NEW HORIZON
COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

ACADEMIC YEAR: 2024-2025

IV Year/VII Semester

21ECE71 – WIRELESS COMMUNICATION

LAB MANUAL

NEW HORIZON COLLEGE OF ENGINEERING

INSTITUTION

Vision

To emerge as an institute of eminence in the fields of engineering, technology and management in serving the industry and the nation by empowering students with a high degree of technical, managerial and practical competence.

Mission

- To strengthen the theoretical, practical, and ethical dimensions of the learning process by fostering a culture of research and innovation among faculty members and students.
- To encourage long-term interaction between the academia and industry through their involvement in the design of curriculum and its hands-on implementation.
- To strengthen and mould students in professional, ethical, social and environmental dimensions by encouraging participation in co-curricular and extracurricular activities.
- To develop value based socially responsible professionals for the betterment of the society.

Quality Policy

To provide educational services of the highest quality both curricular and co-curricular to enable students integrate skills and serve the industry and society equally well at global level.

Values

- ❖ Academic Freedom
- ❖ Innovation
- ❖ Integrity
- ❖ Professionalism
- ❖ Inclusiveness
- ❖ Social Responsibility

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VISION

To create high quality engineering professionals who can serve the society and earn global recognition.

MISSION

- To build strong foundation in Electronics and Communication Engineering aspects by exposing students to state of the art technology and research.
- To strengthen the curriculum through interaction with industry experts to equip the students with the required competency.
- To mould students to share technical knowledge and to practice professional and moral values.

Program Education objectives (PEOs)

PEO1	To produce graduates with understanding of fundamentals and applications of Electronics and Communication Engineering.
PEO2	To hone graduates with ability to apply, analyze, design and develop electronic systems.
PEO3	To enhance graduates with latest technologies to enable them to engineer products for real world problems.
PEO4	To build leadership qualities, management skills, communication skills, moral values, team spirit and lifelong learning ability for the graduates.

PEO to Mission Statement Mapping

Mission Statements	PEO1	PEO2	PEO3	PEO4
To build strong foundation in Electronics and Communication Engineering aspects by exposing students to state of the art technology and research.	3	3	3	2
To strengthen the curriculum through interaction with industry experts to equip the students with the required competency.	2	3	3	2
To mould students to share technical knowledge and to practice professional and moral values.	1	2	2	3

Correlation: 3- High, 2-Medium, 1-Low

Program Outcomes (PO) with Graduate Attributes

	Graduate Attributes	Program Outcomes (POs)
1	**Engineering knowledge**	**PO1:** Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems in Electronics and Communication Engineering.
2	**Problem analysis**	**PO2:** Identify, formulate, review research literature, and analyze complex engineering problems in Electronics and Communication Engineering reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3	**Design/development of solutions**	**PO3:** Design solutions for complex engineering problems and design system components or processes of Electronics and Communication Engineering that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4	**Conduct investigations of complex problems**	**PO4:** Use research-based knowledge and research methods including design of experiments in Electronics and Communication Engineering, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5	**Modern tool usage**	**PO5:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities in Electronics and Communication Engineering with an understanding of the limitations.
6	**The engineer and society**	**PO6:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice in Electronics and Communication Engineering.
7	**Environment and sustainability**	**PO7:** Understand the impact of the professional engineering solutions of Electronics and Communication Engineering in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8	**Ethics**	**PO8:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9	**Individual and team work**	**PO9:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10	**Communication**	**PO10:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11	**Project management and finance**	**PO11:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12	**Life-long learning**	**PO12:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1	To demonstrate the ability to design and develop complex systems in the areas of next generation Communication Systems, IoT based Embedded Systems, Advanced Signal

	and Image Processing, latest Semiconductor technologies, RF and Power Systems.
PSO2	To demonstrate the ability to solve complex Electronics and Communication Engineering problems using latest hardware and software tools along with analytical skills to contribute to useful, frugal and eco-friendly solutions.

Mapping of PEOs to POs & PSOs

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
PEO1	3	3	2	2	2	1	1	1	1	1	1	1	1	1
PEO2	3	3	3	3	3	2	2	2	2	2	2	2	3	2
PEO3	3	3	3	3	3	3	3	2	2	2	2	2	3	3
PEO4	1	1	1	1	1	2	2	3	3	3	3	3	1	1

Correlation: 3- High, 2-Medium, 1-Low

Prepared By	Verified By	Approved By
Dr. A. B. Gurulakshmi Professor, ECE	Dr. M. Jayanthi Associate Professor, ECE	Dr. Aravinda K. Prof. & Head ECE

WIRELESS COMMUNICATION

Course Code	**21ECE71**	**CIE Marks**	**50**
L:T:P:S	**2:0:1:0**	**SEE Marks**	**50**
Hrs /Week	**2+2**	**Total Marks**	**100**
Credits	**03**	**Exam Hours**	**03**

Course outcomes:

At the end of the course, the student will be able to:

21ECE71.1	Understand the basics of wireless communication and evolution of wirelesscommunication standards with time.
21ECE71.2	Choose appropriate radio signal propagation model for different communicationsystems
21ECE71.3	Identify the basic operations and call setup processes of GSM and CDMA
21ECE71.4	Evaluate the significance of multi-carrier modulation techniques in the current communication scenario
21ECE71.5	Apply the concept of smart multi antenna systems for advanced wireless communication
21ECE71.6	Analyze the concepts of wireless communication using Simulation tools

Mapping of Course Outcomes to Program Outcomes and Program Specific Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
21ECE71.1	2	-	-	-	-	-	-	-	-	-	-	2	3	3
21ECE71.2	3	2	1	-	-	-	-	-	-	-	-	2	3	3
21ECE71.3	3	2	-	-	-	-	-	-	-	-	-	2	3	-
21ECE71.4	3	2	1	1	-	-	-	-	-	-	-	2	3	3
21ECE71.5	3	2	-	-	-	-	-	-	-	-	-	2	3	3
21ECE71.6	3	2	1	-	3	-	-	-	-	-	-	2	3	3

MODULE- 1	**Introduction to wireless communication systems**	**21ECE71.1 21ECE71.6**	**5 Hours**

Evolution of wireless communication systems, Examples of wireless communication systems. Cellular concept - Frequency reuse - channel assignment strategies - hand off strategies - interference & system capacity – trunking & grade of service – Improving coverage and capacityin cellular system.

LIST OF EXPERIMENTS: **3 Hours**

1.Study of basic operation of a spectrum analyzer.
2.Visualization of different waveforms in wireless communication.3.Simulate Communication System using Matlab.

Self-study	Different Cellular systems.
Textbook	**Textbook 1: 1.1,1.4, 3.1,3.2,3.3,3.4, 3.5, 3.6, 3.7**

MODULE- 2	**Free Space Propagation Model**	**21ECE71.2 21ECE71.6**	**5 Hours**

Three Basic Propagation mechanism – Reflection (Ground Reflection -Two Ray model),Diffraction (knife-edge diffraction model)and Scattering ,model - Link Budget design using Path

Loss model(log normal shadowing) Outdoor and Indoor Propagation models –Okumura model, Hata model, long-distance path loss model Small scale multipath propagation –Parameters of mobile multipath channels.			
LIST OF EXPERIMENTS: 3 **Hours** 1.Simulation of Okumura model using MATLAB. 2.Simulation of Hata model using MATLAB. 3.Simulation of log normal shadowing model using MATLAB.			
Self-study	Fading effects due to Multipath time delay spread and Fading effects due to Doppler spread - Rayleigh and Rician distribution.		
Text Book	Text Book 1:4.1, 4.2, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9,4.10,4.11,5.4,5.5,5.5.1,5.5.2, 5.6		
MODULE - 3	**Wireless standards**	**21ECE71.3 21ECE71.6**	**5 Hours**
Introduction to wireless standards – 1G-AMPS, 2G. GSM services and features, Systemarchitecture, Radio subsystem, channel types, Frame structure for GSM CDMA (IS-95) – CDMA frequency bands, Forward and Reverse CDMA Channel.			
LIST OF EXPERIMENTS: 3 **Hours** 1. Study of DS-SS modulation/Demodulation Process (trainer kit based) 2. Study of CDMA(DS-SS) technique using analog signal as an input signal (trainer kit based) 3. Study and identify different blocks of mobile phone units. 4. Sketch the waveforms of different sections in Mobile Communication Trainer board.			
Case Study	Write and simulate a MATLAB program to analyze the propagation models		
Text Book	Text Book 1: 11.1, 11.3, 11.4		
MODULE - 4	**OFDM for Wireless Communication**	**21ECE71.4 21ECE71.6**	**5 Hours**
Basic principles of orthogonality, single Vs Multi-carrier systems, ODFM Block diagram,OFDM signal mathematical representation, pilot insertion and channel estimation.			
LIST OF EXPERIMENTS: 3 Hours 1. To study and execute different types of AT commands using Mobile Communication Trainerboard. 2.To realize Voice communication using AT commands(trainer kit based). 3. Simulation of OFDM transmitter and receiver using MATLAB.			
Application	Derive cyclic prefix in OFDM for 64 sub-carriers.		
Text Book	Text Book 2: 9.1, 9.2, 9.3, 9.4, 9.9		
MODULE - 5	**Multipath Mitigation Techniques**	**21ECE71.5 21ECE71.6**	**5 Hours**
Diversity – Types of Diversity – Diversity combining techniques: Selection, Feedback, Maximal Ratio Combining and Equal Gain Combining Introduction to MIMO, MIMO basedsystem architecture, MIMO channel modeling, Advantages and applications of MIMO. Introduction to advancements in wireless communication-5G and 6G technologies.			
LIST OF EXPERIMENTS: **3 Hours**			

1. Simulation of MIMO system using MATLAB.
2. To write a MATLAB program to calculate the link budget for satellite communication.
3. To write a MATLAB program to calculate the Carrier to noise ratio for uplink and downlink and the overall carrier to noise ratio

Self-Study	Compare SISO and MIMO.
Textbook	Textbook 2: 15.1, 15.2, 15.3,15.8, 15.13

CIE Assessment Pattern (50 Marks – Theory)

RBT Levels		Marks Distribution		
		Test (s)	**Qualitative Assessment**	**Lab**
		25	**05**	**20**
L1	**Remember**	5	-	-
L2	**Understand**	5	-	5
L3	**Apply**	10	5	10
L4	**Analyze**	5	-	5
L5	**Evaluate**	-	-	-
L6	**Create**	-	-	-

SEE Assessment Pattern (50 Marks – Theory)

RBT Levels		Exam Marks Distribution (50)
L1	**Remember**	**10**
L2	**Understand**	**10**
L3	**Apply**	**20**
L4	**Analyze**	**10**
L5	**Evaluate**	**-**
L6	**Create**	**--**

Suggested Learning Resources:

Textbooks:

1. Rappaport T.S., “Wireless communications: Principles and Practices ”, Pearson Education, 2014, ISBN-13: 978-9332535794.
2. Wireless Communication — Upen Dalal, Oxford Univ. Press,2009, ISBN-13. 978-019806066.

References:

1. Lee, W.C.Y., Mobile Communication Engineering, McGraw Hill, 2.017, ISBN: 978-0071810419
2. David Tse and Pramod Viswanath, “Fundamentals of Wireless Communication”, Cambridge University Press, 2005, ISBN: 978-0521845274
3. Andreas.F. Molisch, “Wireless Communications”, John Wiley India, 2006, ISBN: 978-8126511301
4. Wireless Communications-Andrea Goldsmith, 2005 Cambridge University Press, ISBN:978-0521837163

Web links and Video Lectures (e-Resources):

- https://www.coursera.org/learn/wireless-communications
- https://www.youtube.com/watch?v=RrTmXIY3FbM

Activity-Based Learning (Suggested Activities in Class)/ Practical Based learning

- Seminars
- Experiments for different Use cases.
- Contents related activities (Activity-based discussions)
- Group Discussion
- Case- Study

EXPT.1: STUDY OF BASIC OPERATION OF A SPECTRUM ANALYZER

Aim:

To study the basic operation of a spectrum analyzer and analyze the various parameters of FM signal.

Tools Required:

- Spectrum Analyzers
- PC

Theory:

Spectrum analyzer is the common tool for any RF engineer. It is used for viewing RF signals in frequency domain. **Spectrum analyzer** converts time domain signals into frequency domain for display and analysis.

As far as power measurement is concerned, spectrum analyzer displays power levels with accuracy of approx. +/- 0.5 dB. It is not very accurate for frequency measurements, for which other means such as frequency counter can be the bestoption.

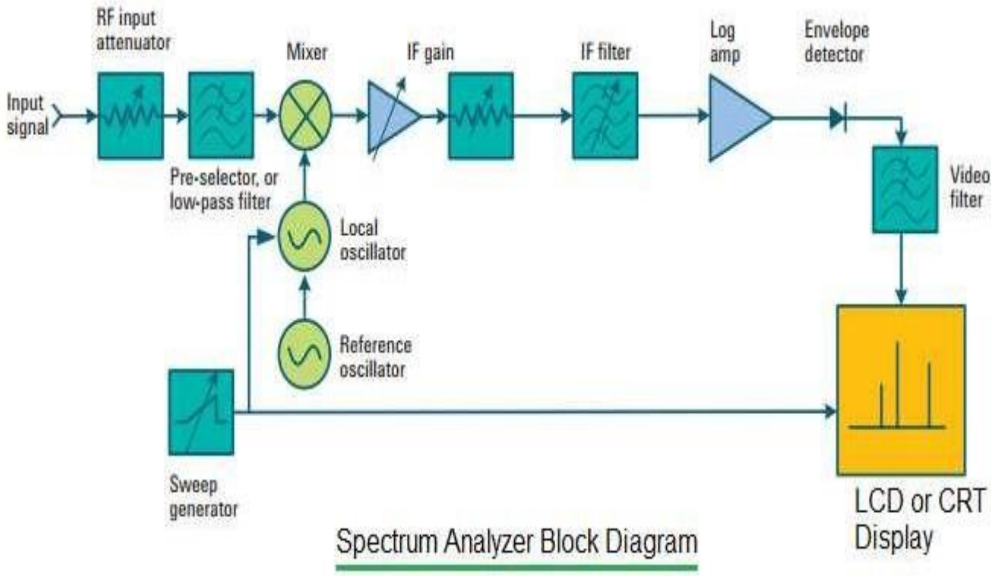


Figure 1

The block schematic mentions major components in a typical spectrum analyzer. They are RF input attenuator, mixer, IF filter, detector, video filter, local oscillator, sweep generator and LCD display. The IF (Intermediate Frequency) gain amplifier is not mentioned in the figure but it is very much required after the mixer. Figure 1 depicts simple spectrum analyzer, which shows that, mixer produces both sum and difference components of the input frequency signals. From this required IF frequency is filtered out using IF BPF. The signals are applied to CRT for displaying X(frequency) and Y(power) data.

Measurement using spectrum analyzer

To perform measurement signal to be measured is connected to RF Input port of the spectrum analyzer and following need to be set appropriately:

- RF Centre frequency (should be equal to RF input frequency to be measured)
- Frequency range or Span (should cover wanted RF frequency to be measured)
- Resolution Bandwidth (RBW) and Video Bandwidth (VBW)
- Sweep time

For example:

If two signals are 100 kHz apart, a 100 kHz RBW will easily separate the responses. A wider RBW makes two signals appear as one signal and difficult to distinguish them. VBW is the low pass filter, which helps smooth out the signal. It is also possible to do video averaging on our spectrum analyzer to improve resolution of weak signals in the presence of noise. For example 3KHz filter does not resolve very smaller frequency signals which can be done using 1KHz filter. Sweep time is the time required to sweep LO frequency across the displayed frequency span. Sweep time need to be set appropriately as sweeping the spectrum analyzer too fast causes a drop in displayed amplitude and a shift in indicated frequency. There is one more setting called Ref level, which is the power level at the top of the screen. Sweep time = 1/sqrt(RBW) .The spectrum analyzer is used for frequency measurement, spuriousm harmonics and phase noise measurements. Tektronix has developed realtime spectrum analyzer (model numbers RSA 3300A, RSA 3408A, RSA5000, RSA6000) which is more powerful compare to conventional spectrum analyzer.

Following are important specifications of spectrum analyzer:

- Frequency tuning range - to include all of the frequency components of the signal to be measured.
- Frequency accuracy and stability - to be more stable and accurate than the signal to be measured.
- Sweep width - the band of frequencies over which the unit can sweep without readjustment.
- Resolution bandwidth - narrow enough to resolve different spectral components of the signal.
- Sensitivity and/or noise figure - to observe very small signals or small parts of large signals.
- Sweep rate - maximum sweep rate is established by the settling time of the filter that sets the resolution bandwidth.
- Dynamic range - the difference between the largest and smallest signal the analyzer can measure without readjustment.
- Phase noise - a signal with spectral purity greater than that of the analyzer conversion oscillators cannot be characterized.

The RSA306 uses your PC and Tektronix Signal Vu-PC™ RF Signal Analysis Software to provide real time spectrum analysis, streaming capture and deep signal analysis capabilities for signals from 9 kHz to 6.2 GHz, all in a low-cost, highly portable package that is ideal for field, factory, or academic use.

Key performance specifications

- 9 kHz to 6.2 GHz frequency range covers a broad range of analysis needs
- +20 dBm to -160 dBm measurement range
- Captures interference to ensure that you see problems first time, every time
- Mil-Std 28800 Class 2 environmental, shock and vibration specifications for use in harsh conditions

Key features

- Full-featured spectrum analysis capability with included Tektronix SignalVu-PC™ software
- 27 spectrum and signal analysis measurements standard
- Options for mapping, modulation analysis, WLAN and Bluetooth standards support, pulse measurements, playback of recorded files, and frequency settling
- Real time Spectrum/Spectrogram display to minimize time spent on transient and interference hunting
- Application programming interface (API) included for Microsoft Windows environments
- MATLAB instrument driver for use with Instrument Control Toolbox
- Streaming capture records long-term events

Applications

- Academic/education
- Maintenance, installation and repair in the factory or field
- Value-conscious design and manufacturing
- Interference hunting

The RSA306: a new class of instrument

The RSA306 offers full-featured spectrum analysis and deep signal analysis at a price unmatched by any previous offering. Using the latest in commercial interfaces and available computing power, the RSA306 separates signal acquisition from measurement, dramatically lowering the cost of instrument hardware. Data analysis, storage and replay is performed on your personal computer, tablet, or laptop. Managing the PC separately from the acquisition hardware makes processing upgrades easy and minimizes IT management issues.

Signal Vu-PC™ software and an API for deep analysis and fast programmatic interaction. The RSA306 operates with Signal Vu-PC, a powerful program that is the basis of Tektronix performance signal analyzers. Signal Vu-PC offers a deep analysis capability previously unavailable in value-priced solutions. Real-time processing of the DPX spectrum/spectrogram is enabled in your PC, further reducing the cost of hardware. Customers who need programmatic access to the instrument can choose either the Signal Vu-PC programmatic interface or use the included application programming interface (API) that provides a rich set of commands and measurements. A MATLAB driver for the API is available, enabling operation with MATLAB and the Instrument Control Toolbox.

Basic functionality of the free Signal Vu-PC program is far from basic. The table below summarizes the measurements included in the free Signal Vu-PC software.

General signal analysis	
Spectrum analyzer	Spans from 1 kHz to 6.2 GHz Three traces plus math and spectrogram trace Five markers with power, relative power, integrated power, power density and dBc/Hz functions
DPX Spectrum/Spectrogram	Real time display of spectrum with 100% probability of intercept of 100 μsec signals in up to 40 MHz span
Amplitude, frequency, phase vs. time, RF I and Q vs. time	Basic vector analysis functions
Time Overview/Navigator	Enables easy setting of acquisition and analysis times for deep analysis in multiple domains
Spectrogram	Analyze and re-analyze your signal with a 2-D or 3-D waterfall display
AM/FM listening	Hear, and record to file, FM and AM signals
Analog modulation analysis	
AM, FM, PM analysis	Measures key AM, FM, PM parameters
RF measurements	
Spurious measurement	User-defined limit lines and regions provide automatic spectrum violation testing across the entire range of the instrument
Spectrum emission mask	User-defined or standards-specific masks
Occupied Bandwidth	Measures 99% power, -xdB down points
Channel Power and ACLR	Variable channel and adjacent/alternate channel parameters
MCPR	Sophisticated, flexible multi-channel power measurements
CCDF	Complementary Cumulative Distribution Function plots the statistical variations in signal level

The RSA306 with Signal Vu-PC offers basic and advanced measurements for field and lab.The 40 MHz real time bandwidth of the RSA306 combined with the processing power of SignalVu-PC shows you every signal, even down to 100 µs in duration. The following figure 2 shows a WLAN transmission (green and orange), and the narrow signals that repeat across the screen are a Bluetooth access probe. The spectrogram (upper part of the screen) clearly separates these signals in time to show any signal collisions.

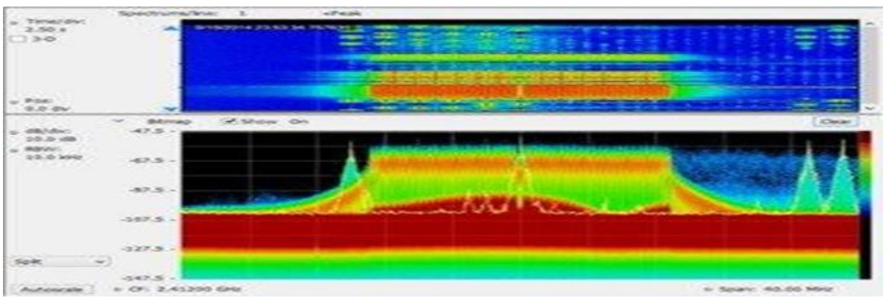


Figure 2 SignalVu-PC

Monitoring has never been easier. Spectrum mask testing captures detail of transients found in the frequency domain, such as intermittent interference. Mask testing can be set to stop acquisition, save acquisition, save a picture, and send an audible alert. The following image shows a spectrum mask (in orange on the spectrum display) created to monitor a band of frequencies for violations. A single transient of 125 µs duration has occurred that violated the mask, with the violation shown in red. The transient is clearly seen on the spectrogram above the red violation area (circled).

<u>Signal Vu-PC offers a wealth of application-oriented measurement and analysis options including:</u>

- General-purpose modulation analysis (27 modulation types including 16/32/64/256 QAM, QPSK, O-QPSK, GMSK, FSK, APSK)
- P25 analysis of phase I and phase 2 signals
- WLAN analysis of 802.11a/b/g/j/p, 802.11n, 802.11ac
- LTE™ FDD and TDD Base Station (eNB) Cell ID & RF measurements
- Bluetooth® analysis of Low Energy, Basic Rate and Enhanced Data Rate
- Mapping and signal strength
- Pulse analysis
- AM/FM/PM/Direct Audio Measurement including SINAD, THD
- Playback of recorded files, including complete analysis in all domains
- Signal Classification and Survey

Modulation analysis application SVM enables multiple displays of modulation quality. The following screen shot shows the standard Channel Power/ACLR measurement combined with a constellation display and vector signal quality measurements on a QPSK signal.

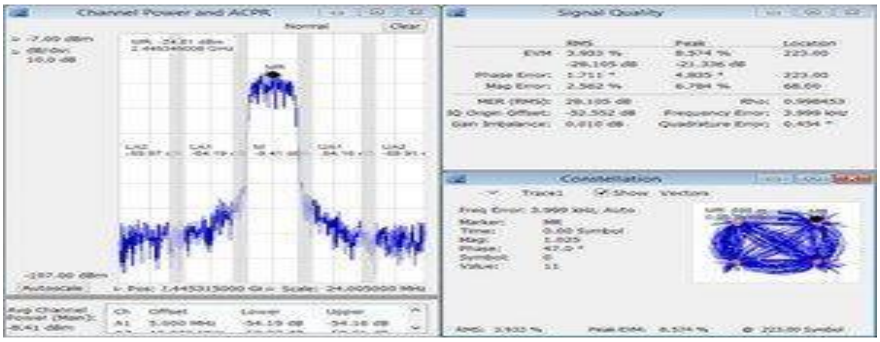


Figure 3: Modulation analysis application SVM

Signal Vu-PC application SV26 enables quick, standards-based transmitter health checks on APCO P25 signals. The following image shows a Phase II signal being monitored for anomalies with the spectrum analyzer while performing transmitter power, modulation and frequency measurements.

Sophisticated WLAN measurements are easy. On the following 802.11g signal display below, the spectrogram shows the initial pilot sequence followed by the main signal burst. The modulation is automatically detected as 64 QAM for the packet and displayed as a constellation. The data summary indicates an EVM of -33.24 dB RMS, and burst power is measured at 10.35 dBm. Signal Vu-PC applications are available for 802.11a/b/j/g/p, 802.11n and 802.11ac to 40 MHz bandwidth.

With application SV27 you can perform Bluetooth SIG standard-based transmitter RF measurements in the time, frequency, and modulation domains. This application supports Basic Rate and Low Energy Transmitter measurements defined by Bluetooth SIG Test Specification RF.TS.4.1.1 for Basic Rate and RF-PHY.TS.4.1.1 for Bluetooth Low Energy.

Application SV27 also automatically detects Enhanced Data Rate packets, demodulates them and provides symbol information. Data packet fields are color encoded in the Symbol table for clear identification.

