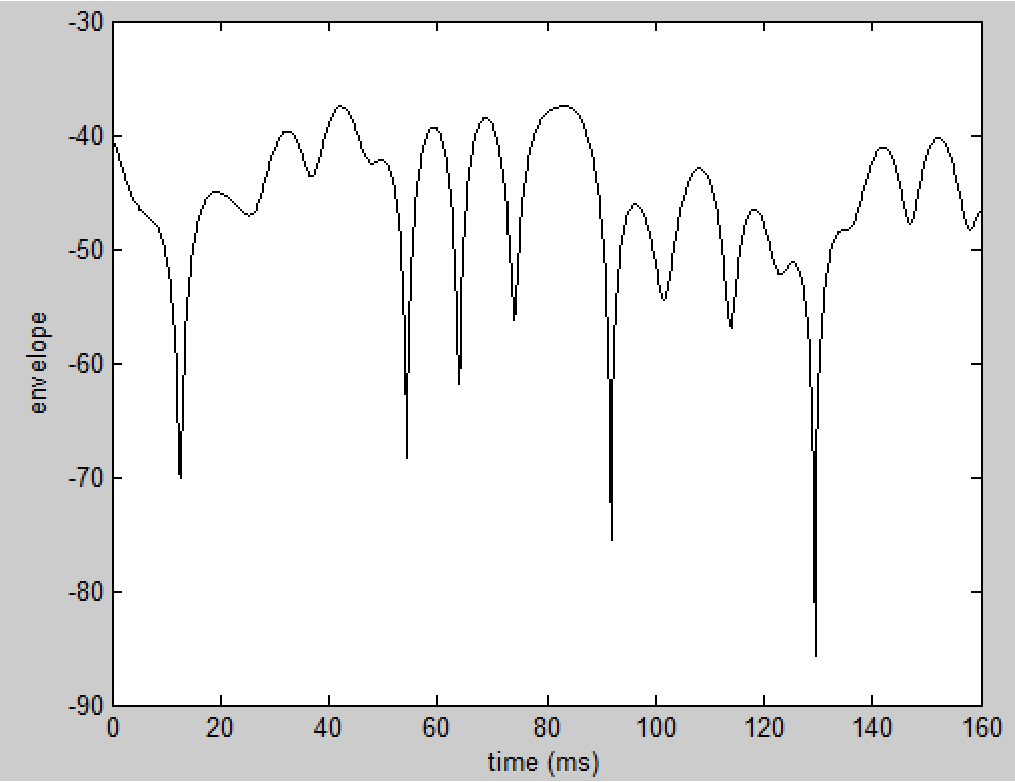

Fig. (4.5) Doppler fading channel with N=25, *fd* =62.5 Hz

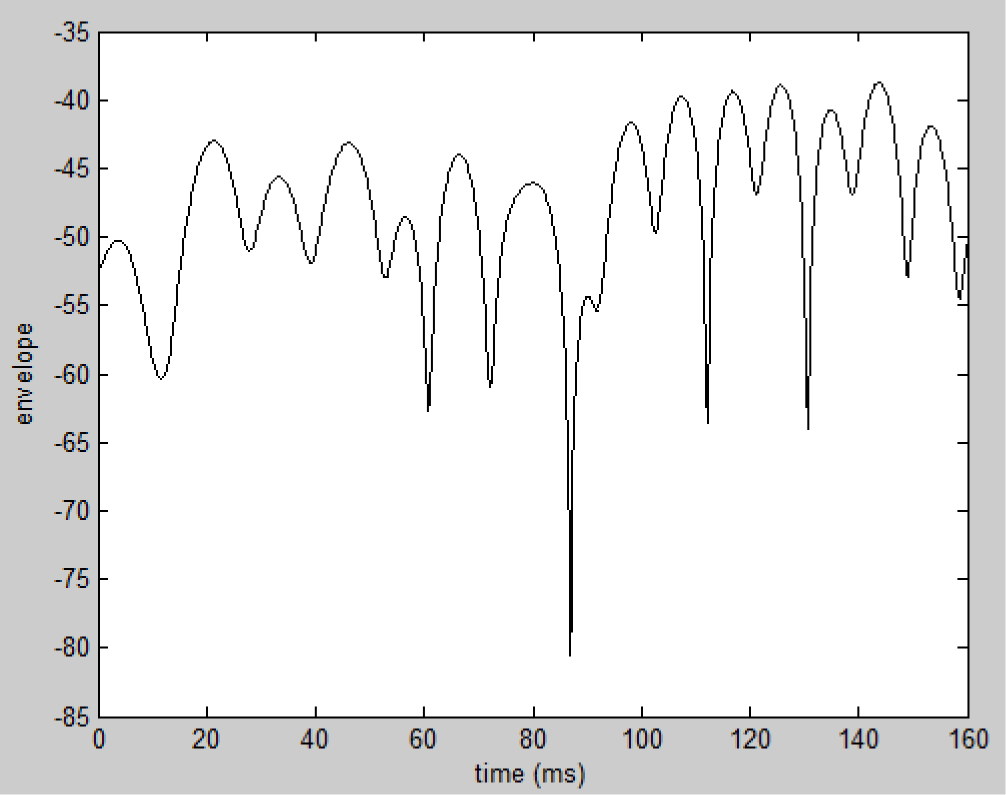

Fig. (4.6) Doppler fading channel with N=30, *fd* =62.5 Hz

We can conclude that, the number of scatters affects the signal, where the increasing of paths result distortion of the signal occurs due to interactions of the many copies of receiving at different times.

In communications system, the multiplicity of paths toward the receiver which known as Multi-path propagation is the most difficult type of transmission problems. Where the reflected signal as a result of colliding with obstacles will arrive to receiver from several paths. Bringing up the signal from the first direct path, and then followed by the reflected signals. this effect is called as Delay Spread and estimated 3sµ within cities.

Now, we can rerun the program of the previous example by increasing and decreasing the number of *fd*, and set N=10.

