Department of Telecommunications Engineering
NED University of Engineering & Technology

LABORATORY WORKBOOK

For the Course

WIRELESS AND MOBILE COMMUNICATION (TC-314)

Instructor Name: ______________________________

Student Name: ______________________________

Roll Number: ________________ **Batch:** ____________

Semester: ________________ **Year:** ____________

Department: ______________________________

LABORATORY WORK BOOK

For The Course

<u>WIRELESS AND MOBILE COMMUNICATION</u>

<u>(TC-314)</u>

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Approved By:

The Board of Studies of Department of Telecommunications Engineering

INTRODUCTION

Wireless Mobile/Cellular Communication Practical Workbook covers those practical that are very knowledgeable and quite beneficial in grasping the core objective of the subject. These practical solidify the theoretical and practical concepts that are very essential for the engineering students.

This work book comprise of practical covering the topics of Wireless Mobile/Cellular Communication that are arranged on modern software and trainer boards. Above all this workbook contains a relevant theory about the Lab session.

CONTENTS

LAB SESSION 01

OBJECTIVE

Generation of random bit stream, random error and white Gaussian noise.

THEORY

The simulation of communication systems deals with generation of random numbers. Their two most common applications include AWGN and random binary data sequence. This lab describes how to use the Communications Toolbox to generate random binary sequences which are generally used to model the data bits that are input to a communication system.

For discrete data samples over a large period of time, the discrete probability density function (PDF) can be obtained using histogram function in Matlab. From the PDF discrete cumulative distribution function (CDF) can be obtained. The CCDF is the complement of the CDF which can be obtained as $CCDF = 1 - CDF$. By looking at the CCDF measurements, system designer can get an idea of what type of modulation or filtering is used in the signal. In fact, multiple digitally modulated signals combined together (e.g. transmitted from a single source like base stations) can also be characterized through CCDF plots.

LAB TASK

1. Generate random binary signal with uniform and normal distribution. Plot histogram for all sources and interpret it. Calculate the power of this signal.

2. Generate a complex Gaussian noise of length 1000 with zero mean and unit variance. Plot the normalized power,

3. Plot an estimate of the PDF of the real and imaginary parts of the noise. Then compute the CDF and CCDF. Briefly, comment.

4. Plot the joint PDF of the complex noise vector (i.e. both real and imaginary parts of the noise). Interpret the plot.

RESULTS

The code, results /plots with discussion must be attached.

Reference reading:

1. Arslan Hüseyin. (2021). Wireless communication signals : a laboratory-based approach. John Wiley & Sons.

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Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 01 Date: ___________________

Software Use Rubric					
Criterion	**Level of Attainment**				
	Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
Identification of software menu (syntax, components, commands, tools, layout etc.).	Can't identify software menus.	Rarely identifies software menus.	Occasionally identifies software menus.	Able to identify software menus.	Perfectly able to identify software menus.
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Remarks	
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LAB SESSION 02

OBJECTIVE

Analysis of hexagonal layout of a cellular system.

THEORY

Network layout is the fundamental components of a given system model as it dictates the communication channel parameters such as path loss, fading, shadowing, etc. It also describes the user distribution and characterizes the system performance from the perspective of interference between different BSs. Hexagonal grid is one of the most popular cellular system layouts. Even though it is non-realistic since no cellular network has such a vivid hexagonal coverage, yet it enables an efficient coverage of a region without overlapping as it has a near perimeter and area to the ideal cell with a circular shape.

In cellular systems, a single high-power BS is replaced with much low power BSs, where each provides coverage to a smaller portion of the service area. The reuse of the same channel frequencies for multiple users named co-channel users while operating in different spatial regions is considered to enhance network capacity. Efficiently using the bandwidth resources is called *frequency reuse*, as long as the users are sufficiently separated to avoid interference. The greater the *reuse distance*, the lower is the probability of interference. Similarly, the lower the power levels used in cells sharing a common channel, the lower the probability of interference. Thus, a combination of power control and frequency planning is used in cellular systems to prevent interference.

The worst signal-to-interference (SIR) scenario occurs when the area is split into multiple cells and all the channels are used within each cell. There always exists a user from each cell causing interference on the user of interest. A general mathematical function of SIR is given as follows,

$$SIR = \frac{P_{r,d}(d)}{\sum_{i=0}^{I-1} P_{r,i}(d_i)}$$

where $P_{r,d}(d)$ and $P_{r,i}(d_i)$ denote the strength of received signal from the desired user and interferes, respectively, with respect to their corresponding distances. I is the number of interferes.