Pass/Fail results are provided with customizable limits and the Bluetooth presets make the different test set-ups push-button. The measurement below shows deviation vs. time, frequency offset and drift, and a measurement summary with pass/fail results.

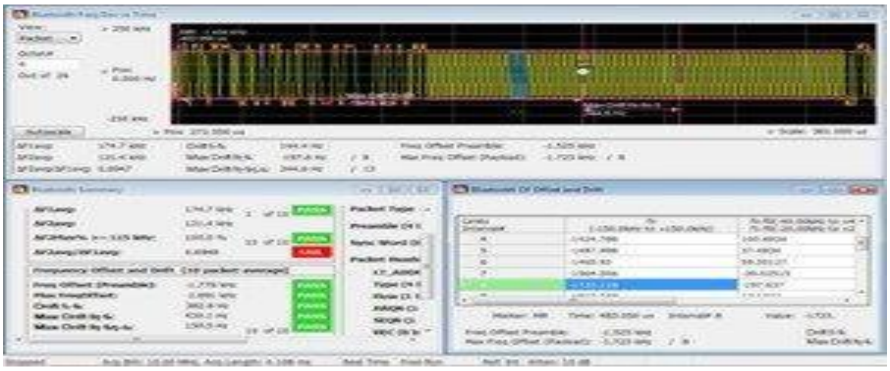


Figure 4: Application SV27 deviation vs. time

The Signal Vu-PC MAP application enables interference hunting and location analysis. Locate interference with an azimuth function that lets you draw a line or an arrow on a mapped measurement to indicate the direction your antenna was pointing when you take a measurement. You can also create and display measurement labels.

Application SV28 enables the following LTE base station transmitter measurements:

- Cell ID
- Channel Power
- Occupied Bandwidth
- Adjacent Channel Leakage Ratio (ACLR)
- Spectrum Emission Mask (SEM)
- Transmitter Off Power for TDD

There are four presets to accelerate pre-compliance testing and determine the Cell ID. These presets are defined as Cell ID, ACLR, SEM, Channel Power and TDD Toff Power. The measurements follow the definition in 3GPP TS Version 12.5 and support all base station categories, including pico-cells and femtocells. Pass/Fail information is reported and all channel bandwidths are supported.
The Cell ID preset displays the Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS) in a Constellation diagram. It also provides Frequency Error. The ACLR preset measures the E-UTRA and the UTRA adjacent channels, with different chip rates for UTRA. ACLR also supports Noise Correction based on the noise measured when there is no input. Both ACLR and SEM will operate in swept mode (default) or in faster single acquisition(real-time) when the measurement bandwidth required is less than 40 MHz.

Result:

The basic operation of spectrum analyzer was studied.

EXPT.2: VISUALIZATION OF DIFFERENT WAVEFORMS IN WIRELESS COMMUNICATION.

Aim:

To generate widely used periodic and aperiodic waveforms, swept-frequency sinusoids, and pulse trains using functions available in Signal Processing Toolbox in MATLAB.

Software Used:

- MATLAB-Version 7.1

Theory:

Periodic Waveforms

A periodic waveform is a function or wave that repeats itself at regular intervals, or periods. Functions like sin, cos, sawtooth and square are some examples for periodic waveform. The sawtooth function generates a sawtooth wave with peaks at ±1 and a period of 2π. An optional width parameter specifies a fractional multiple of 2π at which the signal's maximum occurs. The square function generates a square wave with a period of 2π. An optional parameter specifies duty cycle, the percent of the period for which the signal is positive.

Aperiodic Waveforms

An aperiodic waveform is a signal that doesn't repeat itself after a specific time interval. To generate aperiodic waveforms like triangular, rectangular and Gaussian pulses, the toolbox offers the tripuls, rectpuls, and gauspuls functions. The gauspuls function generates a Gaussian-modulated sinusoidal pulse with a specified time, center frequency, and fractional bandwidth.
The sinc function computes the mathematical sinc function for an input vector or matrix. The sinc function is the continuous inverse Fourier transform of a rectangular pulse of width 2π and unit height.

Swept Frequency Waveforms

A swept frequency waveform is a single waveform that has a frequency that changes continuously in a linear way. The vco (voltage-controlled oscillator), which generates a signal oscillating at a frequency determined by the input vector. The input vector can be a triangle, a rectangle, or a sinusoid, among other possibilities.

Pulse Train Waveforms

A pulse train waveform is a non-sinusoidal waveform that is made up of a series of pulses that can be identical or unique.

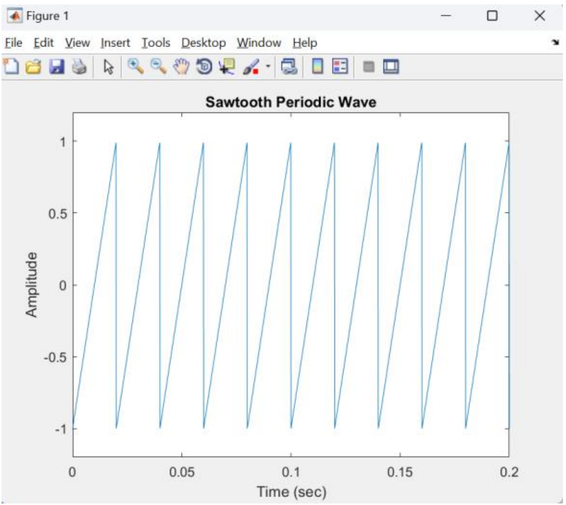
MATLAB Code:

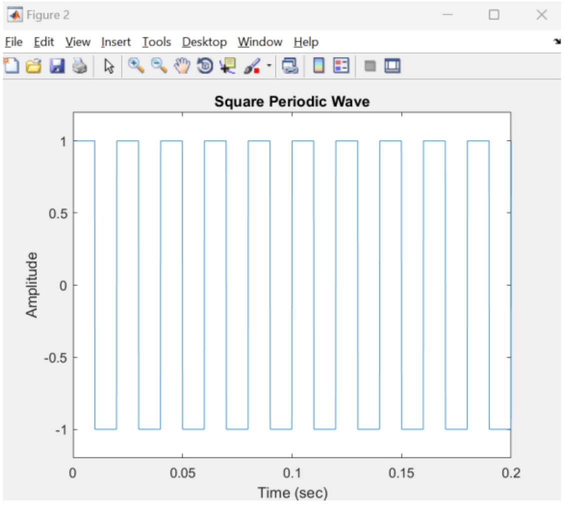
```
%periodic
fs = 10000;
t = 0:1/fs:1.5;
x1 = sawtooth(2*pi*50*t);
x2 = square(2*pi*50*t);

figure
plot(t,x1)
axis([0 0.2 -1.2 1.2])
xlabel('Time (sec)')
ylabel('Amplitude')
title('Sawtooth Periodic Wave')

figure
plot(t,x2)
axis([0 0.2 -1.2 1.2])
xlabel('Time (sec)')
ylabel('Amplitude')
title('Square Periodic Wave')

%Aperiodic
fs = 10000;
t = -1:1/fs:1;
x1 = tripuls(t,20e-3);
x2 = rectpuls(t,20e-3);
```

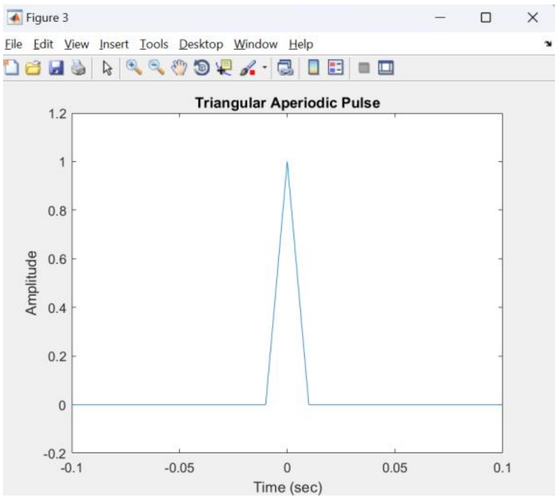
```
%Generate 2 seconds of a triangular pulse with a sample rate of 10 kHz and a width of 20 ms. Repeat the computation for a rectangular pulse.
figure
plot(t,x1)
axis([-0.1 0.1 -0.2 1.2])
xlabel('Time (sec)')
ylabel('Amplitude')
title('Triangular Aperiodic Pulse')

figure
plot(t,x2)
axis([-0.1 0.1 -0.2 1.2])
xlabel('Time (sec)')
ylabel('Amplitude')
title('Rectangular Aperiodic Pulse')

% Generate a 50 kHz Gaussian RF pulse with 60% bandwidth, sampled at a rate of 1 MHz. Truncate the pulse where the envelope falls 40 dB below the peak.
% Generate the sinc function for a linearly spaced vector:
tc = gauspuls('cutoff',50e3,0.6,[],-40);
t1 = -tc : 1e-6 : tc;
y1 = gauspuls(t1,50e3,0.6);
t2 = linspace(-5,5);
y2 = sinc(t2);

figure
plot(t1*1e3,y1)
xlabel('Time (ms)')
ylabel('Amplitude')
title('Gaussian Pulse')

figure
plot(t2,y2)
xlabel('Time (sec)')
ylabel('Amplitude')
title('Sinc Function')

%Swept frequency
% Generate two seconds of a signal sampled at 10 kHz whose instantaneous frequency is a triangle function of time.
fs = 10000;
t = 0:1/fs:2;
x1 = vco(sawtooth(2*pi*t,0.75),[0.1 0.4]*fs,fs);
figure
spectrogram(x1,kaiser(256,5),220,512,fs,'yaxis')
x2 = vco(square(2*pi*t),[0.1 0.4]*fs,fs);
figure
spectrogram(x2,kaiser(256,5),220,512,fs,'yaxis')

%pulse train
%Generate a periodic Gaussian pulse signal at 10 kHz with 50% bandwidth. The pulse repetition frequency is 1 kHz, the sample rate is 50 kHz, and the pulse train length is 10 milliseconds.
%The repetition amplitude should attenuate by 0.8 each time. Uses a function handle to specify the generator function.
fs = 100E9;                    % sample freq
D = [2.5 10 17.5]' * 1e-9;     % pulse delay times
t = 0 : 1/fs : 2500/fs;        % signal evaluation time
w = 1e-9;                      % width of each pulse
yp = pulstran(t,D,@rectpuls,w);

T = 0 : 1/50E3 : 10E-3;
D = [0 : 1/1E3 : 10E-3 ; 0.8.^(0:10)]';
Y = pulstran(T,D,@gauspuls,10E3,.5);

figure
```

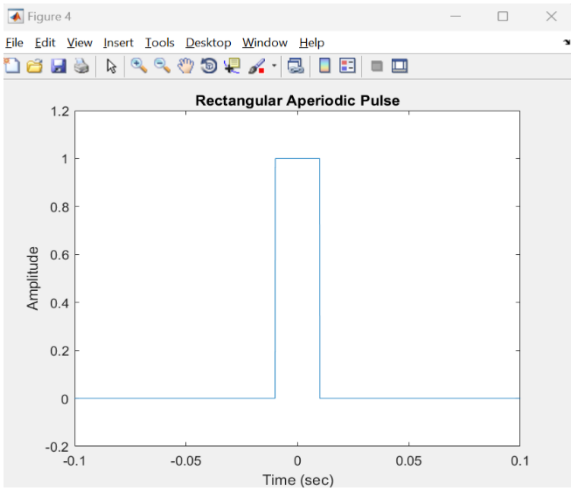
```
subplot(211)
plot(t*1e9,yp);
axis([0 25 -0.2 1.2]);
xlabel('Time (ns)');
ylabel('Amplitude');
title('Rectangular Train');
subplot(212)
plot(T*1e3,Y)
xlabel('Time (ms)');
ylabel('Amplitude');
title('Gaussian Pulse Train');
hgcf = gcf;
hgcf.Color = [1,1,1];
```

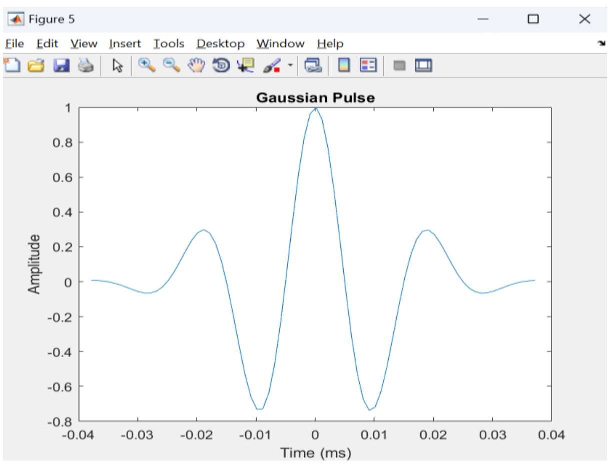
Graph:

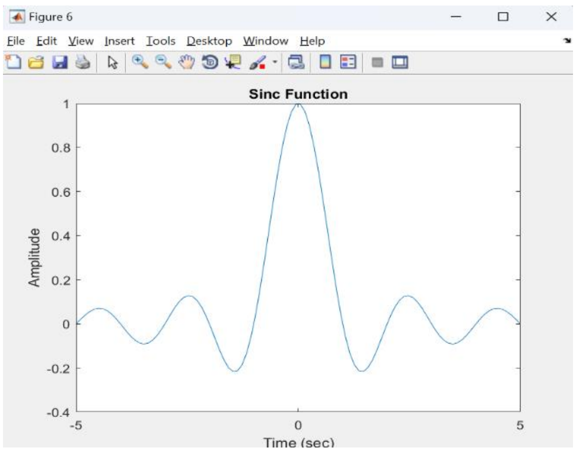


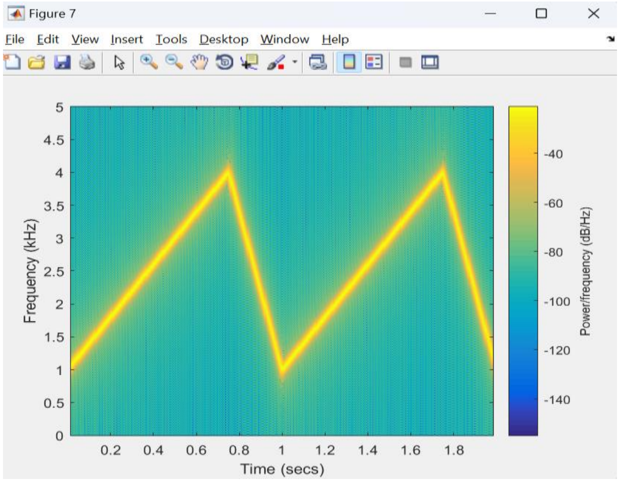


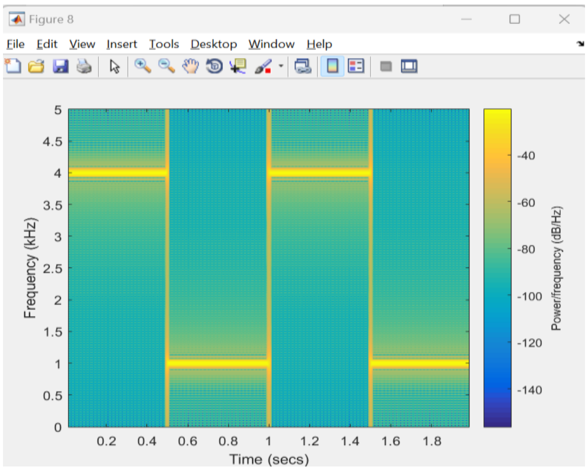


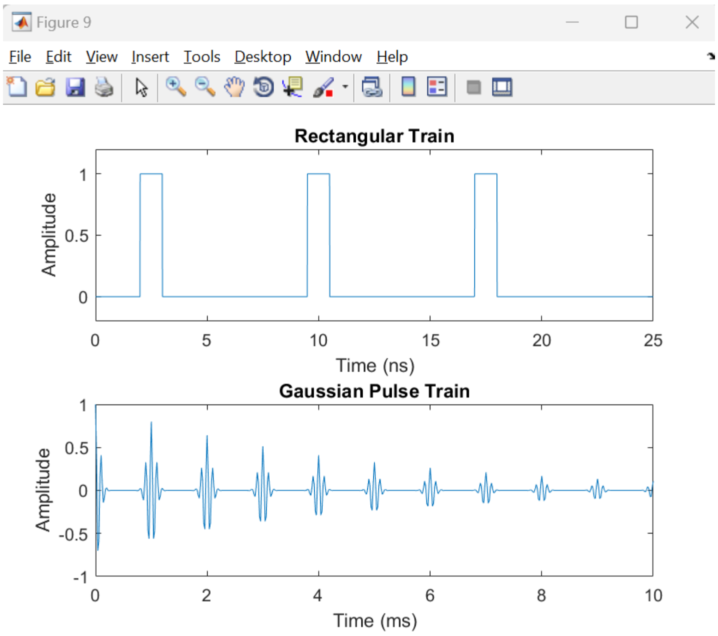












Result:

Periodic and aperiodic waveforms, swept-frequency sinusoids, and pulse trains waveforms are generated and visualised using functions available in Signal Processing Toolbox in MATLAB.

EXPT.3: SIMULATION OF COMMUNICATION SYSTEM USING SIMULINK

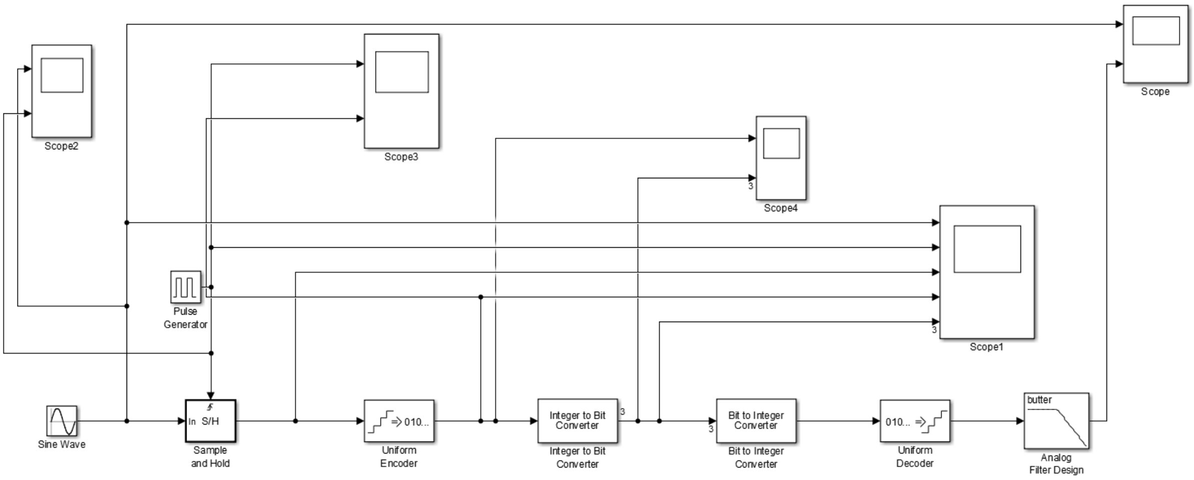
Aim:

To Study of PULSE CODE MODULATION (PCM) and its DEMODULATION Scheme through SIMULINK Models on MATLAB.

Software Used: MATLAB Simulink

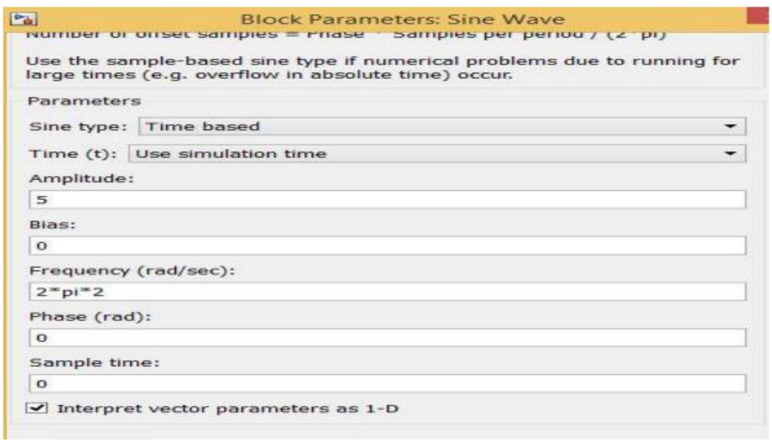
1. Sinusoidal Wave Generator
2. Pulse Generator
3. Sample & Hold
4. Uniform Encoder
5. Integer To Bit Converter
6. Bit To Integer Converter
7. Uniform Decoder
8. Analog Filter Design
9. Scope(S).

Simulink Model of Pulse Code Modulation (PCM)

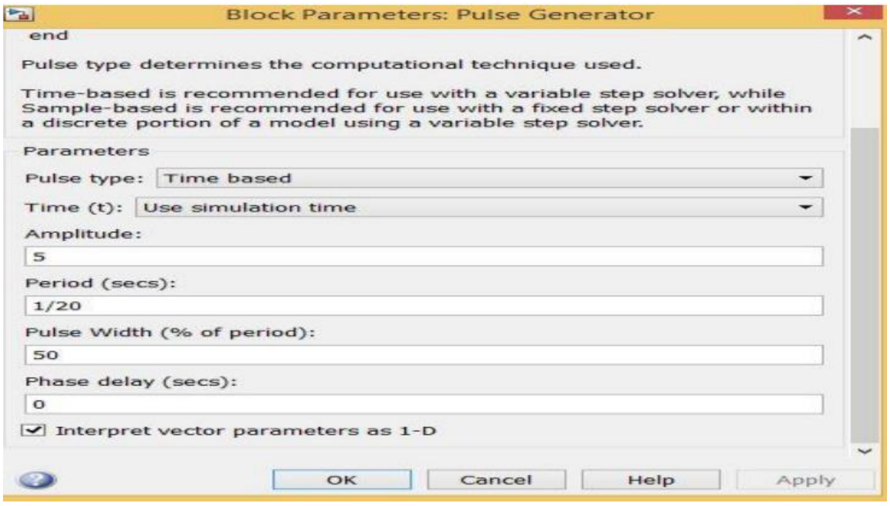


Block Parameters of the Simulink Model of Pulse Code Modulation (PCM)