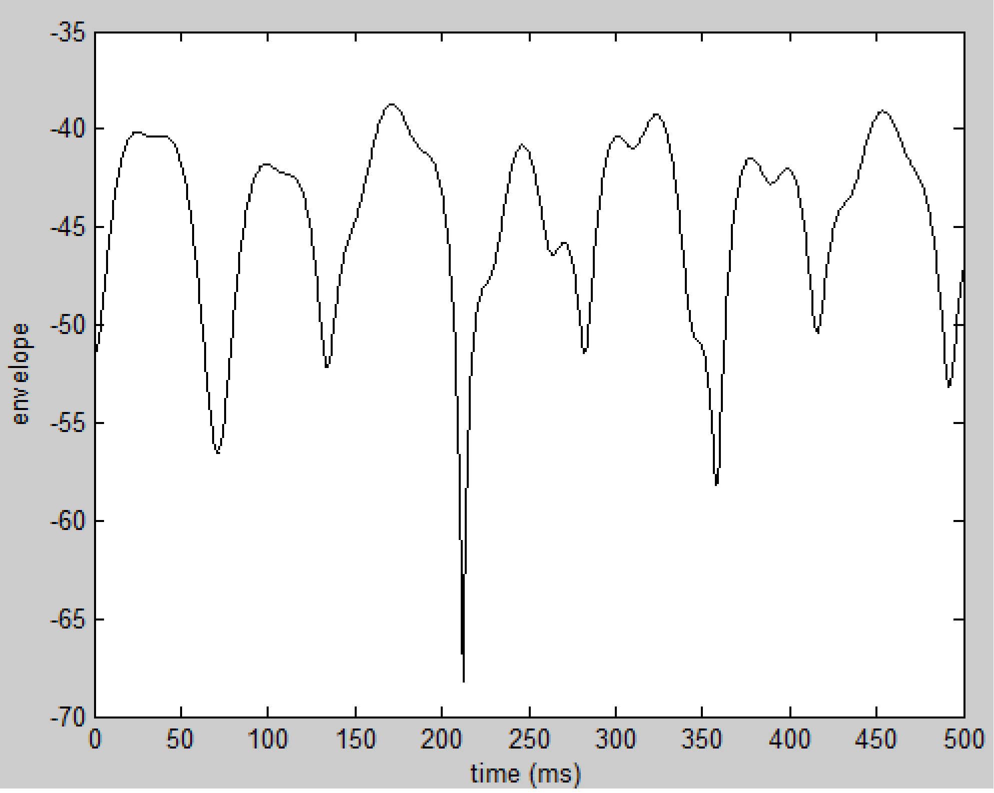

Fig. (4.7) Doppler fading channel with N=10, *fd* =20 Hz

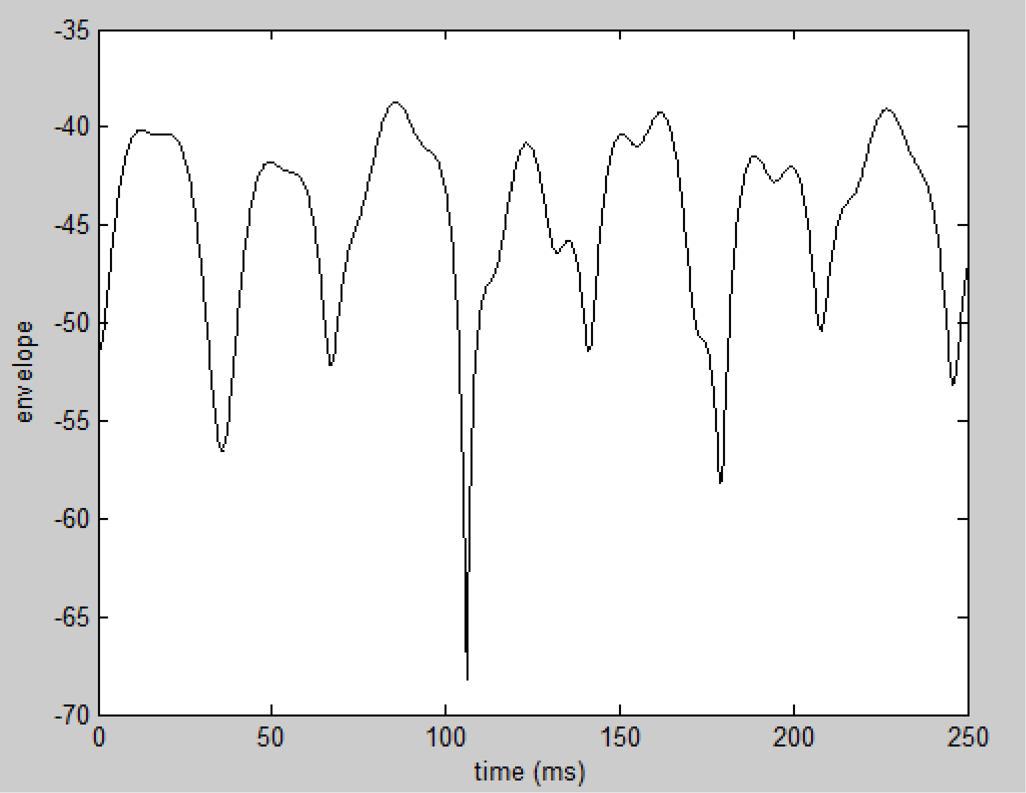

Figure (4.8) Doppler fading channel with N=10, *fd* =40 Hz

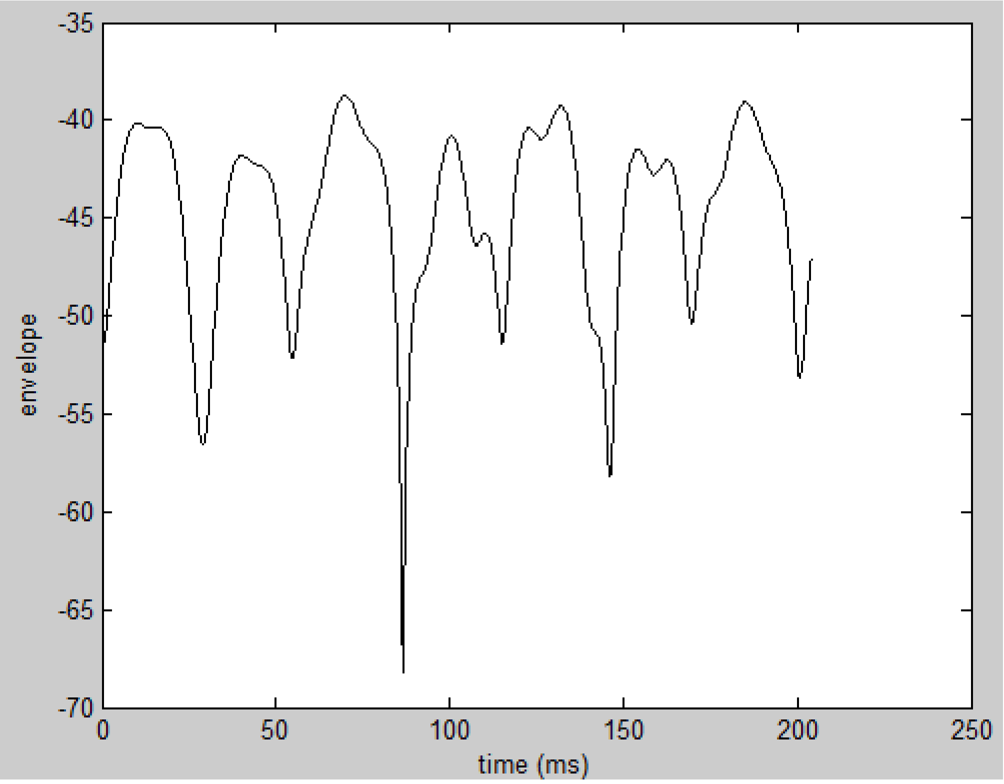

Fig. (4.9) Doppler fading channel with N=10, *fd* =49 Hz

From the previous plots, we can conclude that Doppler frequency affects the signal, by :

1. pulse mutilation

2. irreducible BER

3. ISI distortion

In communications systems , that mean BW of signal > BW of channel, or Delay Spread > Symbol Period .