The number of cells in which all the channels are used for data communication is called a cluster (N). It is assumed that the channels are equally split between the cells within the cluster and reused for all the other clusters. The reuse distance is directly proportional to the cluster size but the relationship is non-linear. Let D be the reuse distance and R be the radius of the cell then,

$$Q = \frac{D}{R} = \sqrt{(3N)}$$

Here, $N = i^2 + ij + j^2$

LAB TASK

1) Construct a homogeneous single-tier cellular network with a reuse factor 7, an inter-site distance of 300 m and uniform user distribution within each cell
2) Compute and plot signal-to-interference ratio (SIR) vs cluster size (N) assuming that only first-tier co-channel users affect the desired signal
3) Compute and plot the co-channel reuse ratio (Q) for different cluster size and plot it against different values of N.

RESULTS

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LAB SESSION 03

OBJECTIVE

Write a MATLAB script to plot various path loss models (Free space, Log-distance/normal path loss model).

THEORY

Path loss normally includes propagation losses caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever-increasing sphere), absorption losses (sometimes called penetration losses), when the signal passes through media not transparent to electromagnetic waves, diffraction losses when part of the radiowave front is obstructed by an opaque obstacle, and losses caused by other phenomena. The signal radiated by a transmitter may also travel along many and different paths to a receiver simultaneously; this effect is called multipath. Multipath can either increase or decrease received signal strength, depending on whether the individual multipath wavefronts interfere constructively or destructively. The total power of interfering waves in a Rayleigh fading scenario vary quickly as a function of space (which is known as small scale fading), resulting in fast fades which are very sensitive to receiver position.

The *free-space propagation model* is used for predicting the received signal strength in the line-of-sight (LOS) environment where there is no obstacle between the transmitter and receiver. Let *d* denote the distance in meters between the transmitter and receiver. When non-isotropic antennas are used with a transmit gain of G_t and a receive gain of G_r, the received power at distance *d*, $P_r(d)$ is expressed by the well-known Friis equation.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

where P_t represents the transmit power (watts), λ is the wavelength of radiation (m), and *L* is the system loss factor. *L* is independent of propagation environment and represents overall attenuation/loss in the system hardware, including transmission line, filter, and antennas.

The average received signal in actual environments decreases with the distance between the transmitter and receiver, *d*, in a logarithmic manner. A more generalized form of the path loss model is the modification of free-space path loss with the path loss exponent *n* that varies with the environments. This is known as the *log-distance path loss model*, in which the path loss at distance *d* is given as

$$PL_{LD}(d) = PL_F(d_0) + 10n\log\left(\frac{d}{d_0}\right)$$

where d_0 is a reference distance at which the path loss inherits the characteristics of free-space loss. The path loss can be represented by the path loss exponent whose value can vary from 2 to 6, depending on the propagation environment. $n=2$ corresponds to the free space and tends to increase as there are more obstructions as shown in Table 1.

Environment	Pathloss exponent (n)
Free space 2	2
Urban area cellular radio	2.7–3.5
Shadowed urban cellular radio	3–5
In building line-of-sight	1.6–1.8
Obstructed in building	4–6
Obstructed in factories	2–3

d_0 is typically set as 1 km for a cellular system with a large coverage (e.g., a cellular system with a cell radius greater than 10 km) and d_0 is 100m or 1 m, respectively, for a macrocellular system (cell radius of 1km) or a microcellular system (extremely small radius).

In realistic situation, *log-normal shadowing model* allows the receivers at the same distance *d* to have a different path loss, which varies with the random shadowing effect X_σ.Let Xσ denote a Gaussian random variable with a zero mean and a standard deviation of σ. Then, the is given as

$$PL_{LD}(d) = PL_F(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma$$

This particular model

LAB TASK

1. Plot free-space path loss at the carrier frequency of f_c=2.4 and 5 GHz for different antenna gains as the distance varies

2. Plot log-distance path loss model for n=2,3,6 for various reference distances (d_0= 10km, 100m, 20 m) at f_c= 2.4 and 5 GHz

3. Plot log-normal path loss model for n=2 and σ=3 dB at f_c=2.4 and 5 GHz

RESULTS

The code, results /plots with discussion must be attached.

Reference reading:
1. Rappaport, T. S. (2002). Wireless communications: Principles and practice. (2nd ed.) (Prentice Hall communications engineering and emerging technologies series). Prentice Hall
2. Cho, Y. S., Kim, J., Yang, W. Y., & Kang, C. G. (2010). MIMO-OFDM wireless communications with MATLAB. John Wiley & Sons.