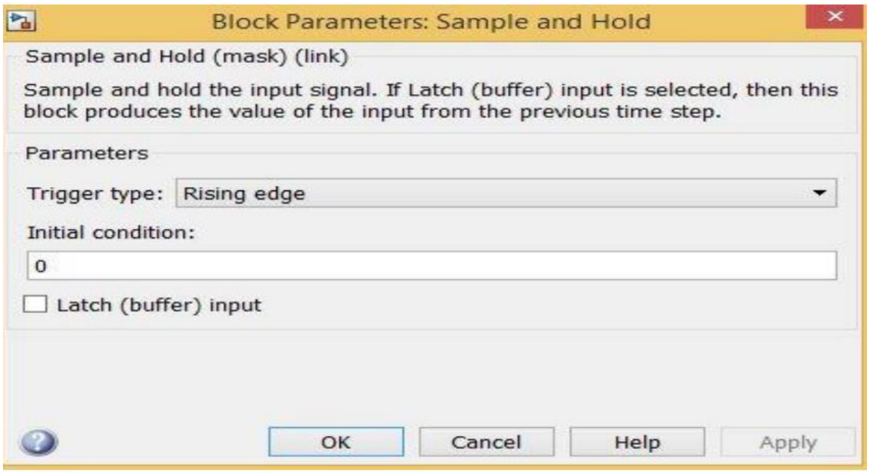
1. Sinusoidal Wave Generator



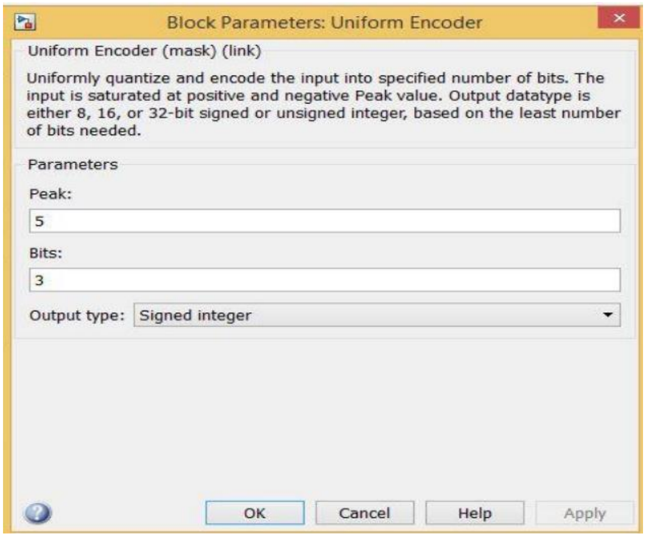
2. Pulse Generator



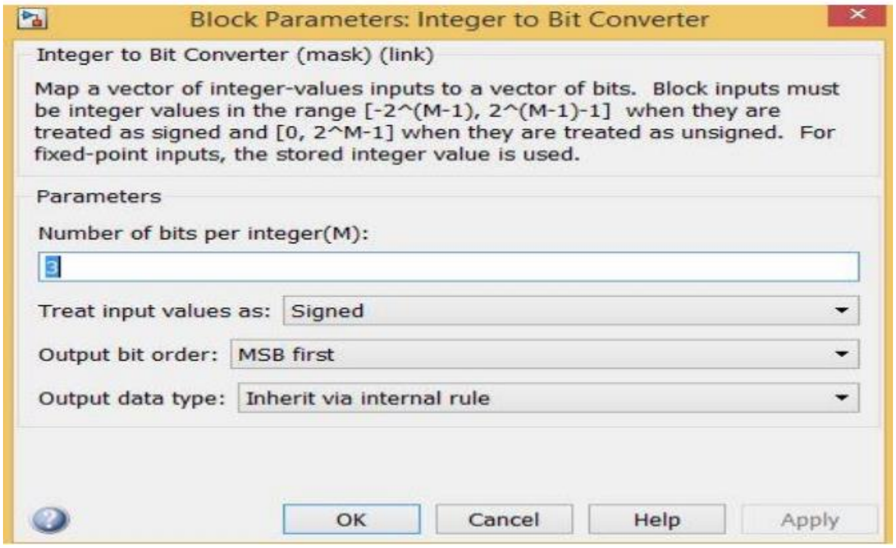
3. Sample & Hold



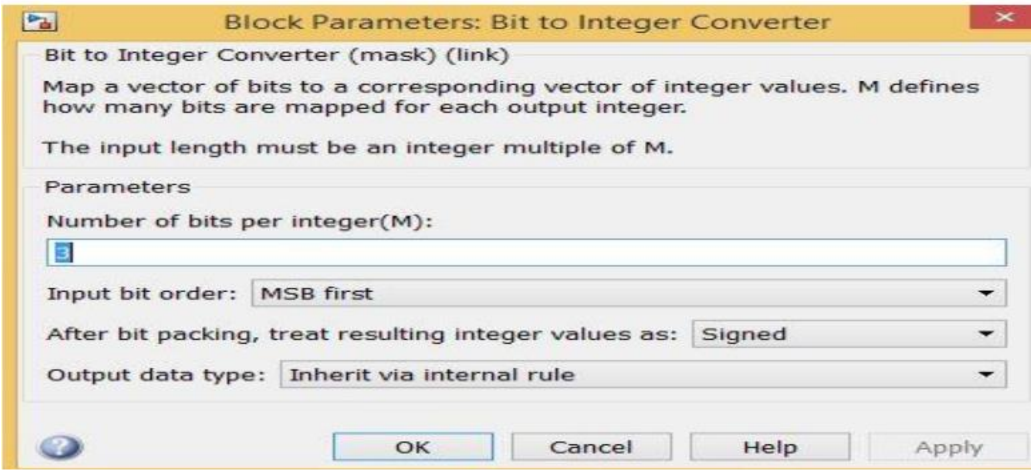
4. Uniform Encoder



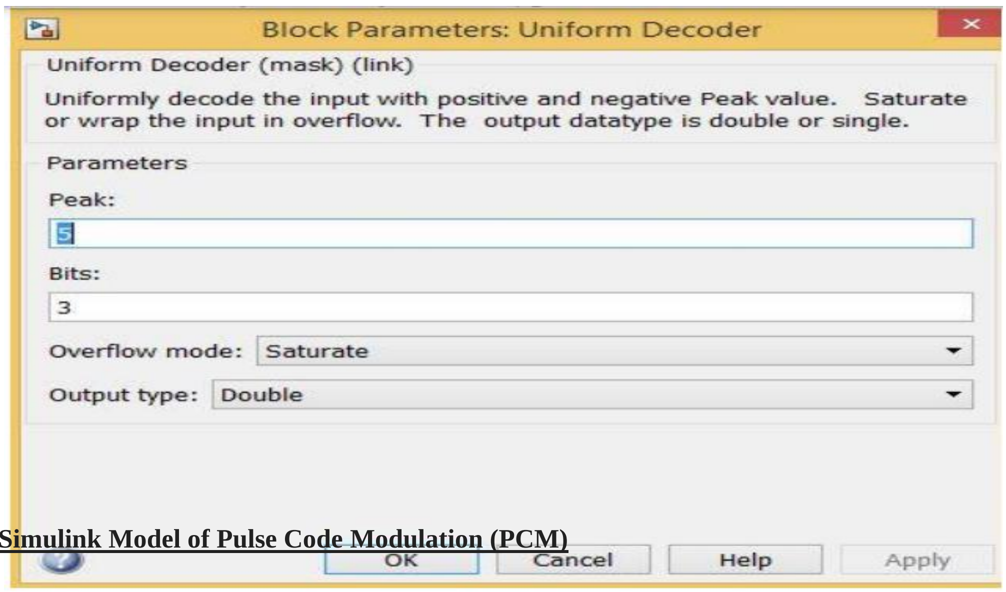
5. Integer To Bit Converter



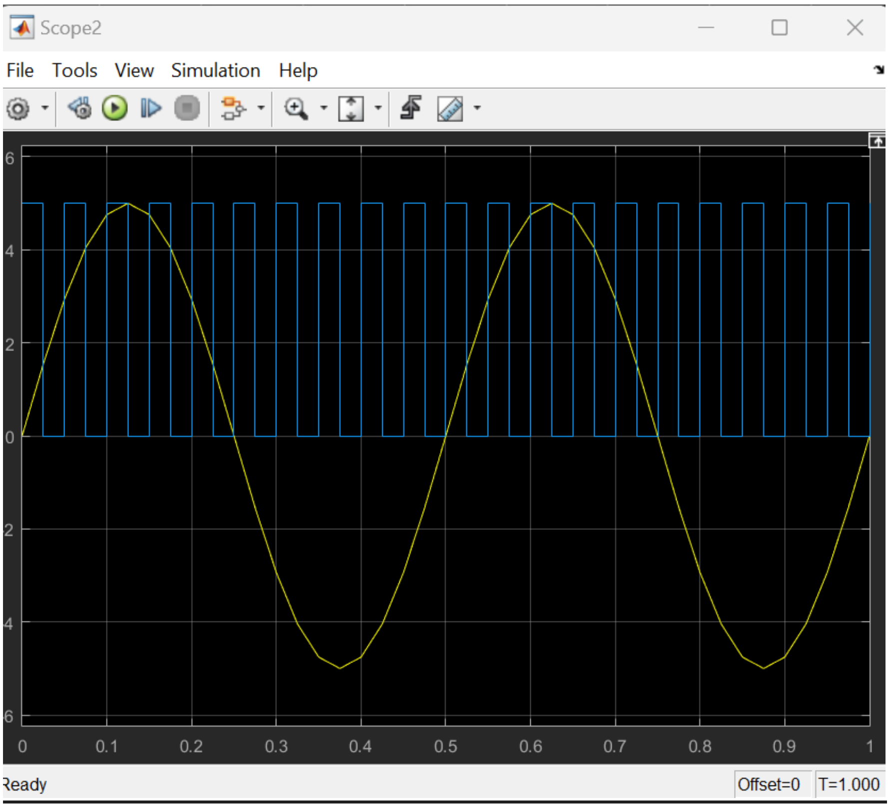
6. Bit To Integer Converter



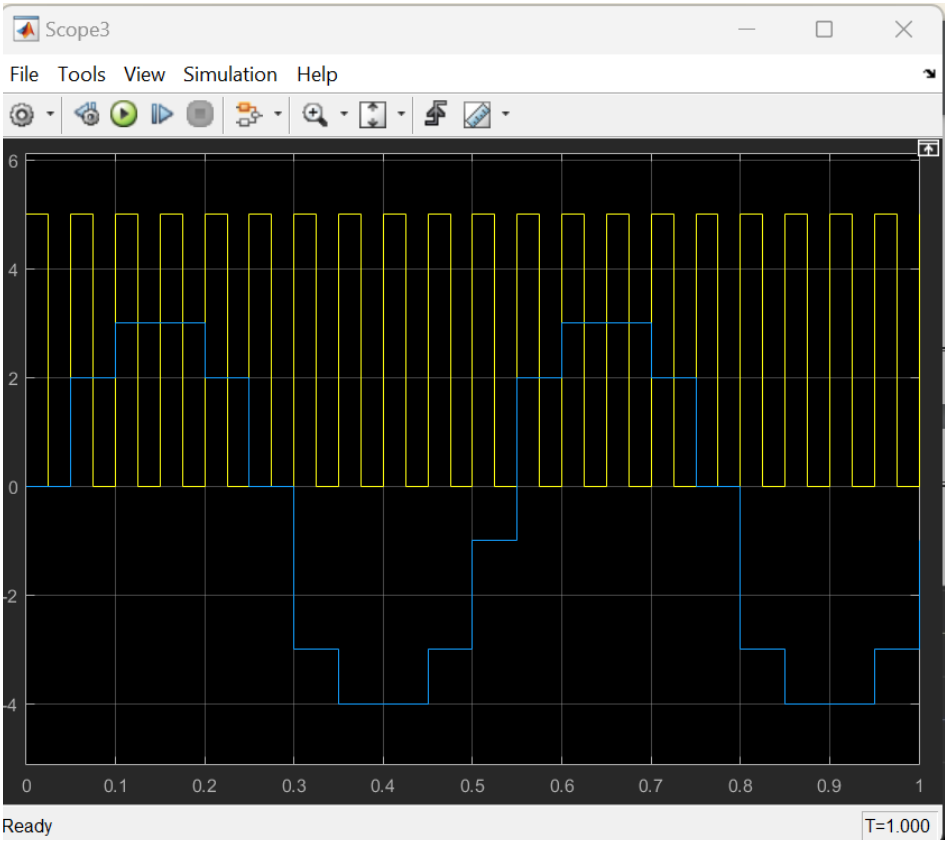
7. Uniform Decoder



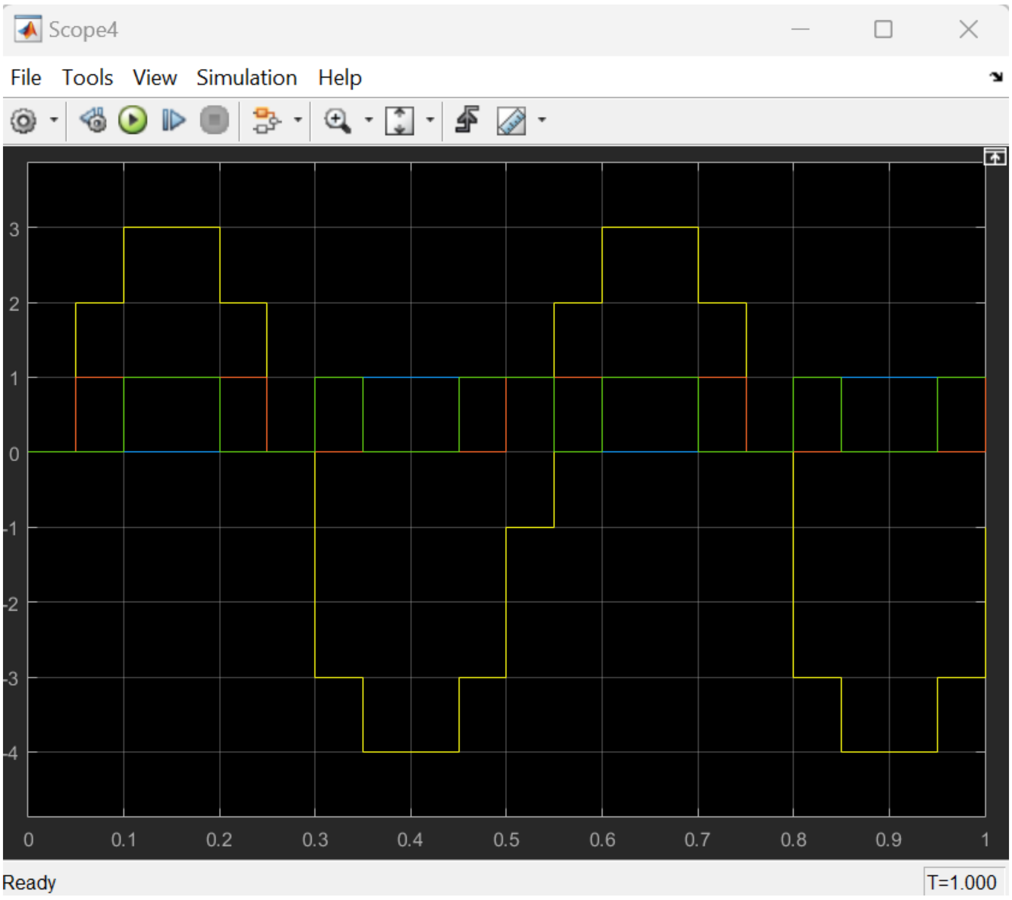
<u>Observations of the Simulink Model of Pulse Code Modulation (PCM)</u>



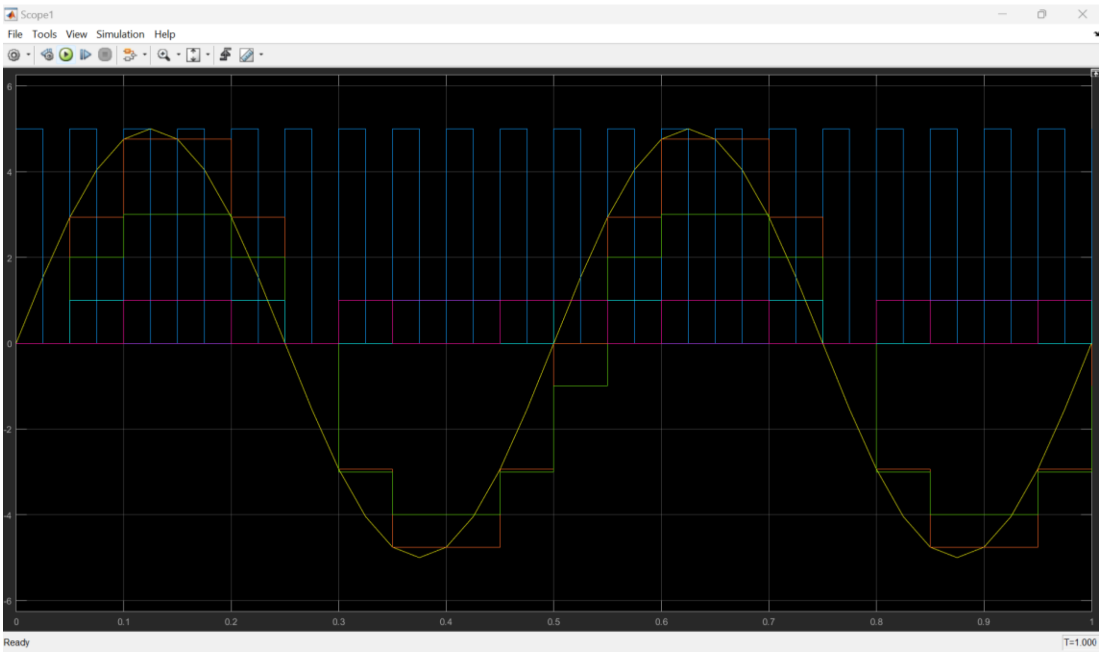
Scope 2 - Sine wave & Pulse generator output



Scope 3 - Pulse generator & Uniform Encoder Output



Scope 4 - Uniform Encoder & Integer to Bit Converter Output



Scope 1 - Sine wave, Pulse generator, Sample & hold, Uniform Encoder, Integer to Bit Converter output

<u>Result:</u>

The MATLAB SIMULINK of the PCM block diagram was studied and executed.

EXPT.4: SIMULATION OF LARGE-SCALE PATH LOSS - OKUMURA MODEL USING MATLAB

Aim:

To write a MATLAB code to calculate the mean path loss for d = 50 km, h_{te} = 100 m, h_{re} = 10m in a various environment. If the base station transmitter radiated an EIRP of 1 kW at a carrier frequency of 900 MHz Find EIRP (dBm) and the power at the receiver. (Gain at receiving antenna is unity). Find 1.Free Propagation path loss,(dB),2. G_{hte},(dB),3.G_{hre},(dB), 4. Lamda (λ),5. L_{50}(dB),6. Power at the receiver and Simulate the curve between transmitter antenna height (h_{te}) to mean path loss L_{50} (dB).

Software Used:

- MATLAB-Version 7.1

Theory:

One of the most widely used models for signal prediction. Operational frequency range from 150 MHz- 1920MHz. But it can be extended up to 3000MHz. Distances range from 1km-100km and antenna height range from 30-1000m. It is the simplest and best in terms of accuracy. Radio transmission in a mobile communication system take place over irregular terrain. To estimate the path losses consider the terrain profile of particular areas. Terrain profile vary from a simple curved earth profile to a highly mountain profile. The okumura model is used to predict path loss over irregular terrain. Outdoor propagation model is used to predict signal strength at a receiving point and Signal prediction in large urban macrocells. Vertical Omni directional antenna used in both base and mobile antenna.

Types of outdoor propagation models

- Longley – Rice model
- Durkin's model
- Okumura model
- Hata model
- PCS extension to Hata model
- Walfishch & Bertuni model
- Wideband PCS microcell model

Okumura Curve:

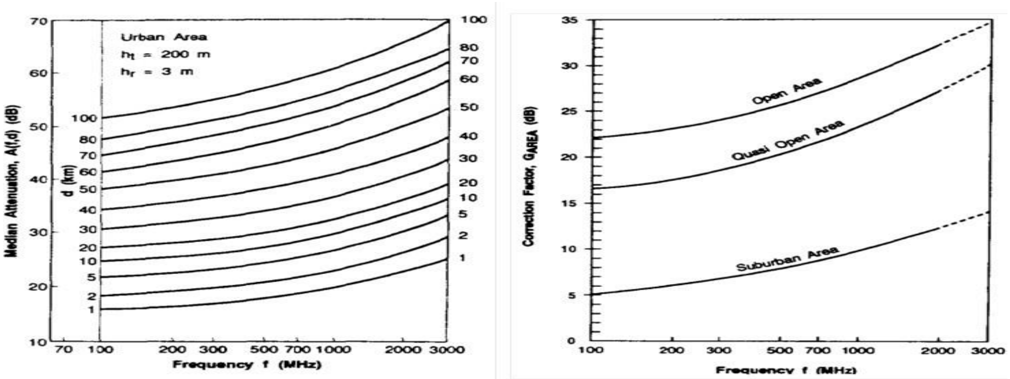


Figure 1:a) F Vs Median Attenuation b) F VS correction factor, GArea

Formula Used:

- Distance from the base station, d(km); **Range: 1km < d < 100km**
- Frequency, f(MHz); **Range:150MHz < f < 1920MHz**
- Base station antenna height ,h_{te}(m); **Range: 30m < h_{te} < 1000m**
- Free Space path Loss, $L_F = 10\, log_{10}\left[\frac{\lambda^2}{(4\pi d)^2}\right]$
- From the Okumura Curves, Find median attenuation relative to free space, (Amu)
- From the Okumura Curves, find gain due to the type of environment G_{area}
- Base station effective antenna height, (h_{te})
- Mobile antenna height, (h_{re})

- Mobile antenna height gain factor, $G_{hre} = 10\ log_{10}\left[\frac{h_{re}}{3}\right]$; **Range: $h_{re} \leq 3m$**
- Mobile antenna height gain factor, $G_{hre} = 20\ log_{10}\left[\frac{h_{re}}{3}\right]$; **Range:10m > h_{re} > 3m**
- Base station antenna height gain factor, $G_{hte} = 20\ log_{10}[\frac{h_{te}}{200}]$; **Range: 30m < h_{te} < 1000m**
- 50^{th} percentile(median) value of propagation path loss,L_{50}

  $L_{50} = L_F + Amu - G_{hte} - G_{hre} - G_{area}$
- Median received power, Pr(d) = EIRP(dBm) – L_{50}(dB) + G_r(dB)
- Gain of receiving antenna, G_r(dB)

Matlab Code:

```
clc; clear
all;close
all;
hte=30:1:100; % base station antenna height
hre=input('enter the receiver antenna height 3m<hre<10m: '); % mobile antenna height
d=input ('Enter the distance from base station 1Km<d<100km: '); % distance 30km
f=input ('Enter the frequency 150MHz<f<1920 MHz: ');
EIRP =input ('enter the EIRP value:');
Gr=input('enter receiver antenna gain: ');
Grdb=10*log10(Gr);
EIRPdBm=10*log10(EIRP/10^-3);
c=3*(10^8);
lamda=(c)/(f*10^6);
Lf=-10*log10((lamda^2)/((4*pi)^2*d^2)); % free space propagation loss
Amu=43; %median attenuation relative to free space (900MHz and 30km)
Garea=9; %gain due to the type of environment (Suburban area)
Ghte=20*log10(hte/200); %base station antenna height gain factor
if(hre>3)
Ghre=20*log10(hre/3);
else
Ghre=10*log10(hre/3);end
%propagation path loss
L50=Lf+Amu-Ghte-Ghre-Garea;
display('propagation path loss is: ');
% calculate the power
Prd= EIRPdBm-L50+Grdb;
disp(Lf);
disp(Ghte);
disp(Ghre);
disp(lamda);
disp(L50);
disp(Grdb);
disp(EIRPdBm);
disp(Prd);
plot(hte, L50,'LineWidth',1.5);
title('Okumura Model Analysis');
xlabel('Transmitter antenna Height (Km)');
ylabel('propagation path loss (db)at 50Km)');
grid on;
```

Result:

Input :

Enter the receiver antenna height 3m<hre<10m 10

Enter the distance from base station 1Km<d<100km 50000

Enter the frequency 150MHz<f<1920Mhz 900

Enter the receiver power (watts), EIRP 1000

Enter the gain of receiver antenna, (Gr) 1

Output:

1.Free Propagation path loss,(dB) : 125.5060
2. G_{hte},(dB) : -6.0206
3.G_{hre},(dB) : 10.4576
4. Lamda (λ),(m) : 0.3333
5. Gr(db) : 0
6. EIRP(dBm) : 60
7. L_{50}(dB) : 155.0690
8. Power at the receiver : -95.069

Graph:

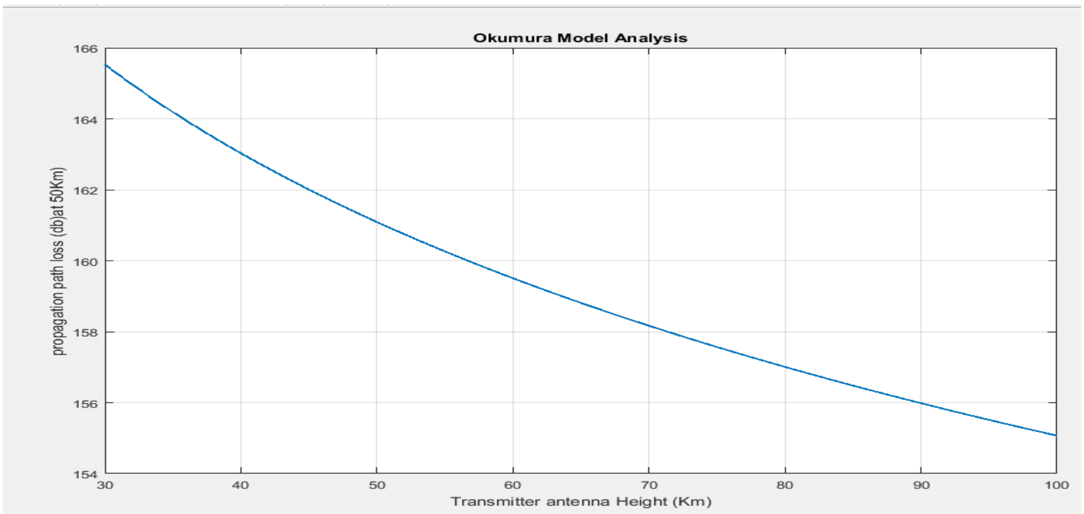


Figure 2: Transmitter antenna height (Km) vs propagation path loss(dB)

Result:

The large-scale OKUMURA model are studied and conclusions are drawn on the basis of MATLABplots as path-loss increases with increase in frequency and decreases with transmitter and receiver antenna heights.

EXPT.5: SIMULATION OF LARGE-SCALE PATH LOSS - HATA MODEL USING MATLAB

Aim:

To write a MATLAB code for determining the propagation path loss for a radio signal at 800MHz; with a transmitting antenna height of 30m and receiving antenna height of 2m over a distance of 10 Km in the mobile environment using HATA propagation path loss model.Plot the graph between entire range of frequency (from 150 MHz to 1500 MHz) to Mean Path Loss L_{50} (dB)

Case 1: Small or medium city → 1. Urban
2. Suburban
3.Rural

Case 2: Large City →1. Urban
2. Suburban
3. Rural

Software Used:

- MATLAB version 7

Theory:

It is an empirical formulation of graphical path loss data provided by Okumura and is valid from 150MHz-1500MHz. Hata established empirical mathematical relationships to describe the graphical information given by Okumura. Hata's formulation is limited to certain ranges of input parameters and is applicable only over quasi-smooth terrain. Hata model considerably enhanced the practical value of the Okumura method, although Hata's formulations do not include any of the path specific corrections available in the original model.The Hata model was derived as a numerical fit to the propagation curves published by Okumura. As such, the model is somewhat specific to Japan's propagation environment. In addition, terms like "small city", "large city", "suburban area" are not clearly defined and can be interpreted differently by people with different backgrounds. Therefore, in practice, the area adjustment factor should be obtained from the measurement data in the process of propagation model optimization. In the Okumura's original model, the effective antenna height of the transmitter is calculated as the height of the TX antenna above the average terrain. Measurements have shown several disadvantages to that approach for effective antenna calculation. In particular, Hata's model tends to average over extreme variations of the signal level due to sudden changes in terrain elevation. To circumvent the problem, some prediction tools examine alternative methods for calculation of the effective antenna height.