4.2.1 Fast versus Slow fading:

4.2.1.1 Fast Fading

It varies quickly with the frequency. Fast fading originates due to effects of constructive and destructive interference patterns which is caused due to multipath.

Doppler spread leads to frequency dispersion and time selective fading.

Fast Fading results due to following:

- ➨ High Doppler Spread
- ➨ Coherence Time < Symbol Period
- ➨ Channel impulse response changes rapidly within the symbol duration.
- ➨ Occurs if Ts > Tc, Bs < B_D
- ➨ It occurs for very low data rates.

4.2.1.2 Slow Fading

It does not vary quickly with the frequency. It originates due to effect of mobility. It is result of signal path change due to shadowing and obstructions such as tree or buildings etc.

Slow Fading results due to following:

- ➨ Low Doppler Spread
- ➨ Coherence Time >> Symbol Period
- ➨ Impulse response changes much slower than the transmitted signal.
- ➨ It occurs if Ts << Tc, Bs >>B_D

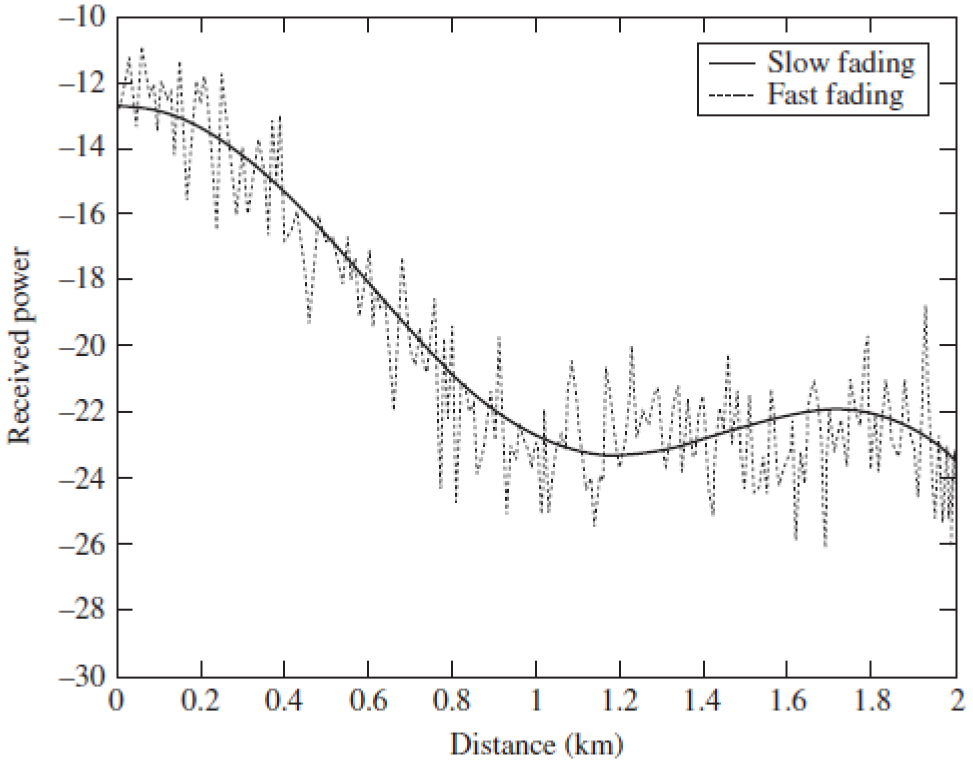

Fig. (4.10) shows a superimposed plot of fast and slow fading.