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Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 03 Date: ___________________

Software Use Rubric					
Criterion	**Level of Attainment**				
	Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
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Weighted CLO (Score)	
Remarks	
Instructor's Signature with Date	

LAB SESSION 04

OBJECTIVE

To analyse path loss using Okumura Hata model.

THEORY

Outdoor propagation models involve estimation of propagation loss over irregular terrains such as mountainous regions, simple curved earth profile, etc., with obstacles like trees and buildings. All such models predict the received signal strength at a particular distance or on a small sector. These models vary in approach, accuracy and complexity. Hata-Okumura model is one such model.

Okumura traveled around Tokyo city and made measurements for the signal attenuation from base station to mobile station. He came up with a set of curves which gave the median attenuation relative to free space path loss. Okumura came up with three set of data for three scenarios: open area, urban area and sub-urban area. This was one of the very first model developed for cellular propagation environment. Since it is based on empirical studies, the validity of parameters is limited in range.

Hata, came up with closed form expressions based on curve fitting of Okumura models. It is the most referred macroscopic propagation model. He extended the Okumura models to include effects due to diffraction, reflection and scattering of transmitted signals by the surrounding structures in a city environment.

The received power level in dBm is given by

$$P_r(dBm) = P_t(dBm) + G_t(dBi) - PL(dB)$$

The generic closed form expression for path loss (PL) in dB, is given by,

$$P_L(dB) = A + Blog_{10}(d) + C$$

where, the Tx-Rx separation distance (*d*) is specified in kilometers (valid range 1 km to 20 Km). The factors *A,B,C* depend on the frequency of transmission, antenna heights and the type of environment.

- f_c = frequency of transmission in MHz, valid range – 150 MHz to 1500 MHz
- h_b= effective height of transmitting base station antenna in meters, valid range 30 m to 200 m
- h_m=effective receiving mobile device antenna height in meters, valid range 1m to 10 m
- $a(h_m)$ = mobile antenna height correction factor that depends on the environment
- C = a factor used to correct the formulas for open rural and suburban areas

The parameters for Hata Model is specified in the following table.

Environment	$a(h_m)$	C
Open	$[1.1log_{10}(f_c) - 0.7]h_m - [1.56log_{10}(f_c) - 0.8]$	$-4.78[log_{10}(f_c)]^2 + 18.33log_{10}(f_c) - 40.98$
Suburban		$-2[log_{10}(f_c/28)]^2 - 5.4$
Small/medium city		0
Metropolitan ($f_c \leq 200$ MHz)	$8.29[log_{10}(1.54h_m)]^2 - 1.1$	0
Metropolitan ($f_c > 200$ MHz)	$3.2[log_{10}(11.75h_m)]^2 - 4.92$	0

Table : Hata Model Parameters

LAB TASK

Using Okumura-Hata model compare the received signal levels at distances 3-20 kilometers from the base station operating at 900 MHz for a medium and large sized city, suburban and open rural areas. The following data is given:
Height of the radiation centerline measured from the base of the BTS = 70 m
Terrain elevation at the location of the BTS = 350 m
Average terrain height = 300 m
Height of the mobile antenna = 3 m
Power delivered to the BTS antenna = 19.5 W
Gain of the BTS antenna = 10 dBi
Gain of the mobile antenna = 0 dBi

1. Plot the path loss and received signal strength vs distance.

RESULTS

The code, results /plots with discussion must be attached.

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Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 04 Date: ___________________

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Criterion	**Level of Attainment**				
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Remarks	
Instructor's Signature with Date	

LAB SESSION 05

OBJECTIVE

To plot the relative power drop of the signal arriving at Mobile Station using two ray ground reflection model.

THEORY

Friis propagation model considers the line-of-sight (LOS) path between the transmitter and the receiver. In two-ray ground reflection model in addition to the line-of-sight path, a single reflected path from the earth surface is also added. This model takes into account the phenomenon of reflection from the ground and the antenna heights above the ground. The ground surface is characterized by reflection coefficient - *R* which depends on the material properties of the surface and the type of wave polarization. The transmitter and receiver antennas are of heights h_t and h_r respectively and are separated by the distance of *d* meters.