Formula Used:

- Distance from the base station, d(km);
- cf =correction factor for effective mobile antenna height which is a function of the size of the coverage area.
- Frequency, f(MHz); **Range:150MHz < f < 1500MHz**
- Base station antenna height ,h_{te}(m); **Range: 30m < h_{te} < 200m**
- Mobile antenna height, (h_{re})); **Range: 1m < h_{re} < 10m**
- Median path loss in urban areas, L_{50}

$$L_{50} = 69.55 + 26.16\, log_{10}[f] - 13.82 log_{10}[h_{te}] - cf + (44.9 - 6.55 log_{10}[h_{te}])\, log_{10}[d] ;$$

- Medium sized city mobile antenna correction factor

$$cf = (1.1 log_{10}[f] - 0.7) h_{re} - (1.56 log_{10}[f] - 0.8) ; dB$$

- Large sized city mobile antenna correction factor

$$cf = 8.29(log_{10}[1.5 * h_{re}])^2 - 1.1; dB \quad f \leq 300MHz$$

- Large sized city mobile antenna correction factor

$$cf = 3.2(log_{10}[11.75 * h_{re}])^2 - 4.97; dB \quad f > 300MHz$$

- Median path loss in suburban areas, L_{50}

$$L_{50} = L_{50\,(urban)} - 2\left(log_{10}\frac{f}{28}\right)^2 - 5.4;$$

- Median path loss in open rural areas, L_{50}

$$L_{50} = L_{50\,(urban)} - 4.78(log_{10} f)^2 + 18.33 log_{10} f - 40.94;$$

MATLAB Code:

```
clc;
```

```
close all;
t = input('Enter type of city (1 - small or medium city, 2 - large city): ');
u = input('Enter type of city (1 - urban, 2 - suburban, 3 - rural): ');
hte = input('Enter height of transmitting antenna (30 to 200m): ');
hre = input('Enter height of receiving antenna (1 to 10m): ');
f = input('Enter frequency in MHz from 150 to 1500: ');
d = input('Distance from the base station, d(km): ');
display('The median path loss for your given data L50 in dB is:');
% Compute correction factor based on city type and frequency
if t == 1
   cf = (1.1 * log10(f) - 0.7) * hre - (1.566 * log10(f) - 0.8);
elseif f <= 300
   cf = 8.29 * (log10(1.54 * hre))^2 - 1.1;
else
   cf = 3.2 * (log10(11.75 * hre))^2 - 4.97;
end

% Calculate the median path loss L50
L50 = 69.55 + 26.16 * log10(f) - 13.82 * log10(hte) - cf + (44.9 - 6.55 * log10(hte)) * log10(d);
if u == 2
   L50 = L50 - (2 * log10(f / 28))^2 - 5.4;
elseif u == 3
   L50 = L50 - (4.78 * log10(f))^2 + 18.33 * log10(f) - 40.94;
end

display(L50);
display(cf);

figure; % Prepare for plotting
hold on; % Keep all plots on the same figure

% Store the range of frequencies and path loss values
frequencies = 150:2:1500;
L50_values = zeros(size(frequencies)); % Pre-allocate for efficiency

% Loop through the range of frequencies and calculate L50 for each
for idx = 1:length(frequencies)
   f = frequencies(idx);

   if t == 1
      cf = (1.1 * log10(f) - 0.7) * hre - (1.566 * log10(f) - 0.8);
   elseif f <= 300
      cf = 8.29 * (log10(1.54 * hre))^2 - 1.1;
   else
      cf = 3.2 * (log10(11.75 * hre))^2 - 4.97;
   end

   L50 = 69.55 + 26.16 * log10(f) - 13.82 * log10(hte) - cf + (44.9 - 6.55 * log10(hte)) * log10(d);

   if u == 2
      L50 = L50 - (2 * log10(f / 28))^2 - 5.4;
   elseif u == 3
      L50 = L50 - (4.78 * log10(f))^2 + 18.33 * log10(f) - 40.94;
   end

   L50_values(idx) = L50; % Store L50 for this frequency
end

% Plot the results
plot(frequencies, L50_values, 'LineWidth', 2);
title('The plot for the entire range of frequencies from 150 MHz to 1500 MHz');
xlabel('Frequency (in MHz)');
ylabel('Median path loss in dB');
```

grid on;
hold off;

Input:

Enter type of city (1 - small or medium city, 2 - large city)-- : 1 or 2
Enter type of city (1 - urban , 2 - suburban, 3-rural)-- : 1 or 2 or 3
Enter height of transmitting antenna(30 to 200m)-- 30
Enter height of receiving antenna(1 to 10m)-- 2
Enter freuency in MHZ from 150 to 1500-- 800
Distance from the base station, d(km))-- 10

Output:

- **Small or medium city – cf = 1.2406**
  - **Urban**
    - L50 = 159.0653 dB
  - **Suburban**
    - L50 = 149.4258dB
  - **Rural**
    - L50 = 131.0534dB

- **Large city – cf = 1.045**
  - **Urban**
    - L50 = 159.2604dB
  - **Suburban**
    - L50 = 149.6210dB
  - **Rural**
    - L50 = 131.2486dB

Graph:

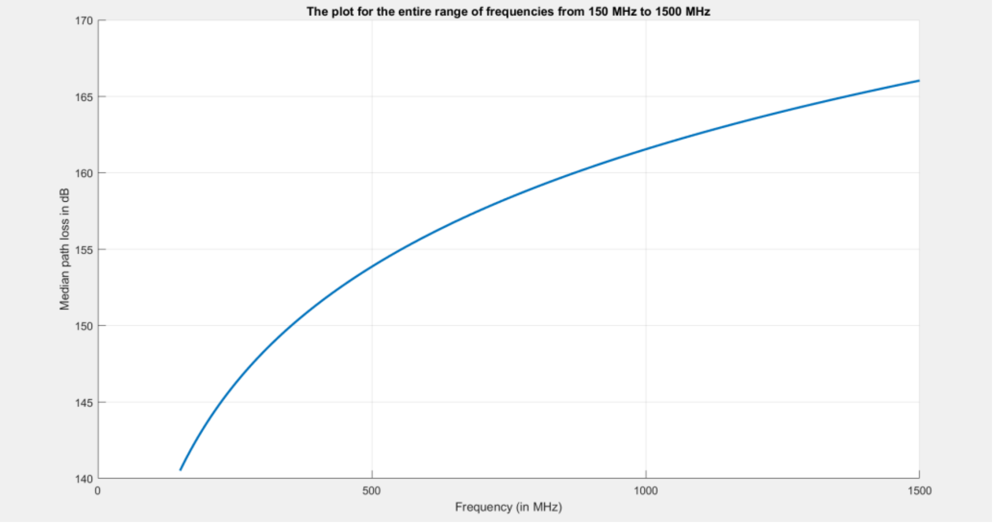


Figure 1: Frequency (MHz) vs Propagation path loss (dB)

Result:

The large scale HATA model are studied and conclusions are drawn on the basis of MATLAB plots as path-loss increases with increase in frequency and decreases with transmitter and receiver antenna heights.

EXPT.6: SIMULATION OF LARGE-SCALE PATH LOSS USING LOG SHADOWING NORMAL MODEL USING MATLAB

Aim:

To write a MATLAB code for determine received power in free space for WCDMA frequency, Distance from the base station (d) = 100m,Trasmitter antenna gain (G_t) = 1dB, Receiver antenna gain (G_r) = 1dB with Transmitter power (P_t)= 0.001watts and simulate received power P_{r0}(dB) of various environment like(1 - Free Space, 2 - Urban area cellular radio, 3 - Shadowed urban cellular radio, 4 - In building line-of-sight, 5 - Obstructed in factories, 6 - Obstructed in building).

Software Used:

- MATLAB version 7

Theory:

The random shadowing effects which occur over a large number of measurement locations which have the same transmitter receiver separation but have different clutters on the propagation path. The measured signal level has a Gaussian (normal) distribution.

Environment	Path Loss Exponent, n
Free Space	2
Urban area cellular radio	2.7 - 3.5
Shadowed urban cellular radio	3 - 5
In building LOS	1.6 - 1.8
Obstructed in building	4 - 6
Obstructed in factories	2 - 3

Formula Used:

- Distance from the base station, d(m); **Range:100m < d < 1000m**
- Frequency, f(Hz); WCDMA **= 2100MHz, LTE= 2000MHz**
- Base station antenna height, hte(m); Range**: 30m < h_{te} < 200m**
- Mobile antenna height, (h_{re}); **Range: 1m < h_{re} < 10m**
- Transmitting antenna gain (G_t ,dB)
- Receiver antenna gain(G_r ,dB)
- Transmitter power, **P_t (watts)**
- System loss factor, (L); **Range: L >= 1**
- Zero mean Gaussian distributed random variable in dB with standard deviation σ, (X_σ)
- Received power in free space,$\mathbf{P_{r0}} = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L}$
- Received power in free space, **P_{r0} (dB) = P_t (dBm) + G_t (dB) + G_r (dB) – 20 $\log_{10}\left(\frac{4\pi d0}{\lambda}\right)$**
- Received power in **P_r (d) [dBm] = P_t (dBm) – PL(d) [dB]**
- **PL(d) [dB] = $\overline{PL}$(d) + X_σ**
- **$\overline{PL}(d) = \overline{PL}(d_0) + 10\, n \log\left(\frac{d}{d_0}\right)$**
- P_r (d) [dBm] = P_t (dBm) – $\overline{PL}(d_0)$ - 10 n $\log\left(\frac{d}{d_0}\right)$ + X_σ (Consider X_σ is positive because noise in additive nature)

MATLAB Code:

```
clc;
clear all;
close all;
C = 3e8; % Speed of light in meters per second
WCDMACellular = 2100 * 1e6; % Frequency in Hz

TXAntennaGain = 1; % Transmit antenna gain in dB
RXAntennaGain = 1; % Receive antenna gain in dB
PTx = 1e-3; % Transmit power in watts
PathLossExponent = 2; % Line of sight default
PTxdBm = 10 * log10(PTx * 1000); % Convert power to dBm

% Ask user for the type of environment
e = input('Enter type of Environment (1 - Free Space, 2 - Urban area cellular radio, 3 - Shadowed urban
cellular radio, 4 - In building line-of-sight, 5 - Obstructed in factories, 6 - Obstructed in building): ');

% Ask user for distance
d = input('Enter Distance in meter from 100 to 2000: ');

% Set PathLossExponent based on environment type
if e == 1
   PathLossExponent = 2;
elseif e == 2
   PathLossExponent = 3.1;
elseif e == 3
   PathLossExponent = 4;
elseif e == 4
   PathLossExponent = 1.7;
elseif e == 5
   PathLossExponent = 2.5;
else
   PathLossExponent = 5;
end

Wavelength = C / WCDMACellular; % Calculate wavelength
d0 = 1; % Reference distance in meters

% Calculate initial received power at reference distance d0
Pr0 = PTxdBm + TXAntennaGain + RXAntennaGain - (10 * PathLossExponent * log10(4 * pi /
Wavelength));

% Display the received power at reference distance
disp(['The Received Power for your given data is Pr0 in dB: ', num2str(Pr0)]);

% Prepare for plotting
figure;
hold on;

% Plotting for entire range of distances from 100m to 2000m
h = waitbar(0, 'Plotting the Received Power for the entire range of distances, please wait...');

rstate = randn('state');
```

```
randn('state', d); % Random number generator state for consistency

% Store results for each environment type
distances = 100:2:2000;
Pr1_values = zeros(size(distances));
Pr2_values = zeros(size(distances));
Pr3_values = zeros(size(distances));
Pr4_values = zeros(size(distances));
Pr5_values = zeros(size(distances));

% Loop over distances and calculate received power for each environment type
for i = 1:length(distances)
   d = distances(i);
   GaussRandom = randn * 0.1; % Random Gaussian noise

   % Calculate received power for each environment type
   Pr1_values(i) = Pr0 - (10 * 2 * log10(d / d0)) + GaussRandom;
   Pr2_values(i) = Pr0 - (10 * 3.1 * log10(d / d0)) + GaussRandom;
   Pr3_values(i) = Pr0 - (10 * 4 * log10(d / d0)) + GaussRandom;
   Pr4_values(i) = Pr0 - (10 * 1.7 * log10(d / d0)) + GaussRandom;
   Pr5_values(i) = Pr0 - (10 * 2.5 * log10(d / d0)) + GaussRandom;

   % Update waitbar
   waitbar(i / length(distances), h);
end

% Plot the results for all environment types
plot(distances, Pr1_values, 'g', 'DisplayName', 'Free Space (2)');
plot(distances, Pr2_values, 'k', 'DisplayName', 'Urban Area (3.1)');
plot(distances, Pr3_values, 'r', 'DisplayName', 'Shadowed Urban (4)');
plot(distances, Pr4_values, 'b', 'DisplayName', 'In Building LOS (1.7)');
plot(distances, Pr5_values, 'c', 'DisplayName', 'In Factory (2.5)');

% Add title and labels
title('Received Power for Various Environments over Distance (100 to 2000 meters)');
xlabel('Distance (in meters)');
ylabel('Received Power (in dBm)');

% Show legend
legend('show', 'Location', 'southwest');

% Close waitbar
close(h);
```

Result :

Example 1:

Input :

Enter d	100
Enter gt	1
Enter pt	10^-3
Enter gr	1

Output:

ptdbm =	0
pro =	-36.8845
xsig =	0.0909

1.freespace-2.urban-3.shadow-4.los-5.obstructedinbuilding-6.obstructedinfactory 1

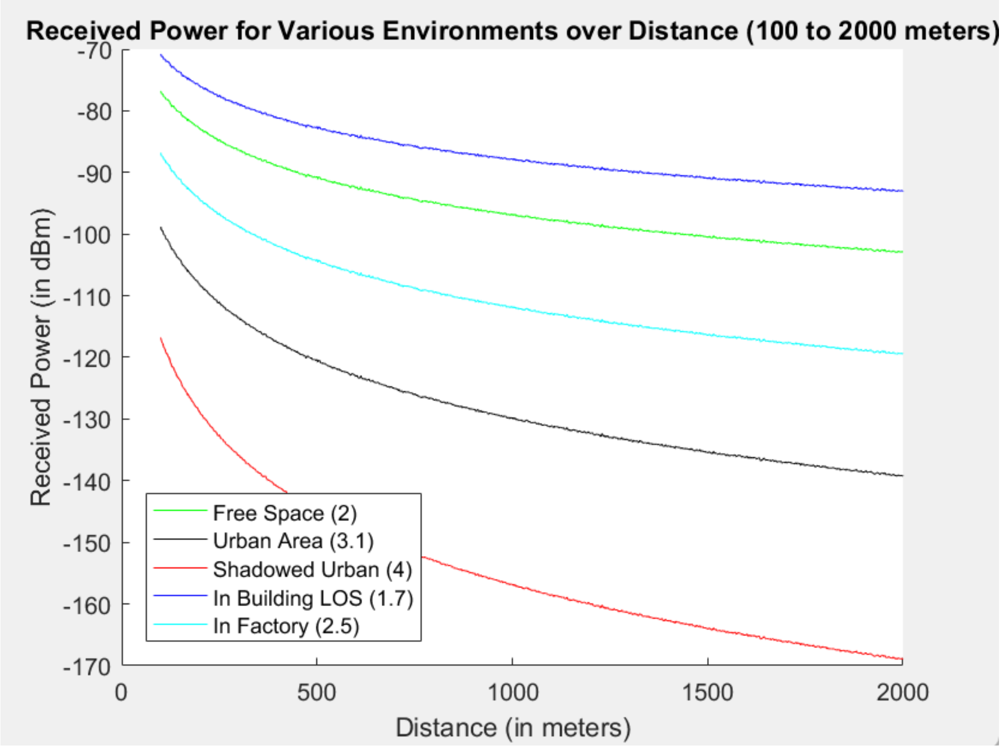


Figure 1: Distance (m) vs Received power (dBm)

Result:

The large scale Log normal model are studied and conclusions are drawn on the basis of MATLAB plots as path-loss increases with increase in frequency and decreases with transmitter and receiver antenna heights.

Introduction to Scientech 2115, CDMA Techniques

Scientech 2115, CDMA Techniques comprises of following major blocks:

- Audio Signal Generator (0- 3.4 KHz)
- Binary Data Generator
- PN Sequence Generator
- Direct Sequence spread spectrum Generator and receiver
- BPSK Modulator and Demodulator
- Pulse Width Modulator and Demodulator

Features:

- Self contained and easy to use
- Functional blocks indicated on board mimic
- Direct sequence spread spectrum (DSSS) generator and decoder
- Analog Modulators:
  Binary Phase Shift Keying (BPSK) Modulator
  Pulse Width Modulator
- Analog Demodulators:
  Binary Phase Shift Keying (BPSK) Demodulator
  Pulse Width Demodulator

Technical Specifications:

- Power supply requirement: 230VAC, 50Hz.
- In built DC regulated Power Supply.
- On board Digital Data signal generator to generate any binary input.
  -Word length: 8 bit
  -Data Rate: 15 K bits/s.
  -Data format NRZ (Non Return to Zero)
- On board Pseudo Random Bit Signal generator to generate pseudo random bit sequence signal.
  -Bit length: 8 bits per Data bit
- On board analog signal generator variable up to 3.4 KHz.
- Carrier generator: 1.44MHz.

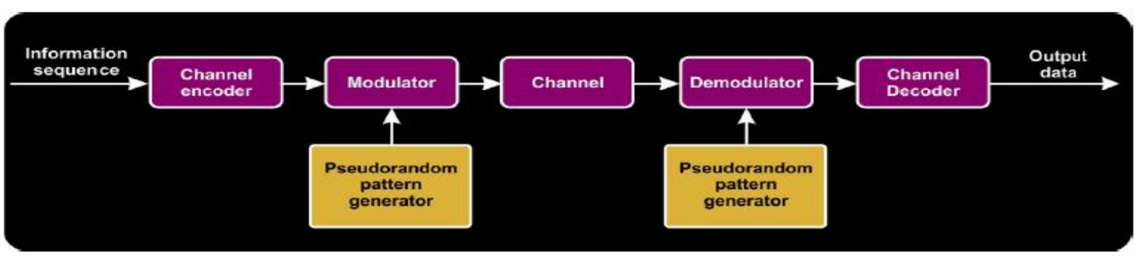
CDMA Features:

- Narrowband message signal multiplied by wideband spreading signal or pseudo noise code
- Each user has his own pseudonoise (PN) code
- Soft capacity limit: system performance degrades for all users as number of users increases
- Cell frequency reuse: no frequency planning needed
- Soft handoff increases capacity
- Near-far problem
- Interference limited: power control is required
- Wide bandwidth induces diversity: rake receiver is used

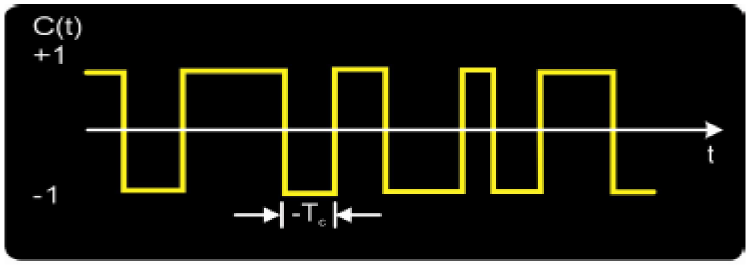
- Extended battery life because of effective power control

Spread-Spectrum Communication Systems:

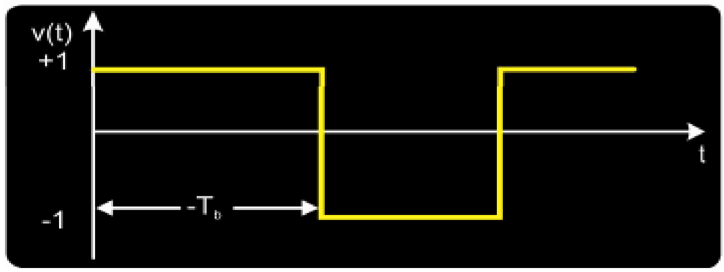
In our treatment of signal design for digital communication over an AWGN channel, the major objective has been the efficient utilization of transmitter power and channel bandwidth. Channel coding allows us to reduce the transmitter power by increasing the transmitted signal bandwidth through code redundancy and, thus, to trade off transmitter power with channel bandwidth. This is the basic methodology for the design of digital communication systems for AWGN channels. In practice, one encounters other factors that influence the design of an efficient digital communication system. For example, in multiple-access communication when two or more transmitters use the same common channel to transmit information, the interference created by the users of the channel limits the performance achieved by the system. The system designer must take into account the existence of such interference in the design of a reliable digital communication system. Even in this complex design problem, the basic system design parameters are transmitter power and channel bandwidth. To overcome the problems of intentional or unintentional interference, we may further increase the bandwidth of the transmitted signal, as described below, so that the bandwidth expansion factor $Be = W/R$ is much greater than unity. This is one characteristic of a *spread-spectrum signal*. A second important characteristic is that the information signal at the modulator is spread in bandwidth by means of a code that is independent of the information sequence. This code has the property of being *pseudorandom*; i.e., it appears to be random to receivers other than the intended receiver that uses the knowledge of the code to demodulate the signal. It is this second characteristic property that distinguishes a spread-spectrum communication system from the conventional communication system that expands the transmitted signal bandwidth by means of channel code redundancy. However, we should emphasize that channel coding is an important element in the design of an efficient spread-spectrum communication system. Spread-spectrum signals for digital communications were originally developed and used for military communications either (1) to provide resistance to jamming (antijam protection), or (2) to hide the signal by transmitting it at low power and, thus, making it difficult for an unintended listener to detect its presence in noise (low probability of intercept). However, spread-spectrum signals are now used to provide reliable communications in a variety of civilian applications, including digital cellular communications and interoffice communications.



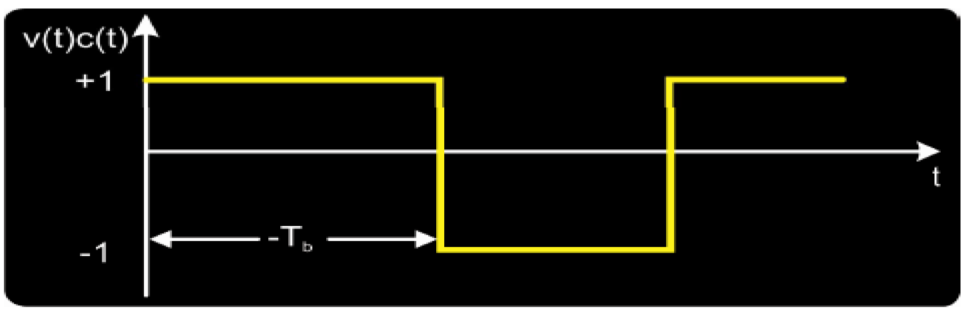
Model of spread-spectrum digital communications system



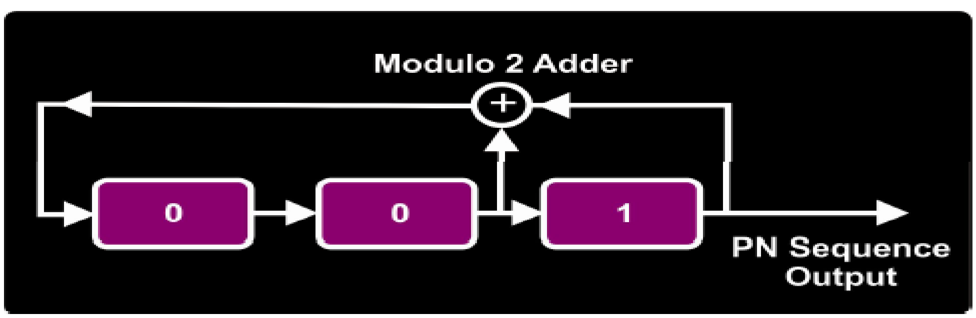
(a) PN signal



(b) Data signal



(c) Product signal



PN Sequence Generator Figure 9

EXPT.7: STUDY OF DS-SS MODULATION/DEMODULATION PROCESS (TRAINER KIT BASED)

Aim:

Study of DS-SS modulation/Demodulation Process (trainer kit based)

Tools Required:

- Scientech 2115 CDMA Techniques TechBook
- Power Supply for Scientech 2115 with Mains Cord
- Oscilloscope- Scientech with connecting probe
- Connecting patch cords

Theory:

Scientech 2115 CDMA Techniques- Brief Description:

Scientech 2115 comprises of following functional blocks:

- **Audio Signal Generator:**

This generator generates a sinusoidal output of variable frequency range of 0 to 3.4 KHz. Both amplitude and frequency can be changed through pots given on the board.

- **Binary Data Generator:**

This binary data generator generates a serial binary data with a rate of 15kbits per second. The data pattern can be changed as per your choice using toggle switches given on the board. The unique pattern length is of 8 bits after which this sequence repeats itself.

- **PN Sequence Generator:**

This generator generates a Pseudo Random sequence at a rate of 120 K chips per second. The chip pattern can be changed by changing the feedback tap positions.

- **Carrier Generator:**

This carrier generator generates a sinusoidal carrier of 1.44MHz frequency.

- **Direct Sequence Spread Spectrum Generator:**

This block spread the binary data or any input data using PN code by Ex-ORing them together.