4.2.2 Doppler power spectrum :-

If we assume a large number of paths, the uniform distribution of angles *θn* results in a sinusoidal variation in the Doppler frequencies *fn*. This transformation of the random variable results in a Doppler power spectrum derived by Gans [53] and Jakes [54].

$$Sd(f) = \frac{\sigma 2}{\pi\, fd\sqrt{1-\left(\frac{f}{fd}\right)}} \qquad |f| \leq fd \qquad (4.2)$$

$$\text{where } \sigma^2 = \sum_{n=1}^{N} E[\,an^2] = \text{average power of signal.}$$

However, the difference lies in the fact that the theoretical spectrum assumes that the number of scatters is large enough to apply the Central Limit Theorem. In that case, there is a true Gaussian distribution on the scattering amplitudes and a true uniform distribution on the angles [53].

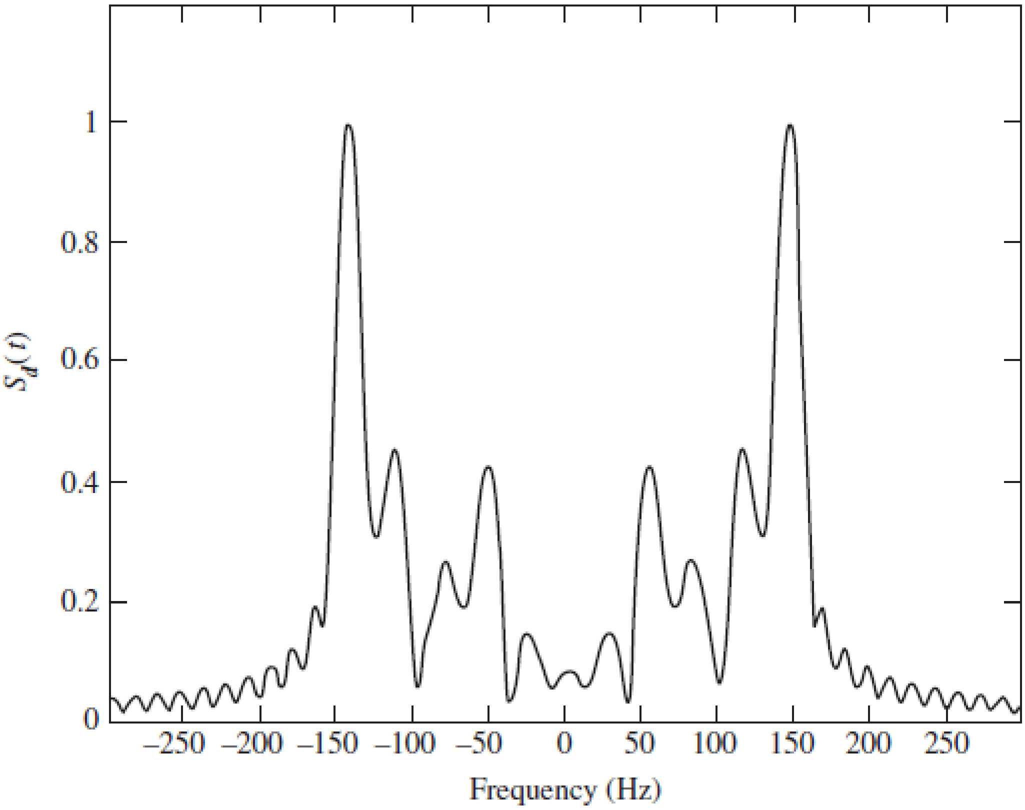

Fig. (4.11) Doppler power density spectrum.

CHAPTER FIVE

CONCLUSION

5.1 Conclusion

This project was aiming to study the behavior of the fading channel models to provide crucial information about the Doppler fading channel in communication system, by using MATLAB simulation for different thresholds of the received signal and compare these values to those calculated analytically, we found :

1. As the vehicle speed of user is increased, the amount of fading is increased in the signal envelope.

2. As we increase the speed, more of the signal goes below the threshold and the amount of fading increased.

5.2 Future work

We are currently investigating applications of the Doppler fading channels described in this project in communication system design. Its important to develop a generic model for fading in mobile communication (vehicular applications) system, which will be reported in future communication.