The received signal consists of two components: LOS ray that travels the free space from the transmitter and a reflected ray from the ground surface. The distances traveled by the LOS ray and the reflected ray are given by,

$$d_{LOS} = \sqrt{d^2 + (h_t - h_r)^2}$$

$$d_{ref} = \sqrt{d^2 + (h_t + h_r)^2}$$

Depending on the phase difference (φ) between the LOS ray and reflected ray, the received signal may suffer constructive or destructive interference. Hence, this model is also called as two ray interference model.

$$\varphi = \frac{2\pi(d_{ref} - d_{LOS})}{\lambda}$$

where, λ is the wavelength of the radiating wave. Under large-scale assumption, the power of the received signal can be expressed as,

$$P_r = P_t \left[\frac{\lambda}{4\pi}\right]^2 \left| \frac{\sqrt{G}_{LOS}}{d_{LOS}} + R\frac{\sqrt{G}_{ref}}{d_{ref}} e^{j\varphi} \right|^2$$

where $\sqrt{G}_{LOS}$ is the product of antenna field patterns along the LOS direction and $\sqrt{G}_{ref}$ is the product of antenna field patterns along the reflected path.

Using two ray ground reflection model, the path loss can be approximated as,

$$L = -20\log_{10}(h_t h_r) + 40\log_{10}(d)$$

LAB TASK

For the data given below,
Reflection coefficient R= -1.
The BS antenna height h_t=100 m,
MS antenna height h_r=3 m,
Distance between BS and MS is *d*.
Power at distance *d* from BS P_t= 1 mW.
Carrier frequency f =900 MHz, 3 GHz and 30 GHz
$G_{LOS} = G_{ref} = 1$

1. For 10<d <10000, plot the relative power drop (P_r/P_t) (in dB) as a function of the distance between Tx and Rx
2. Plot the path loss obtained by two ray model and compare it with the free space path loss model

RESULTS

The code, results /plots with discussion must be attached.

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Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 05 Date: ____________________

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LAB SESSION 06

OBJECTIVE

Performance evaluation of a wireless communication system consisting of a baseband modulator, channel and demodulator.

THEORY

The ultimate goal of any simulation is to provide performance results in an interpretable manner. This requires the selection of the appropriate performance metric. Since signal quality measurement is of interest for a particular simulation, one of the metric i.e. bit error rate (BER) is recorded.

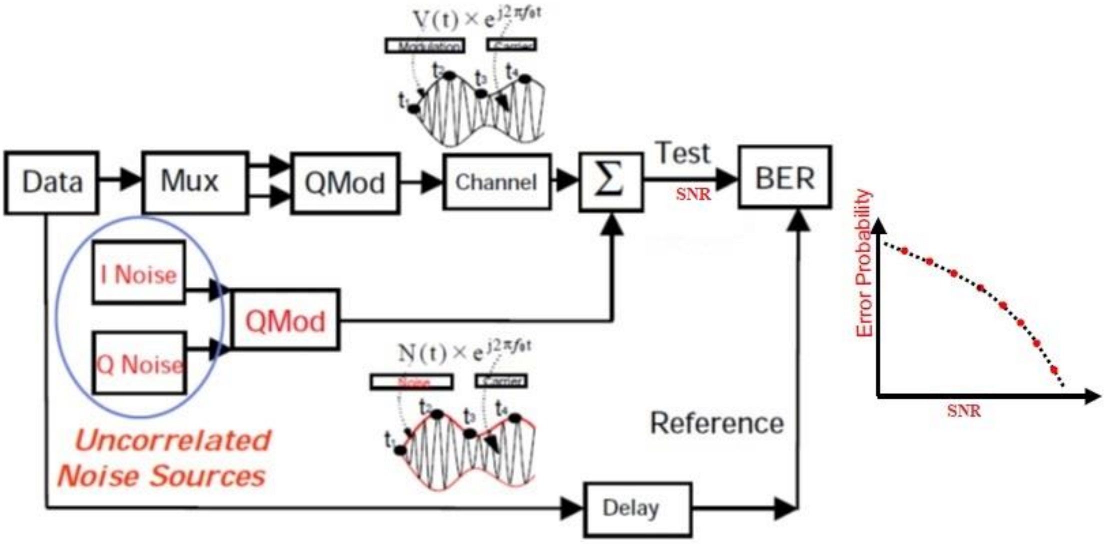

Fig. 1 A typical RF system for BER calculation

Configure a model of communication system in the following steps:

1. Information Source:
   (i) Source and Source Coding: Data is created by modeling them with a binary Sequence.
   (ii) Symbol Mapping/Modulation: The sequence is modulated, often using a quadrature scheme for higher throughput. Symbol mapping involves mapping bits to different symbols or points in the in-phase and quadrature-phase (I/Q) domains. Depending on the order M, an M-ary scheme would map $\log_2 M$ bits to each of the M points in the I/Q domain. The points collectively form the constellation for any scheme.
   (iii) Additional blocks may include upsampling which allows conversion of data symbols to pulses and digital filtering or pulse shaping translates the mapped symbols to physical signals for transmission over the communication link
2. Channel Model:
   (i) For our particular scenario/case study, i.e. AWGN case, we will not consider the presence of any RF impairment in the system. The only impairment to the communication is the added noise
   (ii) An important thing to consider in random number generation is the correlation between different samples. While in cases such as AWGN, the samples are meant to be uncorrelated, there there might be scenarios where an arbitrary amount of correlation is required such as when modeling fading in a network
3. Receiver Design:
   (i) De-mapping operation needs to be implemented. For this, the distances of each received symbol, from the reference constellation points is calculated and mapped to its nearest one.