- **BPSK Modulator:**

BPSK modulator modulates the chipped data for making it suitable for transmission. This modulator accepts only bipolar signals as inputs. So a Unipolar to bipolar converter is also provided on the board

- **BPSK Demodulator:**

The demodulation process accompanies carrier recovery, switching and filtering processes. For proper demodulation, phase adjust is also provided on the board.

- **Comparator:**

Comparator shape up filter output of BPSK demodulator. The threshold bias is adjustable.

- **Data Recovery block:**

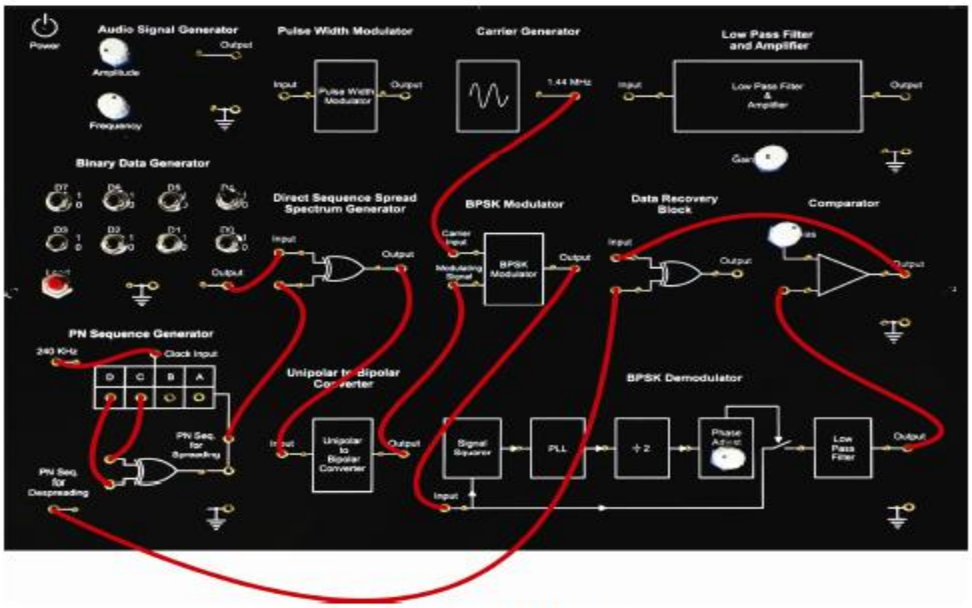
Data recovery block Ex-or the received chipped data with the "synchronized PN Sequence for despreading" to recover original data.

- **Pulse Width Modulator:**

This modulator is provided for converting audio signal into pulse signal, so that we can transmit and recover audio signal using direct sequence spread Spectrum Technique.

Connection Diagram:

Refer to the following diagram to configure experimental setup for the present experiment:



Setup for study of CDMA –DS-SS

Figure 1: Setup for study of CDMA - DSSS

Procedure:

- Connect the 'Power supply' to TechBook and touch the 'Power symbol' for few seconds to switch it on. 'Power symbol' is given at left side top position of mimic near the 'Power Connector'.
- Refer the above Figure while making connections.
- Binary Data Generator block has 8 toggle switches (D7to D0). Select any 8 bit data pattern by selecting logic '0' or logic '1' for each switch and load it by pressing 'Load' switch. Observe the data output on oscilloscope. Figure 4.2 shows the data output for 11000100 data sequence.
- PN Sequence Generator block generates a 15 bit data sequence. Connect 240 KHz clock signal on board to the clock input of this block. Connect any two of the four taps viz. A, B, C or D to the inputs of EX-OR gate of PN Sequence generator. Observe the PN sequence on oscilloscope. Figure 4.3 shows the PN sequence for A & D taps. Different PN sequence patterns can be generated by connecting the taps with different combinations.
- Direct Sequence Spread Spectrum block is an 'Ex-OR gate' with two inputs. Connect Binary Data Generator output to one of the input and 'PN sequence for Spreading' data output to other input of this gate. Observe the DSSS output (chipped data) on oscilloscope. (Figure 4.4)

- Connect the output of DSSS block to the input of Unipolar to Bipolar Converter.Observe the Bipolar output on Oscilloscope. (Figure 4.5)
- Connect the bipolar data output to the ‘Modulating Signal’ input of ‘BPSK Modulator’.
- Connect sinusoidal carrier from the ‘Carrier Generator’ output to the ‘Carrier
- Input’ of ‘BPSK Modulator’.
- Observe the BPSK Output on Oscilloscope. (Figure 4.6)
- Now connect the output of BPSK Modulator to the input of BPSK Demodulator.
- Observe the output of Phase adjust block on oscilloscope in dual channel with DSSS data, and adjust the phase using pot to match the detected output with input data level. (Figure 4.7)
- Observe the output of Low Pass filter on oscilloscope. (Figure 4.8)
- Connect the output of low-pass filter to the input of Comparator to receive chipped data.
- Connect the output of Comparator to one the inputs of Data Recovery Block.
- Connect ‘PN Sequence for Despreading’ output of PN sequence generator block to the other input of data recovery gate.
- **Note:** There are two outputs of PN Sequence Generator shown on the board. One of the outputs is for spreading the binary data signal and the other one is for dispreading the coded signal to recover back the original data(when BPSK modulation is used for RF modulation of Spreaded signal).
- Observe the output of this data recovery block on oscilloscope and set the bias level of Comparator to match the output data with input binary data. This recovered data is same as input binary data. (Figure 4.9)
- **Note:** if you don’t get the proper triggered data at the output of Data recovery block, then slightly adjust the Phase adjust pot and Bias level pot to make triggered. Again, if the recovered output is an inverted replica of input signal, please follow the step 11 and verify that the phase setting has been done according to match the output with the input data level properly.
- The same process can be repeated for different combination of tapes of shift registers (A, B, C or D) with different patterns of PN Sequences as well as the different 8 bit binary data patterns. With each combination we will be quit able to recover the original if we use the same PN sequence for de-spreading.


Figure 4.2 Binary Data 8 bit


Figure 4.3 PN Sequence 15 bit


Figure 4.4 DSSS Output

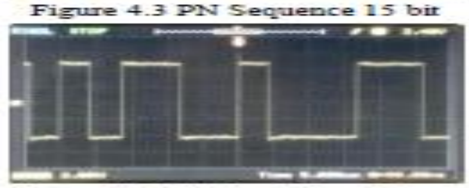


Figure 4.5 Bipolar Chipped Data


Figure 4.6 BPSK Output


Figure 4.7 Phase Adjusted Data


Figure 4.8 LPF Output


Figure 4.9 Recovered Data

Figure 2: Output of CDMA - DSSS

Result:

Studied of DS-SS modulation/Demodulation Process

EXPT. 7 A: STUDY OF CDMA (DS-SS) TECHNIQUE USING ANALOG SIGNAL AS AN INPUT SIGNAL (TRAINER KIT BASED)

Aim:

Study of DSSS Modulation/Demodulation using an analog signal as an input

Tools Required:

- Scientech 2115 CDMA Techniques TechBook
- Power Supply for Scientech 2115 with Mains Cord
- Oscilloscope- Scientech with connecting probe
- Connecting patch cords

Connection Diagram:

Refer to the following figure for configuring the experimental setup:

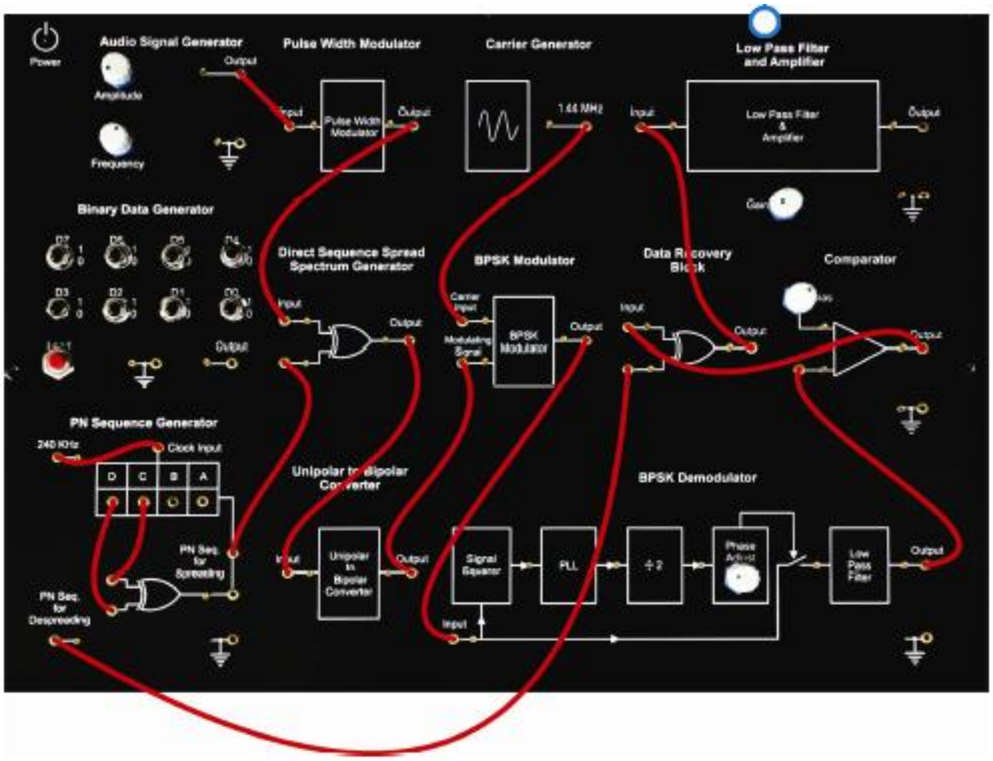
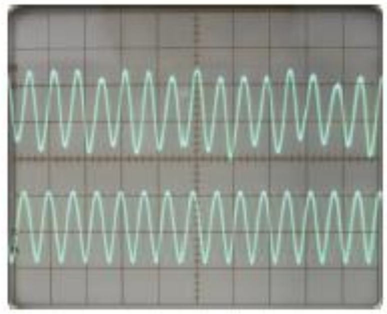


Figure 1

Procedure:

- Connect the ‘Power supply’ to TechBook and touch the ‘Power symbol’ for few seconds to switch it on. ‘Power symbol’ is given at left side top position of mimic near the ‘Power Connector’.
- Refer the Figure 1 given above while making connections.
- Follow the procedure of experiment 7 from step 3 to step 18 and make the setup ready to recover the binary data successfully.
- Once the data recovered successfully, disconnect the binary data generator output from the input of DSSS generator input.
- Now connect the audio signal to the input of Pulse Width Modulator block and connect output of this Modulator to the input of DSSS generator block.
- Rest of the connections will remain as it is.
- Now connect the output of Data Recovery Block to the input of Low pass Filter & Amplifier Block. Observe the output of this block and if required adjust the Phase adjust pot and Bias pot of Comparator slightly to get the proper sine wave. Set the gain of the amplifier to remove any nonlinearity errors. If still output is not proper then change amplitude and frequency of the input audio signal and adjust the gain of the output amplifier to remove distortions.
- **Note:** The shape of the received audio signal will not be as smooth as the input audio signal and the optimum shape will be achieved for 1 KHz audio frequency input.



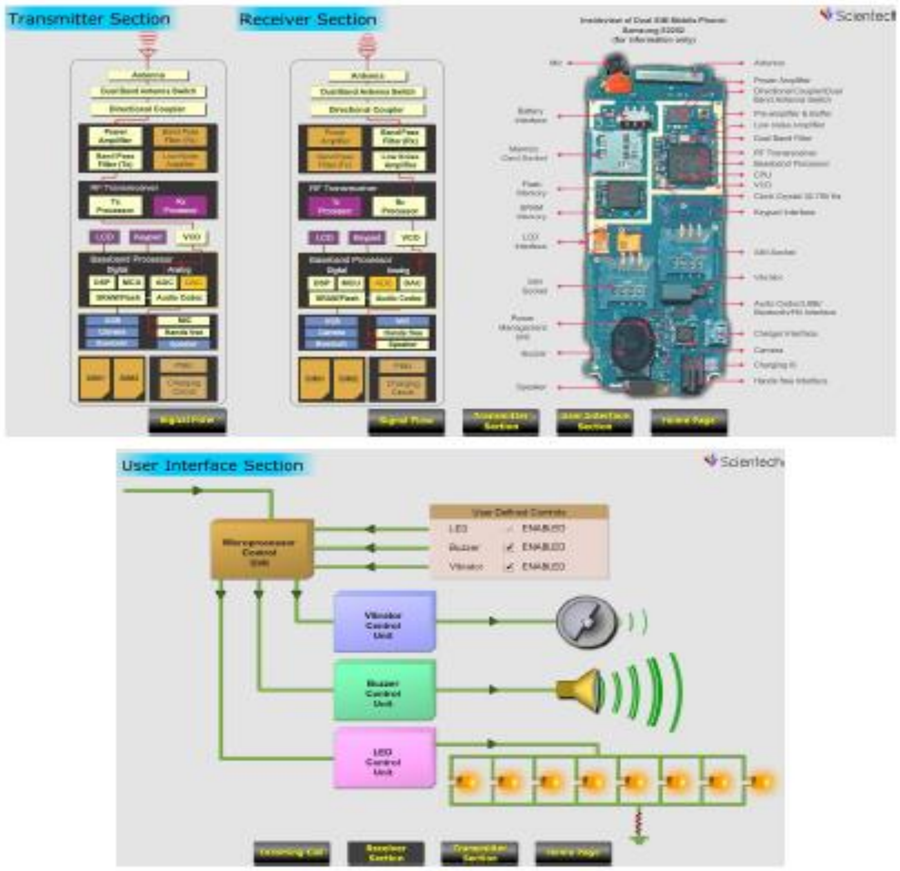
Result:

Studied of DSSS Modulation/Demodulation using an analog signal as an input is done.

Introduction of Dual SIM Mobile phone TechBook -Scientech 2132A

Features:

- Real time mobile operation
- Operates on dual band frequency network (GSM 900/ DCS 1800)
- Colour TFT display
- Full understanding of Dual SIM mobile phone working
- Provides study of all sections in Dual SIM mobile phone
- Tx/ Rx frequency measurement and band verification
- 2G Technology GMSK signal
- Detail study of User Interface Control signals
- Detail study of Dual SIM Operation
- Battery identification and charging study
- Switched Faults



Mobile phone working presentation software

Figure 1

<u>Technical Specifications:</u>

- **Cellular System** : EGSM/GSM 900; DCS1800 (2G-Dual Band)
- **Rx Frequency Band** : **EGSM 900** – 925 to 935 MHz
  GSM 900 – 935 to 960 MHz
  DCS 1800 – 1805 to 1880 MHz
- **Tx Frequency Band** : **EGSM 900** – 880 to 890 MHz
  GSM 900 – 890 to 915 MHz
  DCS 1800 – 1710 to 1785 MHz
- **Output Power** : +5… +33dBm/3.2mW… 2 W
- **Channel Spacing** : 200 KHz
- **Display** : TFT, 256K colours, 128X168 Pixels, 2.0”
- **SIM Support** : Smart Dual SIM, Dual stand by (both GSM)
- **Battery type** : Li-Ion 1000mAH
- **CPU** : 208 MHz
- **Sound** : Speaker and Earphone Jack (3.5mm)
- **On board Sections** : Keypad, Dual SIM, Charging Circuit, User interface: Buzzer, Vibrator, Mic, Speaker,

Hands free port and display LEDs.

- **Test Points** **:** 58 nos.
- **Switched Fault** **:** 35 nos
- **Features that can be Set** **:** Screen saver, Ring tones, Logos, SMS etc.
- **Power Consumption** **:** 3.6VA (approximately)
- **Power Supply** **:** 100 - 260V AC, 50/60 Hz
- **Fuse** **:** 1 A
- **Dimension (mm)** **:** W 326 x D 252 113 x H 52
- **Weight** **:** 2.5 Kg (approximately).
- **Operating Condition** **:** 0-40oC, 85% RH

GSM Technology: Features and Characteristics:

Main technical characteristics of the GSM system are:

GSM radio frequency spectrum

- For **P-GSM**-900 : 890 - 915 MHz and 935 - 960 MHz
- For **E-GSM** : 880 - 915 MHz and 925 - 960 MHz
- For **R-GSM** : 876 - 915 MHz and 921 - 960 MHz
- For **GSM-1800** : 1710 - 1785 MHz and 1805 - 1880 MHz.
- For **GSM-1900** : 1850-1910 MHz and 1930-1990 MHz.

Different Frequency Bands

There are three different frequency bands on which mobile phones are usually operates and these are Dual Band, Tri-Band and Quad Band.

Dual Band **:** Supports two frequencies; 900MHz and 1800 MHz.
Tri-Band **:** Supports three frequencies; 900 MHz, 1800MHz and 1900 MHz.
Quad-Band **:** Supports four frequencies; 850 MHz, 900 MHz, 1800 MHz, 1900 MHz.

GMSK: Gaussian Minimum Shift Keying

Even though MSK's power spectrum density falls quite fast, it does not fall fast enough so that interference between adjacent signals in the frequency band can be avoided. To take care of the problem, the original binary signal is passed through a Gaussian shaped filter before it is modulated with MSK.

Frequency Response:

The principle parameter in designing an appropriate Gaussian filter is the time bandwidth product WTb. Please see the following figure for the frequency response of different Gaussian filters. Note that MSK has a time-bandwidth product of infinity.

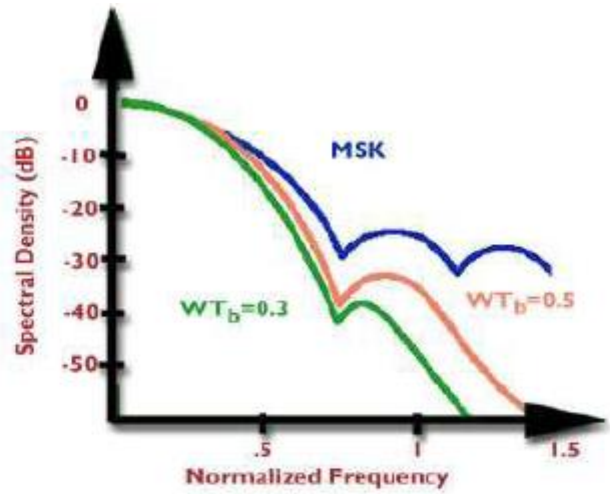


Figure 2: Frequency Response

As can be seen from above, GMSKs power spectrum drops much quicker than MSK's. Furthermore, as WTb is decreased, the roll-off is much quicker.

Time-Domain Response:

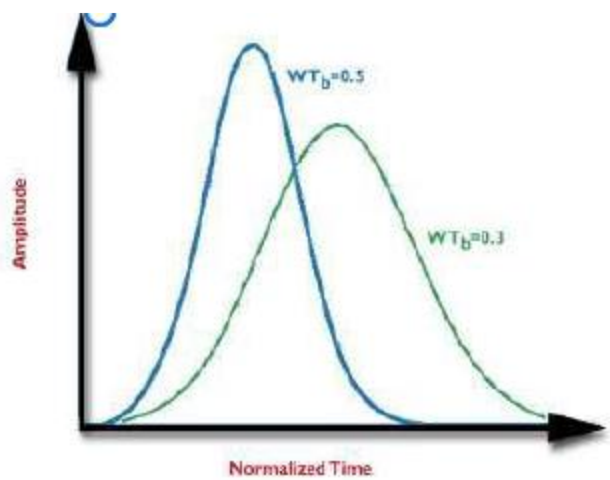


Figure 3: Time - Domain Response

Since lower time-bandwidth products produce a faster power-spectrum roll-off, why not have very small time-bandwidth products. It happens that with lower time bandwidth products the pulse is spread over a longer time, which can cause intersymbol interference. Therefore as a compromise between spectral efficiency and time-domain performance, an intermediate time-bandwidth product must be chosen.
The reliability of a data message produced by a GMSK system is highly dependent on the following:

- Receiver thermal noise: this is produced partly by the receive antenna and mostly by the radio receiver.
- Channel fading: this is caused by the multipath propagation nature of the radio channel.

- Band limiting: This is mostly associated with the receiver If frequency and phase characteristics

- DC drifts: may be caused by a number of factors such as temperature variations, asymmetry of the frequency response of the receiver, frequency drifts of the receiver local oscillator.

- Frequency Offset:
  1. This refers to the receiver carrier frequency drift relative to the frequency transmitted caused by the finite stability of all the frequency sources in the receiver. The shift is also caused partly by Doppler shifts, which result due to the relative transmitter/receiver motion.
  2. The frequency offset causes the received IF signal to be off-center with respect to the IF filter response, and this cause more signal distortion.
  3. The frequency offset also results in a proportional DC component at the discriminator output.
- Timing Errors:
  1. The timing reference causes the sampling instants to be offset from the center of the transmit eye.
  2. As GMSK is a filtered version of MSK, this introduces another variable that can be used to describe the exact nature of the GMSK modulation.
  3. This variable is referred to as the BT, where B is the 3dB point of the Gaussian filter, and T is the bit duration. Therefore a BT of infinity would relate to MSK.
  4. The smaller the BT the smaller the spectral density however this comes at a trade off of increased inter-symbol interference.
  5. This is because by smoothing the edges of the bit pulses they begin to overlap each other. The greater the smoothing, the greater the overlapping, until eventually individual bits may be undetectable.

GMSK Modulation

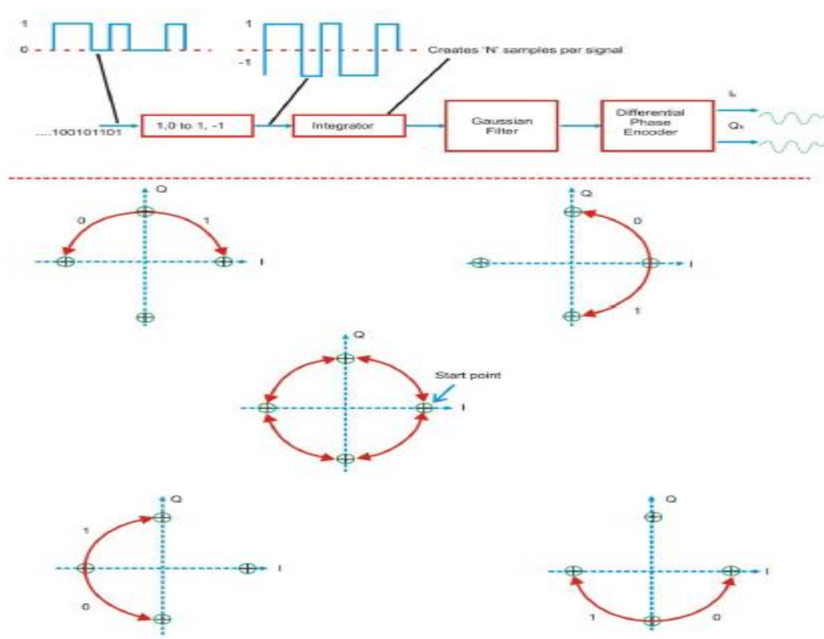


Figure 4: GMSK Consolation

Frequency List

- GSM band 900MHz – Tx – 880-890 MHz, Rx – 925-960 MHz
- Modulation - GMSK (Gaussian Minimum Shift Keying)
- RF carrier Shift - + 67.708 KHz
- GSM data rate – 270.833 Kbit/sec
- Clock frequency – 32.768 KHz
- SIM clock - 3.2 MHz
- VCO signal for Rx – 3700-3840 MHz divided by 4
- VCO signal for Tx – 3520-3660 MHz divided by 4
- VCTXO signal – 26 MHz divided by 2
- System clock – 13 MHz

Test Points:

Test Points

RF Section

1. Tx Signal - 880-915MHz
   1710-1785MHz
   Rx Signal - 925-960MHz
   1805-1880MHz
2. Received Signal (I) Data
3. Received Signal (Q) Data
4. Transmit Signal (I) Data
5. Transmit Signal (Q) Data

LCD Section

6. LCD Voltage 3.8V
7. LED Voltage 1.8V
8. Write enable Signal
9. Display Control Signal
10. I/O Voltage 2.8V
11. Reset Voltage 1.6V

Battery Voltage

12. Battery +Ve 3.7V
13. Battery Status Indicator
14. Battery -Ve (Ground)

Keypad Section

15-19. Key Matrix Row Data
20-24. Key Matrix Column Data

SIM 1 & SIM 2 Interface

25&31. SIM VCC 2.8V
26&32. SIM Reset 2V
27&33. SIM Clock
28&34. SIM Ground
29&35. SIM VPP NC
30&36. SIM Data 2.8V

User Interface Section

37. Vibrator Control Voltage 1.5-3V
38. Buzzer PWM Signal
39&40. Key pad LED 2V (when On)
41. Speaker - Audio Signal (Rx)
42. Mic- Audio Signal (Tx)
43. Hands free Speaker Audio signal
44. Hands free Mic Audio signal

Microprocessor Control Unit

45. CS - Chip select Input
46. D/C - Data / Command control
47. SCL - Serial Clock
48. SDA - Serial Data
49. GSM EN - GSM900 Enable
50. DCS EN - DCS1800 Enable

Power Management Unit

51. VCC - Battery Voltage 3.7V
52. VRF - to RF Section 2.8V
53. VDDIO - to I/O Section 1.8V
54. VDDINT -to Memory 2.8V
55. VCPU - to CPU 1.8V
56. VCTCXO - to VCO 2.8V
57. Charger Supply 6V
58. Charging Voltage 6V

Figure 5: Test Points

Component Layout

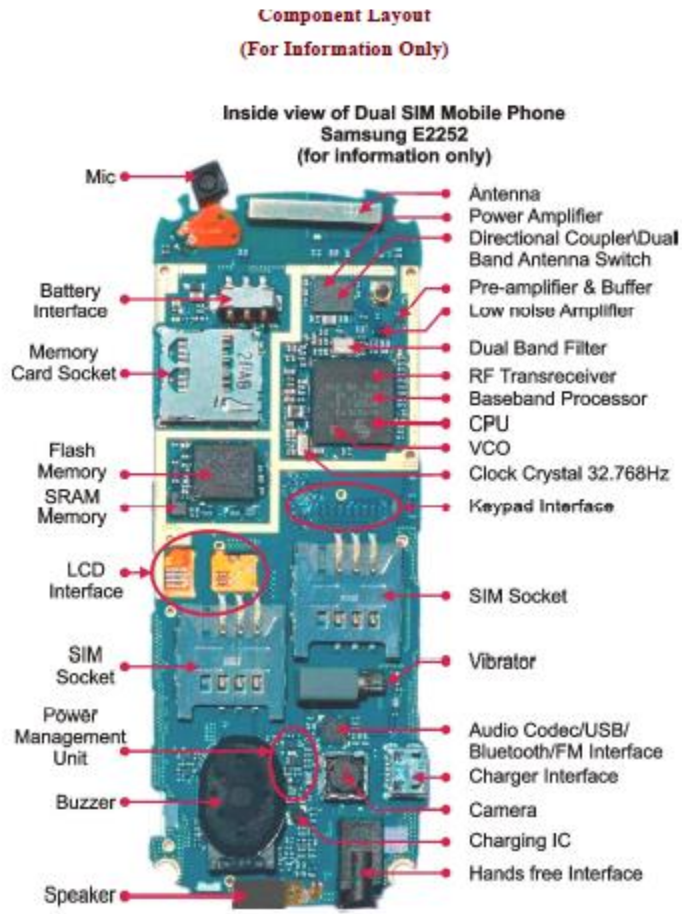


Figure 6: Component Layout

EXPT.8: STUDY AND IDENTIFY DIFFERENT BLOCKS OF MOBILE PHONE UNITS AND SKETCH THE WAVEFORMS OF DIFFERENT SECTIONS IN MOBILE COMMUNICATION TRAINER BOARD.