The capability to predict fading coefficients will reduce the power requirements of wireless communications system and increase the system performance. In particular, it would be possible to avoid transmission during deep fades or to utilize diversity techniques (e.g., use space diversity or hop to another non-fading frequency during the deep fading).

In addition, more efficient modulation and coding techniques are envisioned.

Future work would also include extension of the proposed techniques to multipath fading, as well as investigation of time variation of the parameters associated with individual scatters and the number of scatters. This realistic channel modeling is necessary to verify feasibility of the proposed method. For example, in some channels the scatters can phase in and out rapidly It is important to adjust the duration of the observation and prediction intervals, as well as the rate of convergence of the linear prediction coefficients to keep up with these channel variations. Accomplishment of these tasks is the focus of the current research.

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APPENDIX A

PLAN OF PROJECT

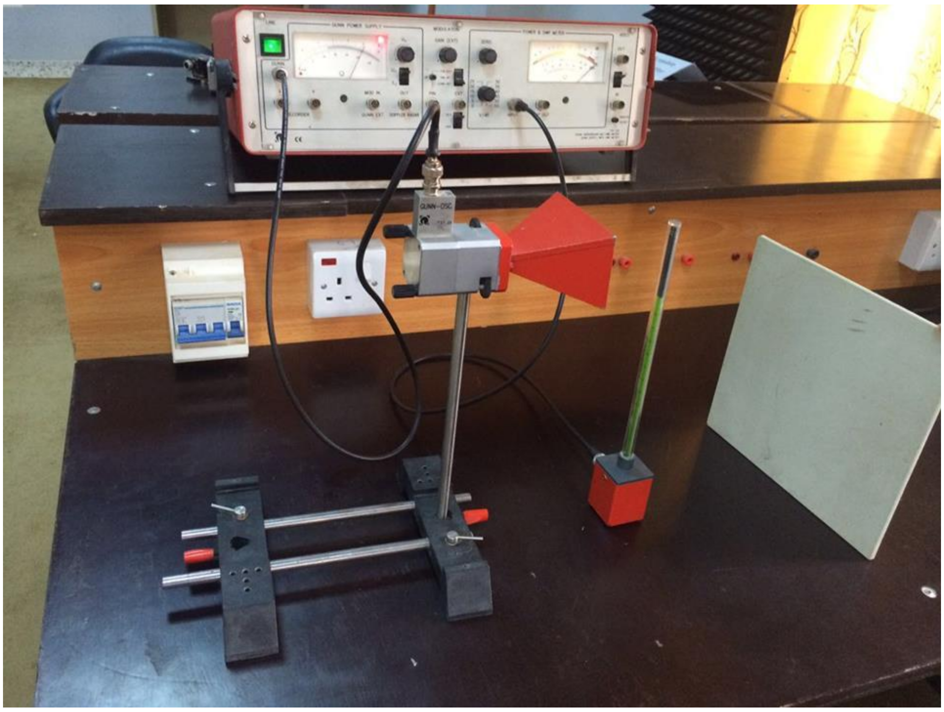
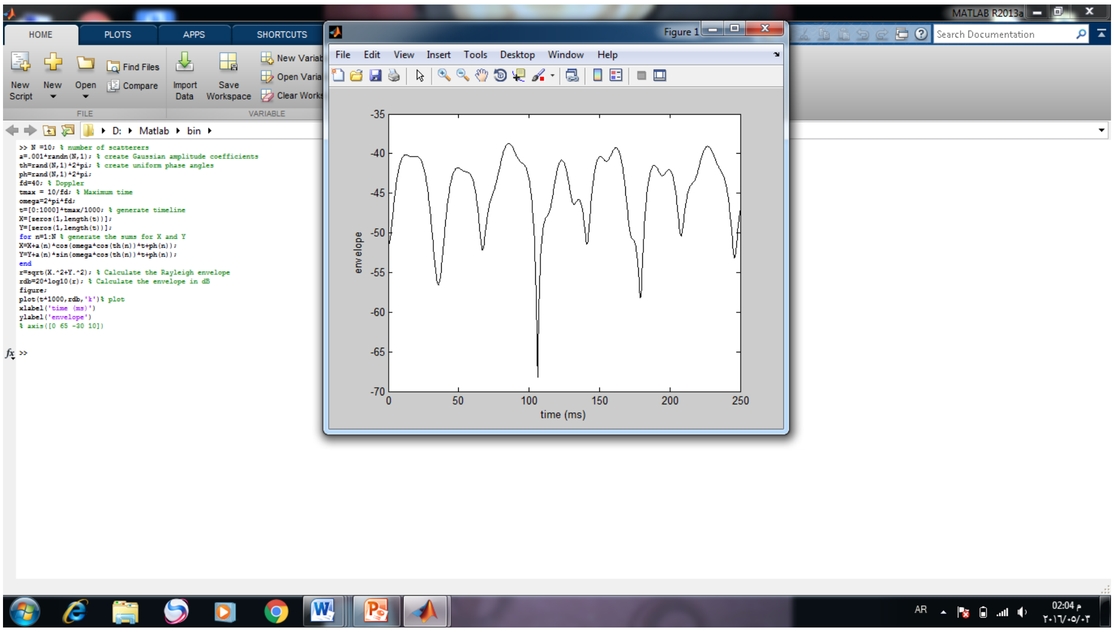