(ii) A bit is in error when the detected bit is different from the one sent by the transmitter. This can be used to calculate BER as:

$$BER = \frac{number\ of\ bits\ in\ error}{total\ number\ of\ transmitted\ bits}$$

(iii) The BER performance can be studied as a function of the Signal to Noise Ratio (SNR) of the system at the detector. The typical range of SNR values used in simulations is from 0 to 30 dB.

<u>LAB TASK</u>

1. Assuming 16-QAM, compute the BER over AWGN channel at different SNR.

2. Plot BER vs. SNR.

3. Plot the constellation diagram of the received signal. Briefly interpret the effect of the noise on the constellation diagram.

4. Make comment on the plots considering the change in SNR.

<u>RESULTS</u>

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LAB SESSION 07

OBJECTIVE

Performance analysis of different modulation schemes over a wireless communication system.

THEORY

Modulation is defined as the mapping of a sequence of binary digits into a set of corresponding waveforms. The mapped waveform can correspond to a single bit, or a sequence of bits (a symbol), and can change in amplitude, phase (delay), or frequency, or in their combination. Another common definition of modulation that implies a similar meaning is the process where the message information is embedded into the radio carrier. When selecting a suitable modulation scheme, a system designer need to understand the trade-offs between various modulation options given the physical characteristics of the channel that the system needs to be operated, the target performance specifications, desired data rate, and hardware limitations. The following characteristics from a modulation option are required:

- Low bit-error-rate (BER) at low signal-to-noise ratio (SNR) (high power efficiency)
- Occupies minimal bandwidth (high spectral efficiency)
- Performs well in multipath fading (robust to multipath effects like Doppler spread, delay spread,
- and fading)
- Performs well in time varying channels (symbol timing jitter)
- Low out of band radiation
- Low cost and easy to implement
- Constant or near-constant envelope (performs well under nonlinear distortion)

A desired BER can be achieved with low-order modulations for lower SNR values. Higher-order modulations need better link quality (higher SNR) in order to obtain the same BER performance.
The spectral efficiency (bandwidth efficiency) η_B for the linear modulation with *M* constellation points is given by

$$\eta_B = \log_2(M) \quad bits/\sec/Hz$$

LAB TASK

1. Simulate BPSK, QPSK, 16-QAM and 64-QAM over AWGN channel.

2. Make a comment on noise power and modulation order relationship.

3. Plot BER and spectral efficiency for SNR from 0 to 30 dB. Compare their performance and comment.

Reference Reading:
Viswanathan, M. (2017). Digital Modulations using MATLAB. Building Simulation Models from Scratch. Pilani.

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Software Use Rubric					
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	Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
Identification of software menu (syntax, components, commands, tools, layout etc.).	Can't identify software menus.	Rarely identifies software menus.	Occasionally identifies software menus.	Able to identify software menus.	Perfectly able to identify software menus.
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Weighted CLO (Score)	
Remarks	
Instructor's Signature with Date	

LAB SESSION 08

OBJECTIVE

Design of a frequency-flat Rayleigh fading channel with performance evaluation of various modulation schemes over the channel.

THEORY

There exist direct and major reflected paths between a stationary radio transmitter and a moving receiver. Buildings behave as reflectors. The major reflected paths result in the arrival of delayed versions of the signal at the receiver. In addition, the radio signal undergoes scattering on a local scale for each major path. Such local scattering is typically characterized by a large number of reflections by objects near the mobile. These irresolvable components combine at the receiver and give rise to the phenomenon known as multipath fading. Due to this phenomenon, each major path behaves as a discrete fading path. Typically, the fading process is characterized by a Rayleigh distribution for a non-line-of-sight path and a Rician distribution for a line-of-sight path. The relative motion between the transmitter and receiver causes Doppler shifts. Local scattering typically comes from many angles around the mobile. This scenario causes a range of Doppler shifts, known as the Doppler spectrum. The maximum Doppler shift corresponds to the local scattering components whose direction exactly opposes the mobile's trajectory.