Aim:

Study and identify different blocks of mobile phone units and Sketch the waveforms of different sections in Mobile Communication Trainer board.

Objective:

1. Study and observe Transmitted/Received RF Signal
2. Study and observe Tx IQ/ Rx IQ RF Signals
3. Study and observe signal constellation of GMSK Signal (Rx I/Q)
4. Study and observe signal constellation of GMSK signal (Tx I/Q)

Tools Required:

- Dual SIM Mobile phone TechBook
- SIM card(s) of any GSM service provider supporting 900/1800 frequency band
- Power Supply for Scientech 2132A with Mains Cord
- Hands free kit
- Spectrum Analyzer (Scientech)

Theory:

Operating Mode:

Dual SIM Mobile Phone training system works in two operating mode that can be selected by a 'Mode Selection Switch' provided on the TechBook at left side near Power connector.

- Battery Mode (Switch Released): In this mode the TechBook operates with battery supplied & battery can be charged.

- Adaptor Mode (Switch Pressed): In this mode the TechBook operates on external Power Supply. For this connect Scientech 2132A Power Supply with mains cord to TechBook. The TechBook automatically disconnects the battery contacts when the mode is changed from Battery to Adaptor. So physical presence of the battery in the battery assembly doesn't have any effect. The charging 'On/Off' switch stops functioning in this mode.

- Switch off the TechBook before switching between the Operating modes.

Operating Condition:

Before performing this experiment, please ensure that;

- Insert SIM card(s) before switching on the TechBook (Most important point to be noted)
- Also ensure that the SIM cards in use should be of any GSM service provider supporting 900/1800 frequency band. (Don't use any SIM of a CDMA service provider)
- Battery should be fully charged if you want to operate the system in 'Battery Mode'.
- To charge the battery; connect Scientech 2132A Power Supply to TechBook with Mains Cord; operate the TechBook in 'Battery Mode' and put the 'Charging Switch to 'On' position.
- While charging the Battery, Communication can be done using the TechBook.
- All the Switch Faults should be in 'Off' Position.

Procedure: Study and observe Transmitted/Received RF Signal

- Once the TechBook is initially ready as per the set up given and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.
- Make a Call to the TechBook or from the TechBook.
- Connect the probe of Spectrum Analyzer at test point 1 to observe the signal to observe the transmitted/received RF signal in the respective Tx/ Rx band.
- Capture the frequency in the range of 900 MHz if the SIM in use is of GSM 900 service provider or in the range of 1800 MHz if it is of GSM 1800 service provider.
- You will receive a fluctuating/ blinking frequency component in the respective range as shown in figure.

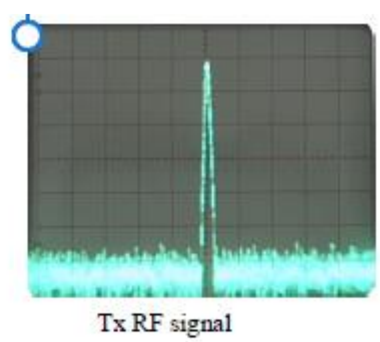


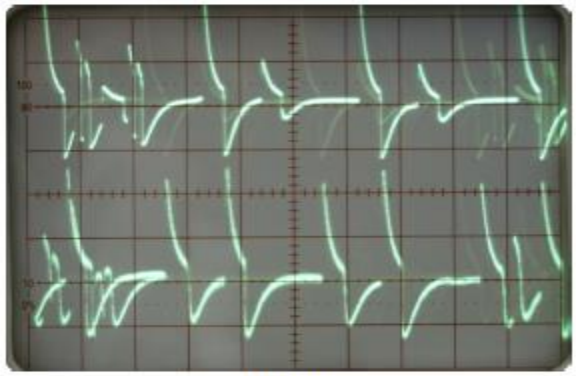
Figure 1: TX RF Signal

Procedure: Study and observe Tx IQ/ Rx IQ RF Signals

- Once the TechBook is initially ready as per the set up given in operating condition if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.

- Make a Call to the TechBook or from the TechBook.

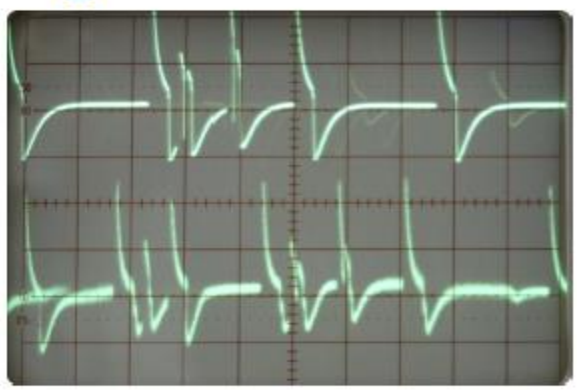
- Connect two probes of Oscilloscope to CH1(Y) at test point 2 (Rx I signal) and CH2(X) at test point 3 (Rx Q signal) to observe them in dual mode as shown in figure.



Rx I/Q Data

Figure 2: RX I/Q Data

- Similarly connect two probes of Oscilloscope to CH1(Y) at test point 4 (Tx I signal) and CH2(X) at test point 5 (Tx Q signal) to observe them in dual mode as shown in figure.



Tx I/Q Data

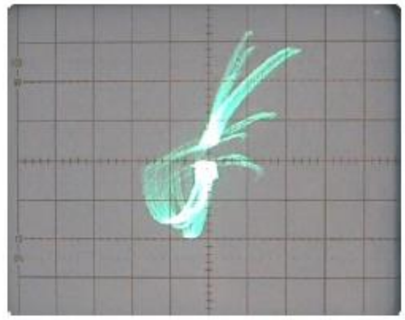
Figure 3: TX I/Q Data

<u>Procedure: Study and observe signal constellation of GMSK Signal (Rx I/Q)</u>

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.

- Make a Call to the TechBook or from the TechBook.

- Connect two probes of Oscilloscope to CH1(Y) at test point 2 (Rx I signal) and CH2(X) at test point 3 (Rx Q signal) and observe them in **XY mode** as shown in figure.



Rx I/Q Data in XY mode

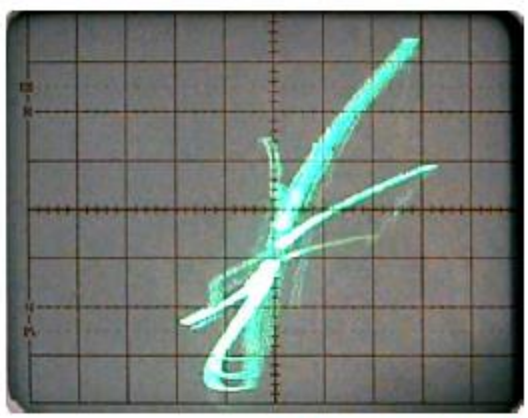
Figure 4: RX I/Q Data in XY mode

Procedure: Study and observe signal constellation of GMSK signal (Tx I/Q)

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.

- Make a Call to the TechBook or from the TechBook.

- Connect two probes of Oscilloscope to CH1(Y) at test point 4 (Tx I signal) and CH2(X) at test point 5 (Tx Q signal) and observe them in **XY mode** as shown in figure.



Tx I/Q Data in XY mode

Figure 5: TX I/Q Data in XY mode

Result:

Studied and identified different blocks of mobile phone units and verified the waveforms of different sections in Mobile Communication Trainer board.

EXPT. 8A : STUDY AND ANALYSE DIFFERENT USER INTERFACE SECTION IN MOBILE COMMUNICATION TRAINER BOARD.

Aim:

Study and analyse different User Interface section in Mobile Communication Trainer board.

Objective:

1. Study and analyze the Buzzer in Dual SIM Mobile Phone TechBook.
2. Study and analyze the vibrator in Dual SIM Mobile Phone TechBook
3. Study and analyze the LED control in Dual SIM Mobile Phone
4. Study and analyze MIC & Speaker section
5. Study and analyze the Hands Free section (MIC/Speaker)

Tools Required:

- Dual SIM Mobile phone TechBook
- SIM card(s) of any GSM service provider supporting 900/1800 frequency band
- Power Supply for Scientech 2132A with Mains Cord
- Hands free kit
- Oscilloscope (Scientech)

Theory:

1. User Interface section: Buzzer

This is the circuit which informs the incoming call by ringing the bell or ringtone. This is also used to here the other tones of the mobile phone like Key tone, Alarm tone, Alert tone etc. Ringer/ Buzzer Control circuit gets the signal form CPU at the time of incoming call. These control signals activate the ringer circuit to provide the pulses to buzzer and it starts ringing. Alerting tones or melodies are generated by a buzzer. Ringing driving circuit is mainly made by CPU, Buzzer driving circuit and Buzzer. Whenever there is an incoming call or message else ringing is software activated. Ringing Driving Control signal that's a PWM signal is obtained from Central Processing Unit (CPU) and given driver circuit. After amplification it reaches at one tapping of buzzer.

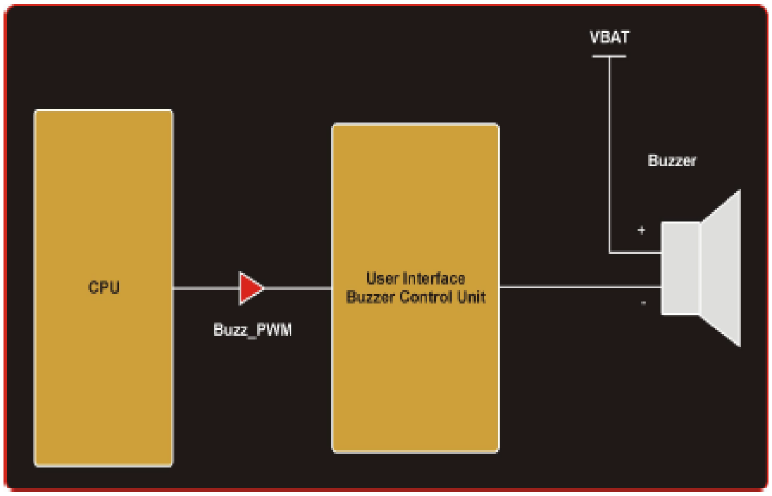


Figure 1: Block Diagram of Buzzer Control Circuit

Operating Mode:

Operate the TechBook either in Battery mode or in Adaptor mode

- Adaptor Mode (Switch Pressed): In this mode the TechBook operates on external Power Supply. For this connect Scientech 2132A Power Supply with mains cord to TechBook. The TechBook automatically disconnects the battery contacts when the mode is changed from Battery to Adaptor. So physical presence of the battery in the battery assembly doesn't have any effect. The charging 'On/Off' switch stops functioning in this mode.

- Switch off the TechBook before switching between the Operating modes.

Operating Condition:

Before performing this experiment, please ensure that;

- Insert SIM card(s) before switching on the TechBook (Most important point to be noted)

- Also ensure that the SIM cards in use should be of any GSM service provider supporting 900/1800 frequency band. (Don't use any SIM of a CDMA service provider)

- Battery should be fully charged if you want to operate the system in 'Battery Mode'.

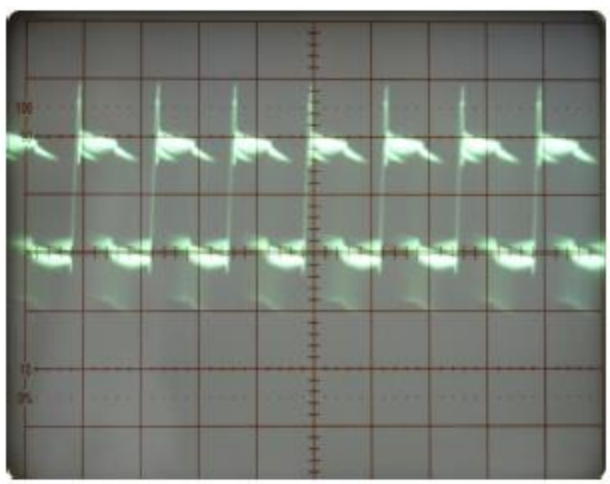
- To charge the battery; connect Scientech 2132A Power Supply to TechBook with Mains Cord; operate the TechBook in 'Battery Mode' and put the 'Charging Switch to 'On' position.

- While charging the Battery, Communication can be done using the TechBook.

- All the Switch Faults should be in 'Off' Position.

Procedure: Study and analyze the Buzzer in Dual SIM Mobile Phone TechBook.

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.
- Press “Menu” button.
- Use scroll keys to until you get the option ‘Settings’.
- Select ‘Sound Profiles’ using Up/Down key.
- Select ‘Normal’ and press ‘Edit’. Select ‘Call Alert Type’ and press ‘Change’. Select ‘Melody’ mode and save.
- Go back and select the ‘Voice Call Ringtone’. Press ’Change’ and select any ring tone.
- Go back and select Volume and check the volume of Call alert. Save it. Go back to initial window.
- Make a Call to the TechBook.
- You will observe that the Buzzer starts to ring when TechBook is called.
- Observe the Buzzer signal at test point in User Interface Section. It is a PWM signal which is converted to sound as shown in figure.



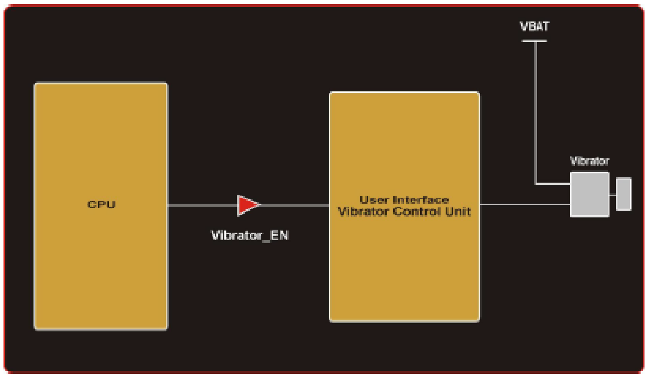
PWM Buzzer signal

Figure 2: PWM Buzzer Signal

2. User Interface section: Vibrator

Theory:

The function of the Vibrator section is to inform the user at the time of incoming call by vibrations. Vibrator control circuit receives the control signal form the CPU and activates the controlling circuit to provide the operating voltage to the vibrator and vibrator starts to vibrate until it gets the signals from the CPU. The vibrator driving circuit is similar to that of ringer circuit. It is used for giving silent information to user for incoming calls. This is also called Vibra Alert Device. When an incoming call comes then this device gives its information to user by vibrating. V BATT supply is given at other tapping of this vibrator. Operation of turning 'On' Vibrator is controlled by software. A vibra alerting device is similar to the DC motor. In the mobile phone it is used to generate a vibration signal for an incoming call.



Block Diagram of Vibrator Control Circuit

Figure 3: Block Diagram of Vibrator Control Circuit

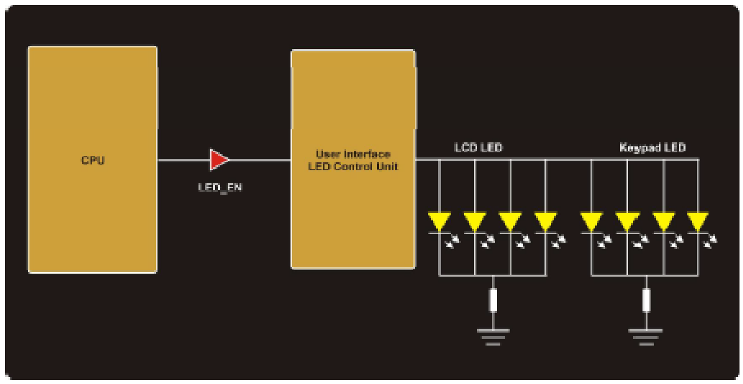
Procedure: Study and analyze the vibrator in Dual SIM Mobile Phone TechBook

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.
- Press "Menu" button.
- Use scroll keys to until you get the option 'Settings'.
- Select 'Sound Profiles' using Up/Down key.
- Select 'Normal' and press 'Edit'. Select 'Call alert type' and press 'Change'.
- Select 'Vibration' mode and save. Go back to initial window.
- Make a Call to the TechBook.
- You will observe that the vibrator starts to vibrate when TechBook is called.
- Observe the Vibrator signal at test point in User Interface Section. It is a DC voltage which drives the vibrator to vibrate. It is approximately 1.5V to 3V.

3. User Interface Section: LED

Theory:

Light Emitting Diode, helps the user while performing function. The LED in mobile phone is of SMD type instead of traditional LED's due to much compactness required and many mobile specifications. The LED circuit consists of CPU, UI section and LED. The DC signal is made out from CPU whenever handset is switched 'On/Off', Tx/Rx even a key is pressed depending on the menu features. The signal obtained from the CPU is given UI section. The UI section gives output for keypad/Display LED separately but simultaneously. The LED's are connected in parallel. The anode of the LED's is connected to VBAT. Varistors are connected for protection in addition resistors are connected for both (LED & Keypad) LED's for intensity control. The time duration for the LED is software controlled often menu driven.



Block Diagram of LED Control Circuit

Figure 4: Block Diagram of LED Control Circuit

<u>Procedure: Study and analyze the LED control in Dual SIM Mobile Phone</u>

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.
- Key pad LED 1 & Key Pad LED 2 are the part of Key pad LED section.
- Whenever we press any key or when we receive a call or message the LEDs glow.
- Observe the controlled LED driving voltage at the test points given in the User Interface section. It is 2V approximately.

4. <u>User Interface Section: MIC & Speaker section</u>

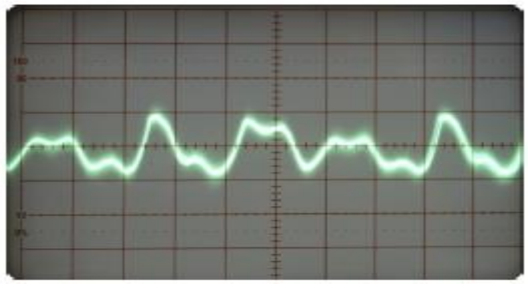
<u>Procedure: Study and analyze MIC & Speaker section</u>

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.
- Make a Call to the TechBook and receive the call.

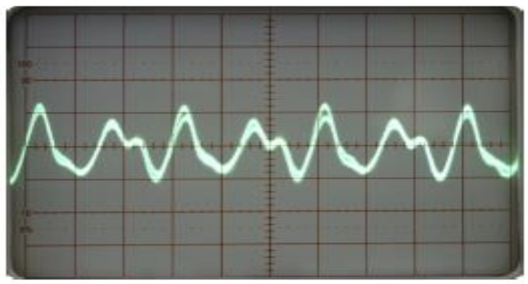
- Now the volume of the speaker can be increased or decreased using the Up/Down key. Set the volume level to maximum.

- Observe the received audio signal from caller at the Speaker test point in User Interface section.

- Observe the transmitted audio signal from the called party at the MIC test point in User Interface section



MIC- Transmitted Audio Signal



Speaker – Received Audio Signal

Figure 5: MIC / Speaker section

5. <u>User Interface Section: Hands Free MIC & Speaker section</u>

<u>Procedure: Study and analyze the Hands Free section (MIC/Speaker)</u>

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.

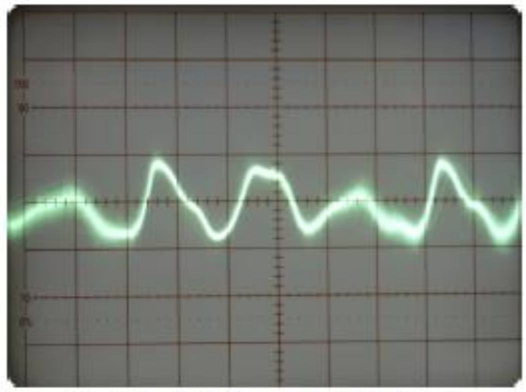
- Connect the Hands Free kit to Hands Free socket in the user Interface section.

- Make a Call to the TechBook and receive the call.

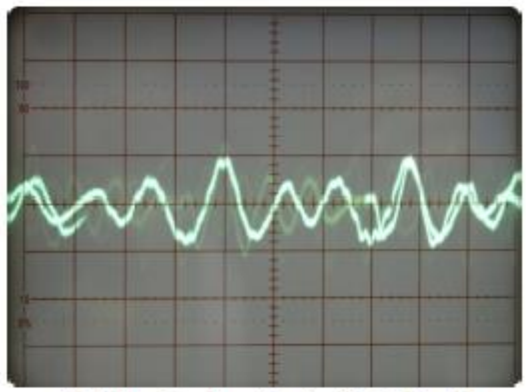
- Now the volume of the speaker can be increased or decreased using the Up/ Down key. Set the volume level to maximum.

- Observe the received audio signal from caller at the Hands Free Speaker test point in User Interface section.

- Observe the transmitted audio signal from the called party at the Hands Free MIC test point in User Interface section.



Hands free MIC- Transmitted Audio Signal



Hands free Speaker – Received Audio Signal

Figure 5: Hands free MIC / Speaker section

<u>Result:</u>

Studied and analysed different User Interface section in Mobile Communication Trainer board.

EXPT. 8C: STUDY AND ANALYSE MODES OF OPERATION: ACTIVE MODE/ACTING DEAD MODE/SLEEP MODE IN MOBILE COMMUNICATION TRAINER BOARD.

Aim:

Study and analyse Modes of operation: Active mode / Acting Dead mode / Sleep mode in Mobile Communication Trainer board.

Objective:

1. Analyze the Active Mode of a mobile Phone
2. Analyze the Acting Dead mode of a mobile phone
3. Analyze the sleep mode of a mobile phone

Tools required:

- Dual SIM Mobile phone TechBook
- SIM card(s) of any GSM service provider supporting 900/1800 frequency band
- Power Supply for Scientech 2132A with Mains Cord

Operating Mode:

Operate the TechBook either in Battery mode or in Adaptor mode as instructed in previous experiments.

Operating Condition:

- Follow all the conditions as instructed in Experiment 8.
- Check that all the Switch Faults should be in 'Off' position.

Procedure: Analyze the Active Mode of a mobile Phone

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.

- Measure the voltages at the test points given in Power Management unit and the test points 6, 7, 10 & 11 of LCD display section.

- Call make and Call receive experiment can be done and the signals at the respective test points can be observed.

Procedure: Analyze the Acting Dead mode of a mobile phone

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.

- Switch off the TechBook.
- Connect the Scientech 2132A Power Supply with mains cord.
- Do not switch on the TechBook. Only switch on the ‘Charger Supply’ switch for charging the battery.
- Observe the battery charging status on display.
- Measure the voltages at the test points given in Power Management unit and the test points 6, 7, 10 & 11 of LCD display section.
- Measure the voltages at the battery terminal test points 12 and 13 with respect to ground test point 14.
- Observe that keypad LEDs glow when any key is pressed. And display shows the battery charging status.
- You will observe that the phone acts as it is switched ‘Off’. A battery-charging alert is given and a battery charging indication on the display is shown to acknowledge the user that the battery is being charged.