photo from antenna laboratory clarify the practical experiment

```
N =20; % number of scatterers
a=.001*randn(N,1); % create Gaussian amplitude coefficients
th=rand(N,1)*2*pi; % create uniform phase angles
ph=rand(N,1)*2*pi;
fd=40; % Doppler
tmax = 10/fd; % Maximum time
omega=2*pi*fd;
t=[0:1000]*tmax/1000; % generate timeline
X=[zeros(1,length(t))];
Y=[zeros(1,length(t))];
for n=1:N % generate the sums for X and Y
X=X+a(n)*cos(omega*cos(th(n))*t+ph(n));
Y=Y+a(n)*sin(omega*cos(th(n))*t+ph(n));
end
r=sqrt(X.^2+Y.^2); % Calculate the Rayleigh envelope
rdb=20*log10(r); % Calculate the envelope in dB
figure;
plot(t*1000,rdb,'k')% plot
```



```
>> N =10; % number of scatterers
a=.001*randn(N,1); % create Gaussian amplitude coefficients
th=rand(N,1)*2*pi; % create uniform phase angles
ph=rand(N,1)*2*pi;
fd=40; % Doppler
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omega=2*pi*fd;
t=[0:1000]*tmax/1000; % generate timeline
X=[zeros(1,length(t))];
Y=[zeros(1,length(t))];
for n=1:N % generate the sums for X and Y
X=X+a(n)*cos(omega*cos(th(n))*t+ph(n));
Y=Y+a(n)*sin(omega*cos(th(n))*t+ph(n));
end
r=sqrt(X.^2+Y.^2); % Calculate the Rayleigh envelope
rdb=20*log10(r); % Calculate the envelope in dB
figure;
plot(t*1000,rdb,'k')% plot
xlabel('time (ms)')
ylabel('envelope')
% axis([0 65 -30 10])

>>
```

screenshot for MATLAB program clarify the simulation behavior

الخلاصة:

الهدف الرئيسي من هذا المشروع هو دراسة قناة متلاشية دوبلر ويتم تقييم هذا التلاشي من خلال طريقتين، حيث تتكون الطريقة الأول من اثنين من الهوائيات على مسافة معينة (س) لتقييم تأثير دوبلر لروابط النقل اثناء الحركة النسبية بين هوائيات الإرسال والاستقبال.

وفي الاسلوب الثاني ، نستخدم برنامج MATLAB لتوضيح اداء قناة متلاشية دوبلر مع الأخذ بعين الاعتبار سرعة المصدر.

وزارة التعليم العالي والبحث العلمي
جامعة ديالى
كلية الهندسة
قسم هندسة الأتصالات

محاكاة قناة متلاشية دوبلر

مشروع
مقدم الى قسم هندسة الأتصالات
في جامعة ديالى – كلية الهندسة كجزء من متطلبات نيل درجة البكلوريوس
في هندسة الأتصالات

من قبل
سراب حامد عبدالله
ايلاف عبدالرزاق عبدالكريم

بأشراف
د. رياض خلف العزاوي

جمادي الأول/ ١٤٣٧
May/2016