LAB TASK

1. Design a frequency-flat Rayleigh fading channel. At each symbol generate the channel independently and plot time correlated channel amplitudes with different normalized Doppler values

2. Use the channel to process MPSK, MQAM and MPAM. Plot BER for SNR from 0 to 20 dB. Compare the empirical results with theoretical results

RESULTS

The code, results /plots with discussion must be attached.

Reference Reading:
Viswanathan, M. (2017). Digital Modulations using MATLAB. Building Simulation Models from Scratch. Pilani.

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Department of Telecommunications Engineering

Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 08 Date: ___________________

Software Use Rubric					
Criterion	**Level of Attainment**				
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Remarks	
Instructor's Signature with Date	

LAB SESSION 09

OBJECTIVE

Design of a frequency-flat Rician fading channel and performance evaluation of various modulation schemes over the channel.

THEORY

In wireless environments, transmitted signal may be subjected to multiple scatterings before arriving at the receiver. This gives rise to random fluctuations in the received signal and this phenomenon is called fading. The scattered version of the signal is designated as non-line of sight (NLOS) component. If the number of NLOS components is sufficiently large, the probability-density-function of fading process follows Rayleigh distribution. Rayleigh distribution is well suited for the absence of a dominant line of sight (LOS) path between the transmitter and the receiver. If an LOS path does exist, the distribution is no longer Rayleigh, but Rician. If the LOS component arrive at the receiver at an angle of arrival θ, phase φ and with the maximum Doppler frequency f_D, the fading process in baseband can be represented as

$$h(t) = \sqrt{\frac{K\Omega}{K+1}} e^{(j2\pi f_D \cos\theta t + \phi)} + \sqrt{\frac{\Omega}{K+1}} g(t)$$

where, K represents the Rician K factor given as the ratio of power of the LOS component (A^2) to the power of the scattered components (S^2). i.e., $K = A^2/S^2$. The received signal power **Ω** is the sum of power in LOS component and the power in scattered components, given as $\Omega = A^2 + S^2$. The above mentioned fading process is called Ricean fading process. The best and worst-case Ricean fading channels are associated with K = ∞ and K = 0 respectively. A Ricean fading channel with K = ∞ is a Gaussian channel with a strong LOS path. Ricean channel with K = 0 represents a Rayleigh channel with no LOS path.

LAB TASK

1. Design a frequency-flat Rician fading channel with different K-factor and observe the channel

2. Use the channel to process MPSK, MQAM and MPAM. Plot BER for SNR from 0 to 20 dB. Compare the empirical results with theoretical results

RESULTS

The code, results /plots with discussion must be attached.

Reference Reading:
Viswanathan, M. (2017). Digital Modulations using MATLAB. Building Simulation Models from Scratch. Pilani.

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 09 Date: ___________________

Software Use Rubric					
Criterion	**Level of Attainment**				
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Weighted CLO (Score)	
Remarks	
Instructor's Signature with Date	

LAB SESSION 10

OBJECTIVE

Performance analysis of an encoded wireless communication system and its comparison with an un-coded system.

Theory

Given figure represents a typical digital communication system employing an FEC scheme. A channel encoder in the transmitter side, adds redundancy to the incoming message based on a selected error correction technique. The output of the encoder is called codewords. The codewords are modulated using a digital modulator before sending them through a communication channel. The channel may corrupt the transmitted data. The receiver, upon receiving the data, demodulates it and sends it to a channel decoder. The channel decoder uses the redundant information and attempts to correct the errors in received data. Upon successful error correction, the redundant part of the data is stripped off and the recovered message is delivered as output. Depending on the presence or absence of memory in the encoding structure, FEC codes are broadly classified as either block codes or convolutional codes.

Block Coding
Block coding is a special case of error-control coding. Block coding techniques map a fixed number of message symbols to a fixed number of code symbols. A block coder treats each block of data independently and is a memoryless device.

Convolutional Coding
Convolutional coding is a special case of error-control coding. Unlike a block coder, a convolutional coder is not a memoryless device. A convolutional coder accepts a fixed number of message symbols and produces a fixed number of code symbols.Its computations depend on the current set of input symbols as well as some of the previous input symbols.