Procedure: Analyze the sleep mode of a mobile phone

- Once the TechBook is initially ready as per the set up and if it detects the GSM service provider network(s) with sufficient network strength, further experiment can be done with this TechBook as follows.
- Now switch off the TechBook after some seconds.
- Do not remove the battery.
- Measure the voltages at the test points given in Power Management unit. All voltages except VCC will be 0V.
- Measure the voltages at the battery terminal test points 12 and 13 with respect to ground test point 14.
- You will observe that in the sleep mode all the regulators are off sleep mode is activated by the CPU after CPU and DSP clocks have been switched ‘Off’.

Result:

Studied and analysed various modes of operation: Active mode / Acting Dead mode / Sleep mode in Mobile Communication Trainer board.

EXPT.9: SIMULATION OF OFDM TRANSMITTER AND RECEIVER USING MATLAB

Aim:

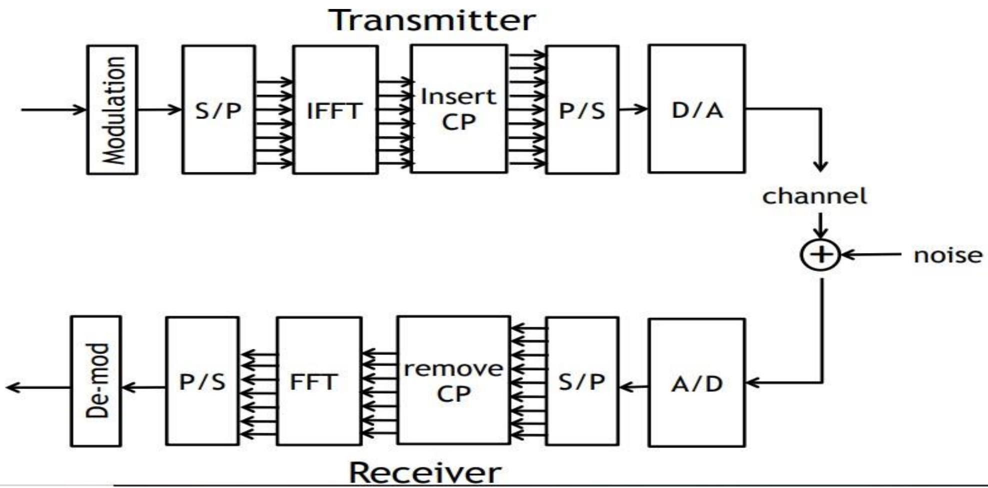
To write a MATLAB code for the given data: Number of bits 64, Number of subcarrier 4; Total number of bits to be transmitted256, Block size of OFDM 16 using PSK Modulation and simulate the transmitter and receiver blocks of OFDM.

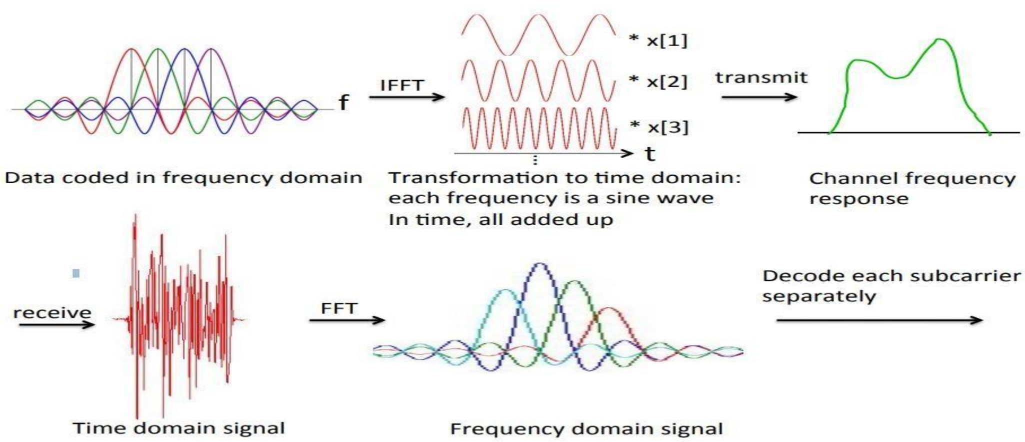
Software Used:

- Matlab Version 7

Theory:

OFDM Transmitter & Receiver:





The technique used for radio transmission and reception in LTE. Carries out the same functions as any other multiple access technique, by allowing the BS to communicate with several different mobiles at the same time. A powerful way to minimize the problems of fading and inter-symbol interference. OFDMA is used by several other radio communication systems

1. IEEE 802.11 versions a, g and n
2. WiMAX (IEEE 802.16)
3. Digital television 4.Radio broadcasting.

OFDM transmitter:

- Divides the information into several parallel sub-streams
- Sends each sub-stream on a different frequency (sub-carrier)
    1. If the total data rate stays the same, then
        - The data rate on each sub-carrier is less than before, so the symbol duration is longer
    2. This reduces the amount of ISI, and reduces the error rate

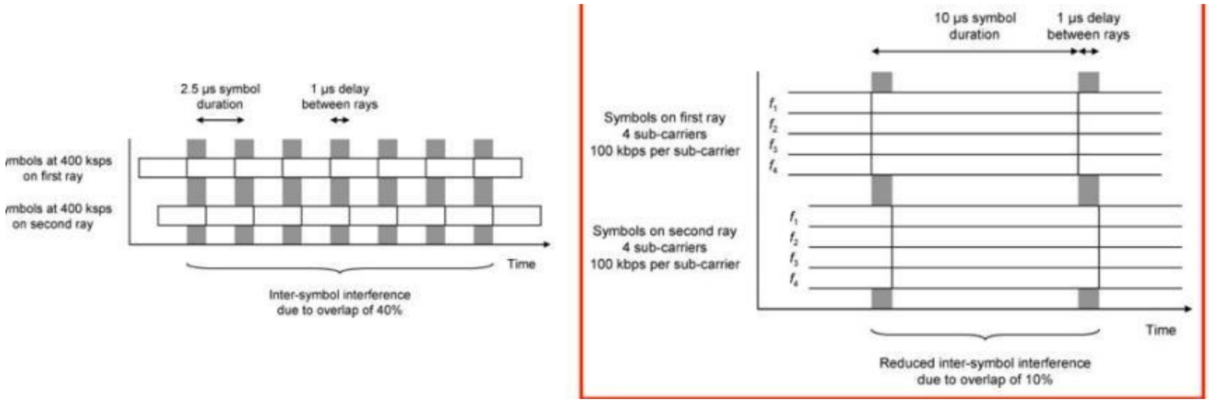


Figure 1: OFDM Transmitter

MATLAB Code:

```
clc;
clear
all;
close
all;
```

% Initiation

```
no_of_data_bits = 64%Number of bits per channel extended to
128M =4 %Number of subcarrier channel
n=256;%Total number of bits to be transmitted at the
transmitter block_size = 16; %Size of each OFDM block to
add cyclic prefixcp_len = floor(0.1 * block_size); %Length of
the cyclic prefix
```

% Transmitter

% Source generation and modulation

% Generate random data source to be transmitted of length 64

```
data = randsrc(1, no_of_data_bits, 0:M-1);
figure(1),stem(data); grid on; xlabel('Data Points');
ylabel('Amplitude')title('Original Data ')
```

% Perform BPSK modulation on the input source data

```
psk_modulated_data = pskmod(data, M);
figure(2),stem(psk_modulated_data);title('PSK
Modulation ')
```

% Converting the series data stream into four parallel data stream to form
% four sub carriers

```
S2P = reshape(psk_modulated_data,
no_of_data_bits/M,M)Sub_carrier1 = S2P(:,1)
Sub_carrier2 =
```

```
S2P(:,2)
Sub_carrier3        =
S2P(:,3)
Sub_carrier4        =
S2P(:,4)
figure(3), subplot(4,1,1),stem(Sub_carrier1),title('Subcarrier1'),grid on;
subplot(4,1,2),stem(Sub_carrier2),title('Subcarrier2'),grid on;
subplot(4,1,3),stem(Sub_carrier3),title('Subcarrier3'),grid on;
subplot(4,1,4),stem(Sub_carrier4),title('Subcarrier4'),grid on;
```

% IFFT OF FOUR SUB_CARRIERS

```
number_of_subcarriers=4;
cp_start=block_size-cp_len;
ifft_Subcarrier1 =
ifft(Sub_carrier1)
ifft_Subcarrier2 =
ifft(Sub_carrier2)
ifft_Subcarrier3 =
ifft(Sub_carrier3)
ifft_Subcarrier4 =
ifft(Sub_carrier4)
figure(4), subplot(4,1,1),plot(real(ifft_Subcarrier1),'r'),
title('IFFT on all the sub-carriers')
subplot(4,1,2),plot(real(ifft_Subcarrier2),'c')
subplot(4,1,3),plot(real(ifft_Subcarrier3),'b')
subplot(4,1,4),plot(real(ifft_Subcarrier4),'g')
```

% ADD-CYCLIC PREFIX

```
for i=1:number_of_subcarriers,
ifft_Subcarrier(:,i) = ifft((S2P(:,i)),16)% 16 is the ifft
pointfor j=1:cp_len,
cyclic_prefix(j,i) =
ifft_Subcarrier(j+cp_start,i)end
Append_prefix(:,i) = vertcat( cyclic_prefix(:,i), ifft_Subcarrier(:,i))
```

% Appends prefix to each subcarriers

```
end
A1=Append_prefix(:,
1);
A2=Append_prefix(:,
2);
A3=Append_prefix(:,
3);
A4=Append_prefix(:,
4);
figure(5), subplot(4,1,1),plot(real(A1),'r'),title('Cyclic prefix added to all the sub-carriers')
subplot(4,1,2),plot(real(A2),'c')
subplot(4,1,3),plot(real(A3),'b')
subplot(4,1,4),plot(real(A4),'g')
figure(11),plot((real(A1)),'r'),title('Orthogonality'),hold on ,plot((real(A2)),'c'),hold on ,
plot((real(A3)),'b'),hold on ,plot((real(A4)),'g'),hold on ,grid on
```

%Convert to serial stream for transmission

```
[rows_Append_prefix
```

cols_Append_prefix]=size(Append_prefix)len_ofdm_data =
rows_Append_prefix*cols_Append_prefix

% OFDM signal to be transmitted

ofdm_signal = reshape(Append_prefix, 1, len_ofdm_data);
figure(6),plot(real(ofdm_signal)); xlabel('Time'); ylabel('Amplitude');
title('OFDM Signal');grid on;

Result:

no_of_data_bits = 64

M

=

4

S2

P

=

-0.0000 - 1.0000i -0.0000 - 1.0000i 0.0000 + 1.0000i 0.0000 + 1.0000i
1.0000 -0.0000 - 1.0000i -0.0000 - 1.0000i 1.0000
-1.0000 + 0.0000i 0.0000 + 1.0000i 0.0000 + 1.0000i 1.0000
0.0000 + 1.0000i -0.0000 - 1.0000i 0.0000 + 1.0000i -1.0000 + 0.0000i
-0.0000 - 1.0000i 1.0000 -0.0000 - 1.0000i 0.0000 + 1.0000i
-0.0000 - 1.0000i 0.0000 + 1.0000i -1.0000 + 0.0000i -1.0000 + 0.0000i
0.0000 + 1.0000i -0.0000 - 1.0000i 1.0000 1.0000
1.0000 1.0000 -1.0000 + 0.0000i -1.0000 + 0.0000i
-0.0000 - 1.0000i 1.0000 -0.0000 - 1.0000i 0.0000 + 1.0000i
0.0000 + 1.0000i 1.0000 1.0000 -0.0000 - 1.0000i
-1.0000 + 0.0000i 1.0000 -1.0000 + 0.0000i -0.0000 - 1.0000i
-0.0000 - 1.0000i -1.0000 + 0.0000i 0.0000 + 1.0000i -1.0000 + 0.0000i
-0.0000 - 1.0000i 0.0000 + 1.0000i -0.0000 - 1.0000i 0.0000 + 1.0000i
-1.0000 + 0.0000i 1.0000 -1.0000 + 0.0000i -0.0000 - 1.0000i
1.0000 1.0000 -1.0000 + 0.0000i -0.0000 - 1.0000i
0.0000 + 1.0000i -1.0000 + 0.0000i 0.0000 + 1.0000i -1.0000 + 0.0000i

Sub_carrier1 =

-0.0000 - 1.0000i
1.0000
-1.0000 + 0.0000i
0.0000 + 1.0000i
-0.0000 - 1.0000i
-0.0000 - 1.0000i
0.0000 + 1.0000i
1.0000
-0.0000 - 1.0000i
0.0000 + 1.0000i
-1.0000 + 0.0000i
-0.0000 - 1.0000i

-0.0000 - 1.0000i
-1.0000 + 0.0000i
1.0000
0.0000 + 1.0000i

Sub_carrier2 =

-0.0000 - 1.0000i
-0.0000 - 1.0000i
0.0000 + 1.0000i
-0.0000 - 1.0000i
1.0000
0.0000 + 1.0000i
-0.0000 - 1.0000i
1.0000
1.0000
1.0000
1.0000
-1.0000 + 0.0000i
0.0000 + 1.0000i
1.0000
1.0000
-1.0000 + 0.0000i

Sub_carrier3 =

0.0000 + 1.0000i
-0.0000 - 1.0000i
0.0000 + 1.0000i
0.0000 + 1.0000i
-0.0000 - 1.0000i
-1.0000 + 0.0000i
1.0000
-1.0000 + 0.0000i
-0.0000 - 1.0000i
1.0000
-1.0000 + 0.0000i
0.0000 + 1.0000i
-0.0000 - 1.0000i
-1.0000 + 0.0000i
-1.0000 + 0.0000i
0.0000 + 1.0000i

Sub_carrier4 =

0.0000 + 1.0000i
1.0000
1.0000
-1.0000 + 0.0000i
0.0000 + 1.0000i
-1.0000 + 0.0000i
1.0000
-1.0000 + 0.0000i
0.0000 + 1.0000i
-0.0000 - 1.0000i

-0.0000 - 1.0000i
-1.0000 + 0.0000i
0.0000 + 1.0000i
-0.0000 - 1.0000i
-0.0000 - 1.0000i
-1.0000 + 0.0000i

ifft_Subcarrier1 =

-0.0000 - 0.1250i
-0.0338 + 0.0889i
0.1509 - 0.0107i
0.1088 - 0.0817i
0.1250 - 0.3750i
0.0817 + 0.3532i
-0.2393 + 0.0991i
0.1024 + 0.0338i
-0.1250 - 0.2500i
0.0338 - 0.2657i
-0.0259 - 0.3643i
-0.2855 + 0.0817i
-0.0000 - 0.2500i
-0.0817 - 0.1764i
0.1143 + 0.2759i
0.0744 - 0.0338i

ifft_Subcarrier2 =

0.3125 - 0.0625i
-0.1015 - 0.0817i
0.0518 - 0.2134i
-0.2545 - 0.1525i
-0.0625 + 0.1875i
0.2450 - 0.0338i
0.2134 - 0.1250i
0.0243 + 0.1813i
0.1875 + 0.0625i
0.1015 + 0.0817i
-0.3018 - 0.0366i
0.0045 - 0.4511i
0.0625 - 0.1875i
-0.2450 + 0.0338i
0.0366 - 0.1250i
-0.2743 - 0.0777i

ifft_Subcarrier3 =

-0.1875 + 0.0625i
-0.0406 + 0.2539i
0.0259 + 0.1509i
0.1155 + 0.0979i
0.3125 - 0.1875i
0.2039 - 0.1673i
-0.0259 + 0.4527i
0.0478 - 0.0112i

0.0625 - 0.1875i
-0.1362 + 0.3496i
-0.1509 - 0.0259i
-0.1155 + 0.3289i
-0.1875 - 0.1875i
-0.0271 + 0.0637i
0.1509 - 0.0777i
-0.0478 + 0.0844i

ifft_Subcarrier4 =

-0.1250 + 0.0000i
-0.0884 + 0.0884i
0.0884 + 0.0884i
-0.1560 + 0.2517i
0.0000 + 0.6250i
0.0884 - 0.0884i
-0.0884 + 0.0884i
-0.0749 - 0.1560i
0.3750 + 0.2500i
-0.0884 + 0.0884i
-0.0884 - 0.0884i
-0.0207 - 0.0749i
-0.2500 + 0.1250i
0.0884 - 0.0884i
0.0884 - 0.0884i
0.2517 - 0.0207i

ifft_Subcarrier =

-0.0000 - 0.1250i
-0.0338 + 0.0889i
0.1509 - 0.0107i
0.1088 - 0.0817i
0.1250 - 0.3750i
0.0817 + 0.3532i
-0.2393 + 0.0991i
0.1024 + 0.0338i
-0.1250 - 0.2500i
0.0338 - 0.2657i
-0.0259 - 0.3643i
-0.2855 + 0.0817i
-0.0000 - 0.2500i
-0.0817 - 0.1764i
0.1143 + 0.2759i
0.0744 - 0.0338i

cyclic_prefix =

0.0744 - 0.0338i

Append_prefix =

0.0744 - 0.0338i

-0.0000 - 0.1250i
-0.0338 + 0.0889i
0.1509 - 0.0107i
0.1088 - 0.0817i
0.1250 - 0.3750i
0.0817 + 0.3532i
-0.2393 + 0.0991i
0.1024 + 0.0338i
-0.1250 - 0.2500i
0.0338 - 0.2657i
-0.0259 - 0.3643i
-0.2855 + 0.0817i
-0.0000 - 0.2500i
-0.0817 - 0.1764i
0.1143 + 0.2759i
0.0744 - 0.0338i

ifft_Subcarrier =

-0.0000 - 0.1250i 0.3125 - 0.0625i
-0.0338 + 0.0889i -0.1015 - 0.0817i
0.1509 - 0.0107i 0.0518 - 0.2134i
0.1088 - 0.0817i -0.2545 - 0.1525i
0.1250 - 0.3750i -0.0625 + 0.1875i
0.0817 + 0.3532i 0.2450 - 0.0338i
-0.2393 + 0.0991i 0.2134 - 0.1250i
0.1024 + 0.0338i 0.0243 + 0.1813i
-0.1250 - 0.2500i 0.1875 + 0.0625i
0.0338 - 0.2657i 0.1015 + 0.0817i
-0.0259 - 0.3643i -0.3018 - 0.0366i
-0.2855 + 0.0817i 0.0045 - 0.4511i
-0.0000 - 0.2500i 0.0625 - 0.1875i
-0.0817 - 0.1764i -0.2450 + 0.0338i
0.1143 + 0.2759i 0.0366 - 0.1250i
0.0744 - 0.0338i -0.2743 - 0.0777i

cyclic_prefix =

0.0744 - 0.0338i -0.2743 - 0.0777i

Append_prefix =

0.0744 - 0.0338i -0.2743 - 0.0777i
-0.0000 - 0.1250i 0.3125 - 0.0625i
-0.0338 + 0.0889i -0.1015 - 0.0817i
0.1509 - 0.0107i 0.0518 - 0.2134i
0.1088 - 0.0817i -0.2545 - 0.1525i
0.1250 - 0.3750i -0.0625 + 0.1875i
0.0817 + 0.3532i 0.2450 - 0.0338i
-0.2393 + 0.0991i 0.2134 - 0.1250i
0.1024 + 0.0338i 0.0243 + 0.1813i
-0.1250 - 0.2500i 0.1875 + 0.0625i
0.0338 - 0.2657i 0.1015 + 0.0817i
-0.0259 - 0.3643i -0.3018 - 0.0366i
-0.2855 + 0.0817i 0.0045 - 0.4511i
-0.0000 - 0.2500i 0.0625 - 0.1875i

-0.0817 - 0.1764i -0.2450 + 0.0338i
0.1143 + 0.2759i 0.0366 - 0.1250i
0.0744 - 0.0338i -0.2743 - 0.0777i

ifft_Subcarrier =

-0.0000 - 0.1250i 0.3125 - 0.0625i -0.1875 + 0.0625i
-0.0338 + 0.0889i -0.1015 - 0.0817i -0.0406 + 0.2539i
0.1509 - 0.0107i 0.0518 - 0.2134i 0.0259 + 0.1509i
0.1088 - 0.0817i -0.2545 - 0.1525i 0.1155 + 0.0979i
0.1250 - 0.3750i -0.0625 + 0.1875i 0.3125 - 0.1875i
0.0817 + 0.3532i 0.2450 - 0.0338i 0.2039 - 0.1673i
-0.2393 + 0.0991i 0.2134 - 0.1250i -0.0259 + 0.4527i
0.1024 + 0.0338i 0.0243 + 0.1813i 0.0478 - 0.0112i
-0.1250 - 0.2500i 0.1875 + 0.0625i 0.0625 - 0.1875i
0.0338 - 0.2657i 0.1015 + 0.0817i -0.1362 + 0.3496i
-0.0259 - 0.3643i -0.3018 - 0.0366i -0.1509 - 0.0259i
-0.2855 + 0.0817i 0.0045 - 0.4511i -0.1155 + 0.3289i
-0.0000 - 0.2500i 0.0625 - 0.1875i -0.1875 - 0.1875i
-0.0817 - 0.1764i -0.2450 + 0.0338i -0.0271 + 0.0637i
0.1143 + 0.2759i 0.0366 - 0.1250i 0.1509 - 0.0777i
0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i

cyclic_prefix =

0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i

Append_prefix =

0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i
-0.0000 - 0.1250i 0.3125 - 0.0625i -0.1875 + 0.0625i
-0.0338 + 0.0889i -0.1015 - 0.0817i -0.0406 + 0.2539i
0.1509 - 0.0107i 0.0518 - 0.2134i 0.0259 + 0.1509i
0.1088 - 0.0817i -0.2545 - 0.1525i 0.1155 + 0.0979i
0.1250 - 0.3750i -0.0625 + 0.1875i 0.3125 - 0.1875i
0.0817 + 0.3532i 0.2450 - 0.0338i 0.2039 - 0.1673i
-0.2393 + 0.0991i 0.2134 - 0.1250i -0.0259 + 0.4527i
0.1024 + 0.0338i 0.0243 + 0.1813i 0.0478 - 0.0112i
-0.1250 - 0.2500i 0.1875 + 0.0625i 0.0625 - 0.1875i
0.0338 - 0.2657i 0.1015 + 0.0817i -0.1362 + 0.3496i
-0.0259 - 0.3643i -0.3018 - 0.0366i -0.1509 - 0.0259i
-0.2855 + 0.0817i 0.0045 - 0.4511i -0.1155 + 0.3289i
-0.0000 - 0.2500i 0.0625 - 0.1875i -0.1875 - 0.1875i
-0.0817 - 0.1764i -0.2450 + 0.0338i -0.0271 + 0.0637i
0.1143 + 0.2759i 0.0366 - 0.1250i 0.1509 - 0.0777i
0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i

ifft_Subcarrier =

-0.0000 - 0.1250i 0.3125 - 0.0625i -0.1875 + 0.0625i -0.1250 + 0.0000i
-0.0338 + 0.0889i -0.1015 - 0.0817i -0.0406 + 0.2539i -0.0884 + 0.0884i
0.1509 - 0.0107i 0.0518 - 0.2134i 0.0259 + 0.1509i 0.0884 + 0.0884i
0.1088 - 0.0817i -0.2545 - 0.1525i 0.1155 + 0.0979i -0.1560 + 0.2517i
0.1250 - 0.3750i -0.0625 + 0.1875i 0.3125 - 0.1875i 0.0000 + 0.6250i
0.0817 + 0.3532i 0.2450 - 0.0338i 0.2039 - 0.1673i 0.0884 - 0.0884i
-0.2393 + 0.0991i 0.2134 - 0.1250i -0.0259 + 0.4527i -0.0884 + 0.0884i

0.1024 + 0.0338i 0.0243 + 0.1813i 0.0478 - 0.0112i -0.0749 - 0.1560i
-0.1250 - 0.2500i 0.1875 + 0.0625i 0.0625 - 0.1875i 0.3750 + 0.2500i
0.0338 - 0.2657i 0.1015 + 0.0817i -0.1362 + 0.3496i -0.0884 + 0.0884i
-0.0259 - 0.3643i -0.3018 - 0.0366i -0.1509 - 0.0259i -0.0884 - 0.0884i
-0.2855 + 0.0817i 0.0045 - 0.4511i -0.1155 + 0.3289i -0.0207 - 0.0749i
-0.0000 - 0.2500i 0.0625 - 0.1875i -0.1875 - 0.1875i -0.2500 + 0.1250i
-0.0817 - 0.1764i -0.2450 + 0.0338i -0.0271 + 0.0637i 0.0884 - 0.0884i
0.1143 + 0.2759i 0.0366 - 0.1250i 0.1509 - 0.0777i 0.0884 - 0.0884i
0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i 0.2517 - 0.0207i

cyclic_prefix =

0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i 0.2517 - 0.0207i

Append_prefix =

0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i 0.2517 - 0.0207i
-0.0000 - 0.1250i 0.3125 - 0.0625i -0.1875 + 0.0625i -0.1250 + 0.0000i
-0.0338 + 0.0889i -0.1015 - 0.0817i -0.0406 + 0.2539i -0.0884 + 0.0884i
0.1509 - 0.0107i 0.0518 - 0.2134i 0.0259 + 0.1509i 0.0884 + 0.0884i
0.1088 - 0.0817i -0.2545 - 0.1525i 0.1155 + 0.0979i -0.1560 + 0.2517i
0.1250 - 0.3750i -0.0625 + 0.1875i 0.3125 - 0.1875i 0.0000 + 0.6250i
0.0817 + 0.3532i 0.2450 - 0.0338i 0.2039 - 0.1673i 0.0884 - 0.0884i
-0.2393 + 0.0991i 0.2134 - 0.1250i -0.0259 + 0.4527i -0.0884 + 0.0884i
0.1024 + 0.0338i 0.0243 + 0.1813i 0.0478 - 0.0112i -0.0749 - 0.1560i
-0.1250 - 0.2500i 0.1875 + 0.0625i 0.0625 - 0.1875i 0.3750 + 0.2500i
0.0338 - 0.2657i 0.1015 + 0.0817i -0.1362 + 0.3496i -0.0884 + 0.0884i
-0.0259 - 0.3643i -0.3018 - 0.0366i -0.1509 - 0.0259i -0.0884 - 0.0884i
-0.2855 + 0.0817i 0.0045 - 0.4511i -0.1155 + 0.3289i -0.0207 - 0.0749i
-0.0000 - 0.2500i 0.0625 - 0.1875i -0.1875 - 0.1875i -0.2500 + 0.1250i
-0.0817 - 0.1764i -0.2450 + 0.0338i -0.0271 + 0.0637i 0.0884 - 0.0884i
0.1143 + 0.2759i 0.0366 - 0.1250i 0.1509 - 0.0777i 0.0884 - 0.0884i