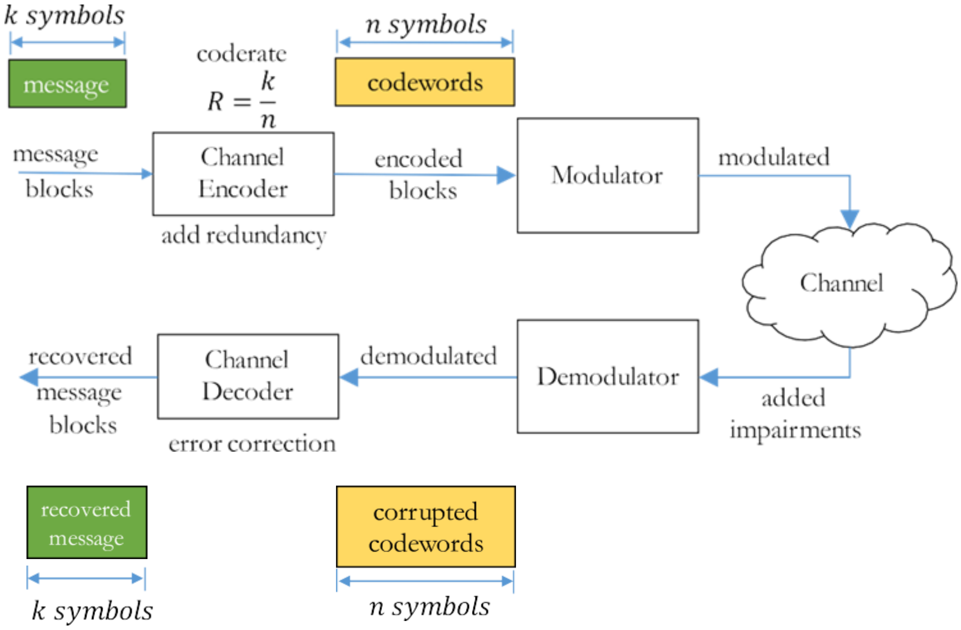

Figure: A wireless communication system with a channel encoder and decoder

LAB TASK:

1. Simulate 16-QAM encoded signal (Linear block codes and Convolutional codes) over AWGN channel and compare performance of these codes.

2. Plot BER vs SNR and compare it with the uncoded 16-QAM signal transmission over AWGN channel observed in Lab 3.

RESULTS

The code, results /plots with discussion must be attached.

Reference Reading:

Viswanathan, M. (2017). Digital Modulations using MATLAB. Building Simulation Models from Scratch. Pilani.

NED University of Engineering & Technology
Department of Telecommunications Engineering

Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 10 Date: ___________________

Software Use Rubric					
Criterion	**Level of Attainment**				
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Remarks	
Instructor's Signature with Date	

LAB SESSION 11

OBJECTIVE

Performance analysis of DSSS transmitter and receiver over a range of signal-to-noise ratios of an AWGN channel.

THEORY

Spread spectrum system was originally developed for military applications. It is extremely resistant techniques to unauthorized detection, jamming, interference and noise. It converts a narrowband signal to wideband signal by the means of spreading. Standards like WiFi and Bluetooth use spread spectrum technology such as *direct sequence spread spectrum (DSSS)* and *frequency hopping spread spectrum (FHSS)*. Spread spectrum techniques use any form of coding sequences like m-sequences, Gold codes, Walsh-Hadamard sequences, etc., The design and selection of a particular code sequence for a given application depends on its properties.

Maximum length sequences (m-sequence) are generated using linear feedback shift registers (LFSR) structures that implement linear recursion. The generator polynomial of the given LFSR is,

$$g(x) = g_0 + g_1 x + g_2 x^2 + \cdots + g_{L-1} x^{L-1} + g_L x^L \ (mod\ 2)$$

where, $g_0, g_1, ..., g_{L-1} \in GF(2)$, i.e, they take only binary values. The first and last coefficients are usually unity: $g_0 = g_L = 1$.

In DSSS, a binary input sequence $d \in \{0,1\}$ is converted to a waveform of bit duration T_b. The data rate of the input is $R_b = 1/T_b$. The resulting waveform is then multiplied with a pseudo-random spreading sequence waveform having the rate $R_c = 1/T_c$ that is much larger than the input data rate i.e, $R_c >> R_b$. The bit duration of the spreading sequence T_c is called chip duration and $R_c = 1/T_c$ is called the chip rate. The process of multiplying a low rate input data sequence with a very high rate pseudorandom sequence, results in a waveform that occupies a bandwidth much larger than the bandwidth of the input data. For transmission, the signal after spreading, is then modulated using BPSK modulation.

The receiver down-converts the transmitted signal using a locally generated carrier. The down-converted signal is then passed through a low-pass filter. The resulting baseband spread-spectrum signal is then multiplied by the same spreading sequence waveform. (synchronized with the transmitter). The de-spreaded signal is then sampled and the data bits are estimated after passing them through a threshold detector.

LAB TASK

1. Design m-sequence codes.
2. Use the codes in part 1 to simulate DSSS transmitter and receiver over AWGN channel. Plot BER vs. SNR

RESULTS

The code, results /plots with discussion must be attached.

Reference Reading:

Viswanathan, M. (2017). Digital Modulations using MATLAB. Building Simulation Models from Scratch. Pilani.

NED University of Engineering & Technology
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Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 11   Date: ____________________

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Remarks	
Instructor's Signature with Date	

LAB SESSION 12

OBJECTIVE

Performance analysis of OFDM signal over frequency selective fading channel.

THEORY

Orthogonal frequency division multiplexing (OFDM) is the most popular multi-carrier waveform that is used to achieve high spectral efficiencies. OFDM is employed in many wireless technologies, including digital audio/video broadcasting and high-speed wireless standards. OFDM has also become a dominant radio access method for cellular standards including 4G, LTE and 5G NR.

OFDM has been promoted for broadband communications due to its high performance in time-dispersive channels. In OFDM, the transmission bandwidth is divided into several narrow bandsub-channels, and data is transmitted in parallel over these sub-channels with a set of narrow carriers. If the bandwidth of each carrier is less than the coherence bandwidth of the channel, each carrier experiences flat fading channel. When the transmission bandwidth exceeds the coherence bandwidth of the channel, the signal experiences a frequency-selective fading which results in significant communication performance degradation such as inter symbol interference (ISI). To avoid the multipath component that leak from the previous symbol to the following symbol, OFDM symbol duration is extended by adding a guard interval with a period of T_B to the beginning of each symbol with cyclic prefix (CP). The guard interval should be longer than the maximum excess delay of the channel, which is defined as the delay between the first and last received paths over the channel.

LAB TASK

1. Generate an OFDM signal and plot it in time and frequency domain.

2. Create a frequency selective fading channel, and transmit OFDM over it. Plot BER vs specified SNR range.

RESULTS

The code, results /plots with discussion must be attached.

Reference reading:

2. Arslan Hüseyin. (2021). Wireless communication signals : a laboratory-based approach. John Wiley & Sons.

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Department of Telecommunications Engineering

Course Code and Title: TC-314 Wireless and Mobile Communication

Laboratory Session No. 12 Date: ___________________

Software Use Rubric					
Criterion	**Level of Attainment**				
	Below Average (1)	**Average (2)**	**Good (3)**	**Very Good (4)**	**Excellent (5)**
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Instructor's Signature with Date	

LAB SESSION 13
OPEN ENDED LAB

OBJECTIVE

To explore, analyse and develop hands-on experience in designing a wireless communication system using the software/hardware platform of LabVIEW and USRP.

PROBLEM STATEMENT

Design a multicarrier communication system and *demonstrate* its performance over 2x2 MIMO using USRPs.

BACKGROUND/PRE-REQUISITE

To perform this activity student must have the knowledge and understanding of
- Wireless communication system and its performance requirements
- LabVIEW/MATLAB
- USRP

OUTCOME

This activity is mapped to CLO3 of the course and results in the attainment of PLO 5 (Modern Tool Usage)

CLO	Taxonomy Level	PLO	Outcome
3	P3	5	The students must be able to build the model of wireless communication system and analyze various aspects of the system through experimental work/simulation following instructor guidance and operating manual instructions.

INSTRUCTIONS FOR PROBLEM SOLUTION

You need to study and understand the mathematical principles/algorithms involved in working of the system. In the design phase, you might need to implement various sub-blocks of communication system using simulation software and then test it over the hardware. Set the parameters values of each communication blocks for optimum results. Use suitable metric at different points of your system to study wireless signal both in time domain and frequency domain. Analyze the strength of received signal and observe the performance of your system design.

DELIVERABLES

Write a detailed report on the design of your communication system. The report should be in the standard format including abstract, objectives, background, system working/description and diagrams, simulation results/code/discussions and conclusions. The report must essentially include:

1. A labeled system diagram mentioning function of each block in detail
2. All working equations and formulae must be clearly indicated and numbered
3. Indicate the system parameters in form of a table, captioned and numbered
4. All figures and graphs must be captioned with proper labeling and numbering

F/OBEM 01/18/00

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Department of Telecommunications Engineering
Course Code & TitleTC-314 Wireless and Mobile Communication
Assessment Rubric for CEP

Criterion	Level of Attainment				
	Below Average (0)	**Average (1)**	**Good (2)**	**Very Good (3)**	**Excellent (4)**

Student's Name: ____ Roll No.: ____________

Total Score = ___________________________

Instructor's Signature: ____________________