0.0744 - 0.0338i -0.2743 - 0.0777i -0.0478 + 0.0844i 0.2517 - 0.0207i

Graph:

Original Data:

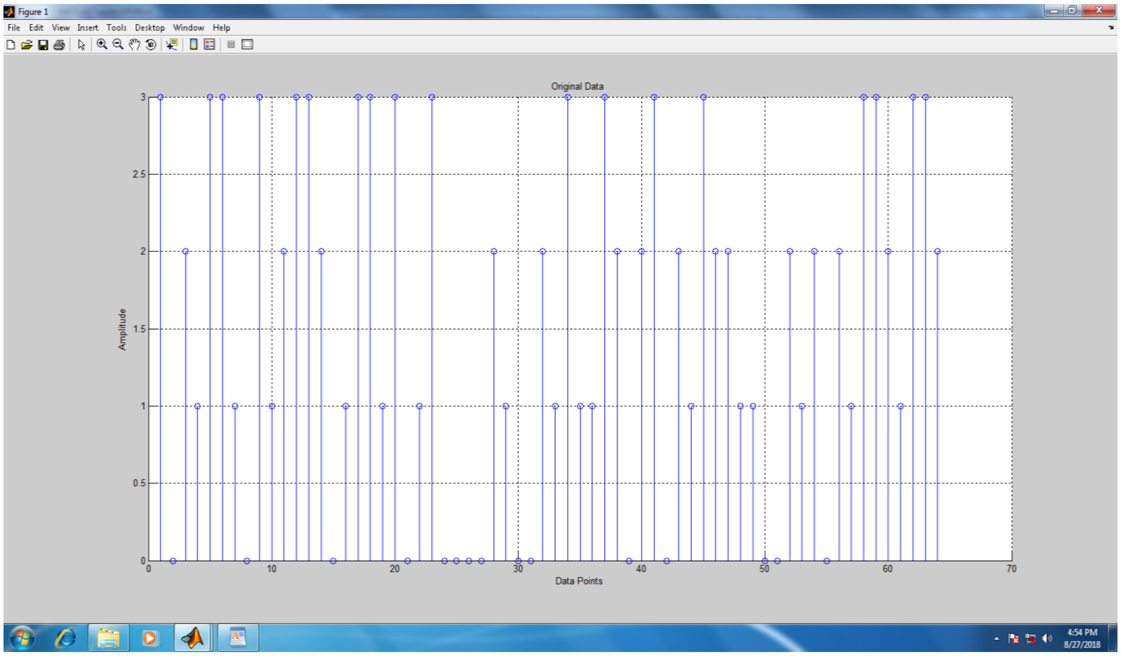


Figure2:Original Data

BPSK Modulation:

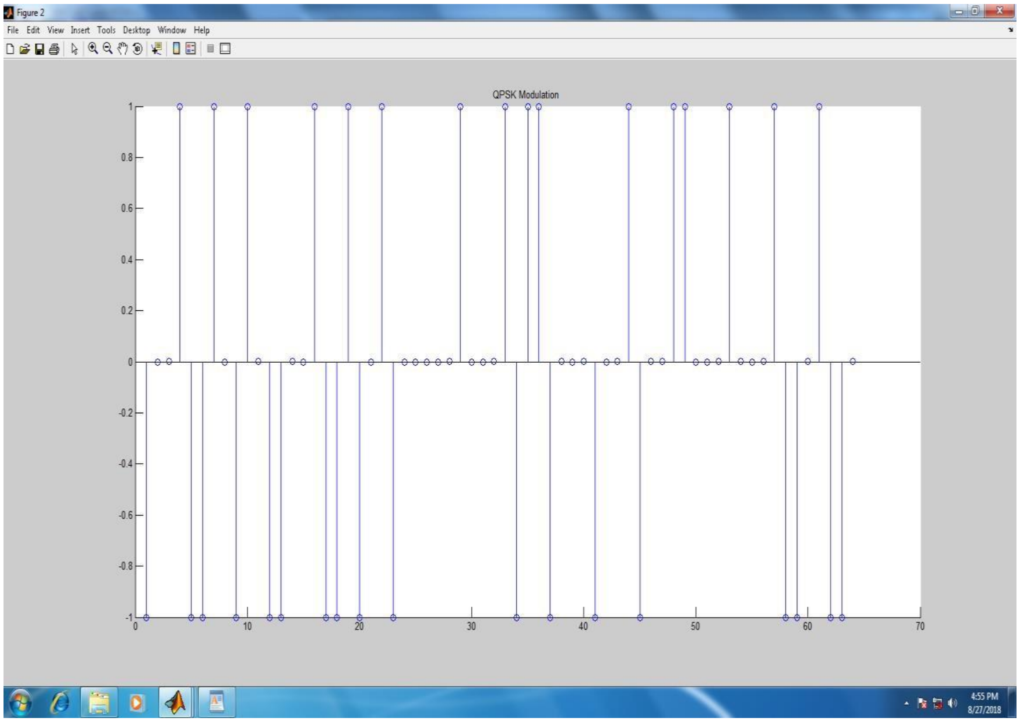


Figure3:BPSK Modulation

<u>Sub Carriers 1 to 4:</u>

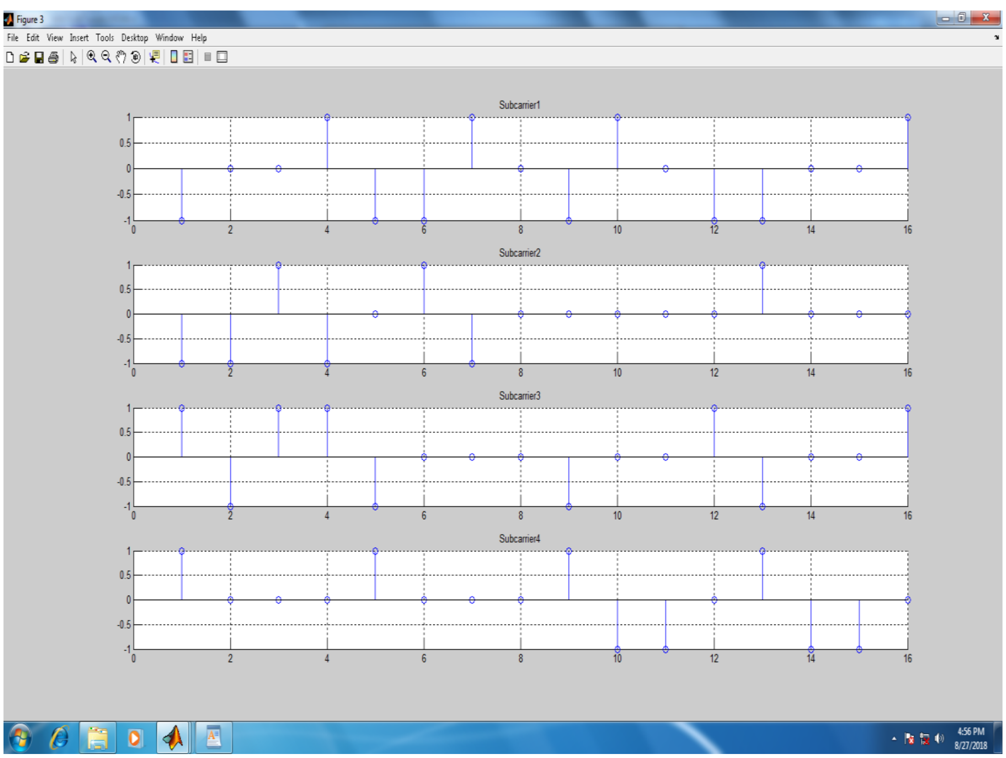


Figure 4: Sub Carriers 1 to 4

<u>IFFT of the Sub Carriers:</u>

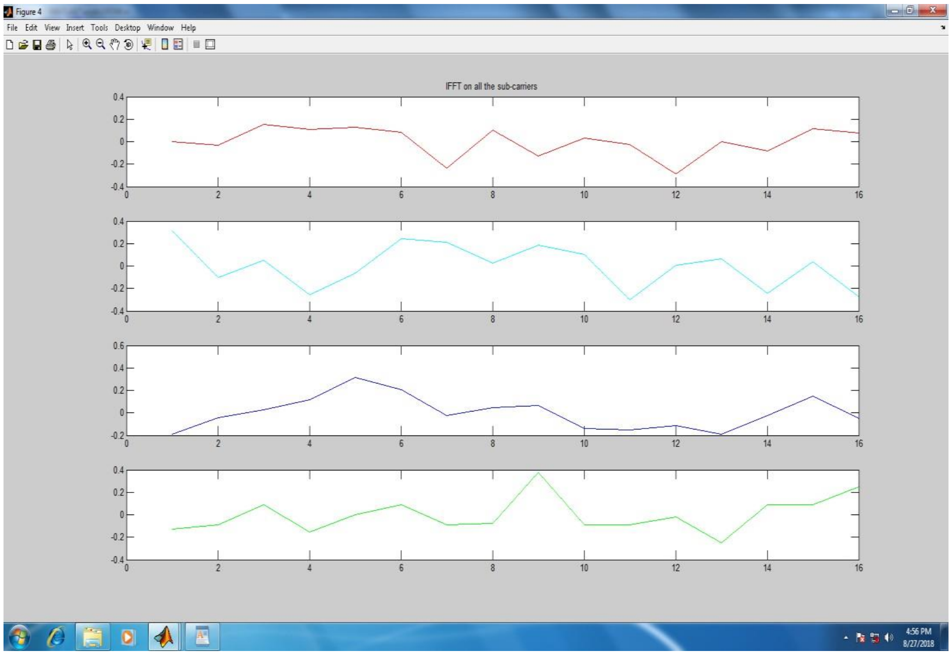


Figure 5: IFFT of the sub carriers

<u>Orthogonality:</u>

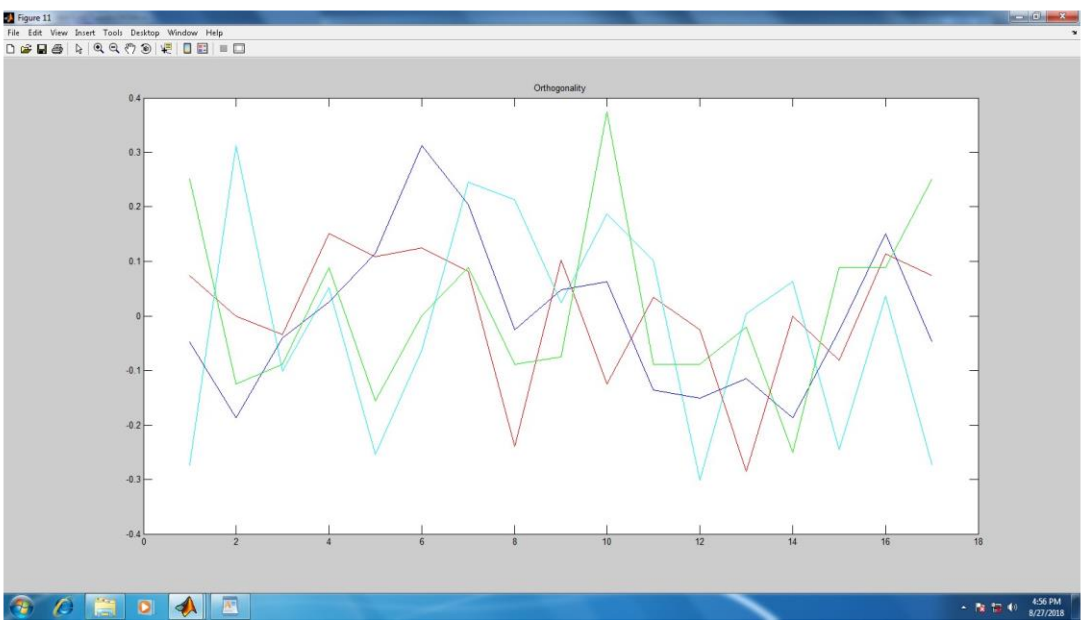


Figure 6: Orthogonality

OFDM Signal:

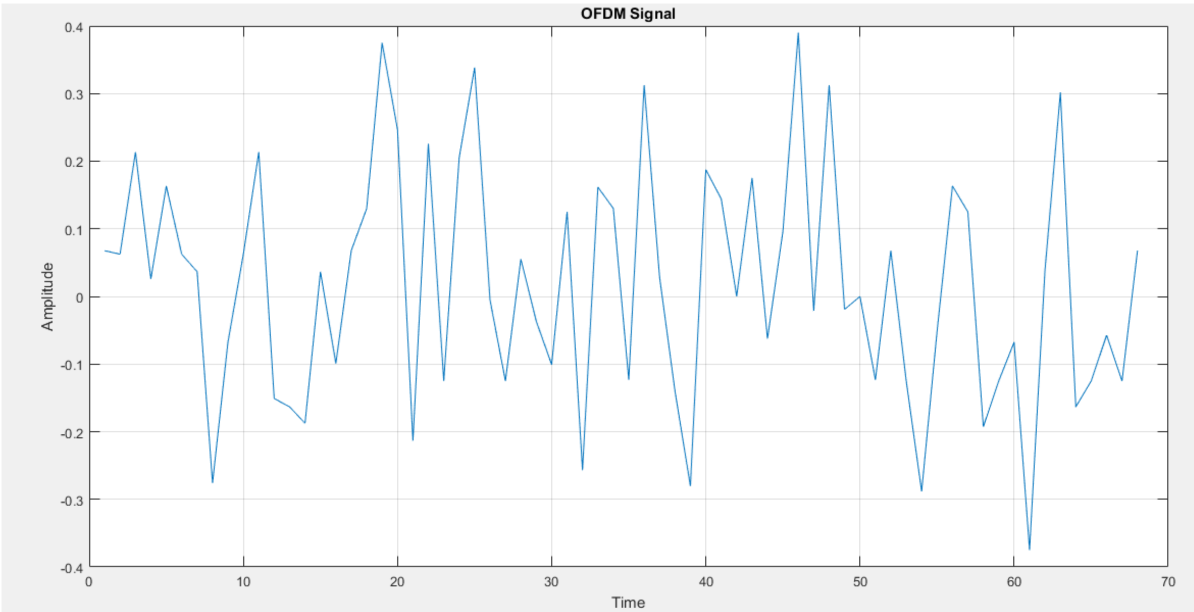


Figure 7: OFDM signal

OFDM Receiver:

```
recvd_signal_paralleled = reshape(recvd_signal,rows_Append_prefix, cols_Append_prefix);
```

% Remove cyclic Prefix

```
recvd_signal_paralleled(1:cp_len,:)=[];
R1=recvd_signal_paralleled(:,1);
R2=recvd_signal_paralleled(:,2);
R3=recvd_signal_paralleled(:,3);
R4=recvd_signal_paralleled(:,4);
figure(8),plot((imag(R1)),'r'),subplot(4,1,1),plot(real(R1),'r'),
title('Cyclic prefix removed from the four sub-carriers')
subplot(4,1,2),plot(real(R2),'c')
subplot(4,1,3),plot(real(R3),'b')
subplot(4,1,4),plot(real(R4),'g')
```

% FFT Of received signal

```
for i=1:number_of_subcarriers,
```

% FFT

```
fft_data(:,i) = fft(recvd_signal_paralleled(:,i),16);
end
F1=fft_data(:,1);
F2=fft_data(:,2);
```

```
F3=fft_data(:,3);
F4=fft_data(:,4);
figure(9), subplot(4,1,1),plot(real(F1),'r'),title('FFT of all the four sub-carriers')
subplot(4,1,2),plot(real(F2),'c')
subplot(4,1,3),plot(real(F3),'b')
subplot(4,1,4),plot(real(F4),'g')
```

% Signal reconstructed
% Conversion to serial and demodulation

```
recvd_serial_data = reshape(fft_data, 1,(16*4));
qpsk_demodulated_data = pskdemod(recvd_serial_data,4);
figure(10)
stem(data)
hold on
stem(qpsk_demodulated_data,'rx');
grid on;xlabel('Data Points');ylabel('Amplitude');
title('Recieved Signal with error')
```

Orthogonality:

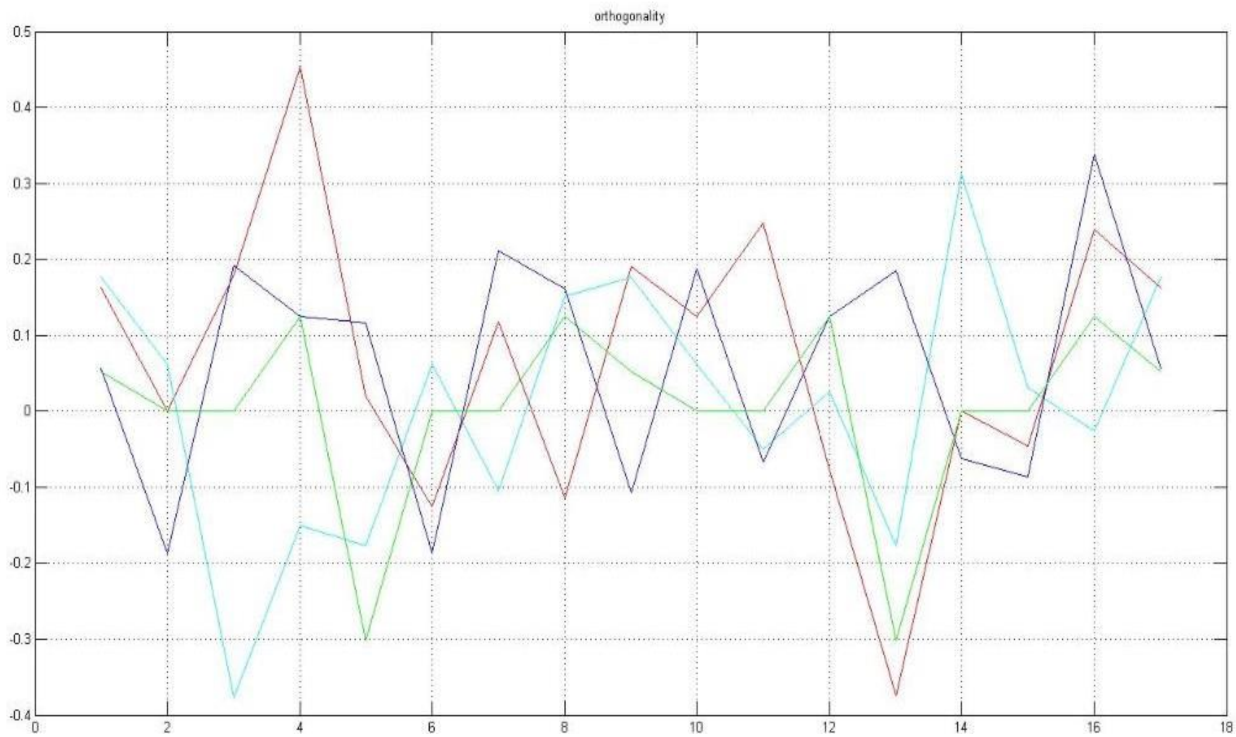


Figure8: Orthogonality

FFT of the Sub Carriers:

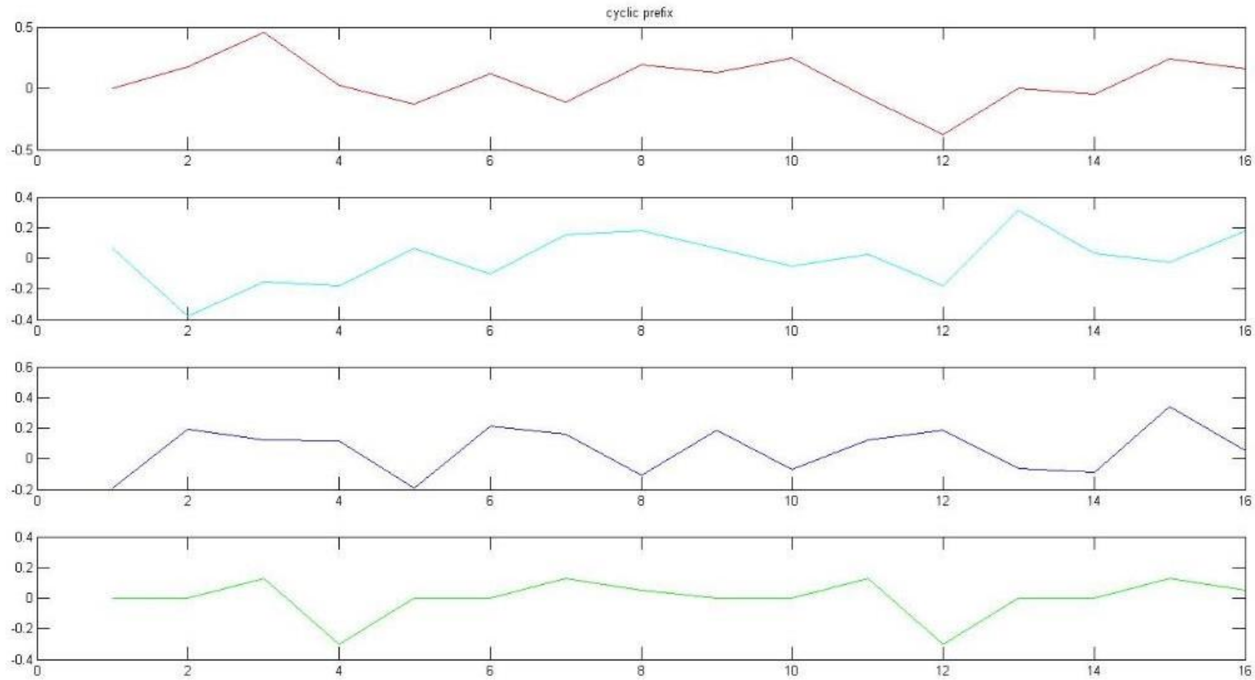


Figure 9: FFT of the sub carriers

Sub carriers 1 to 4:

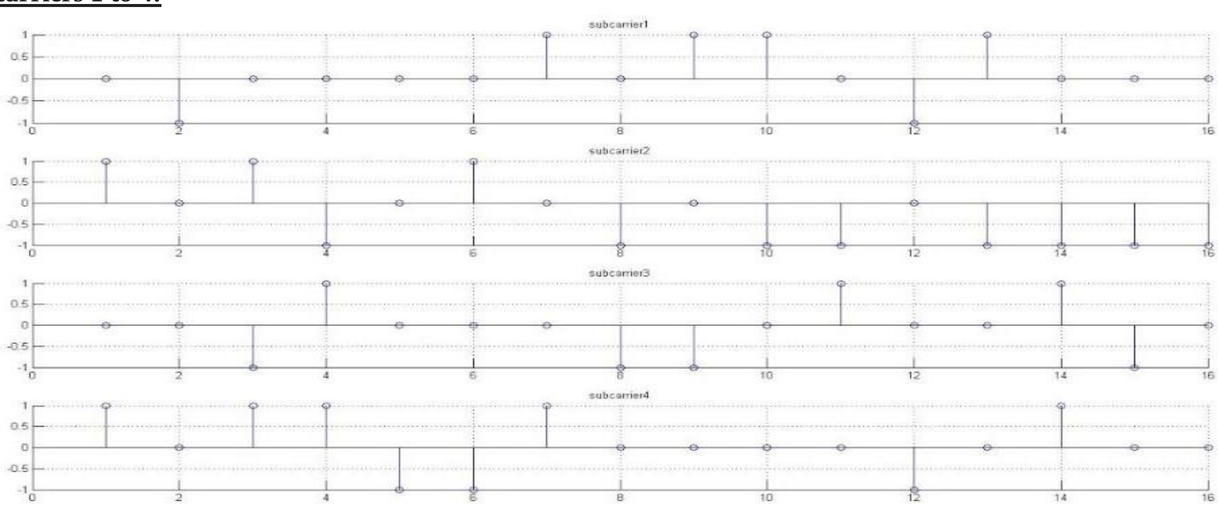


Figure10: Sub Carriers 1 to 4

BPSK Demodulation:

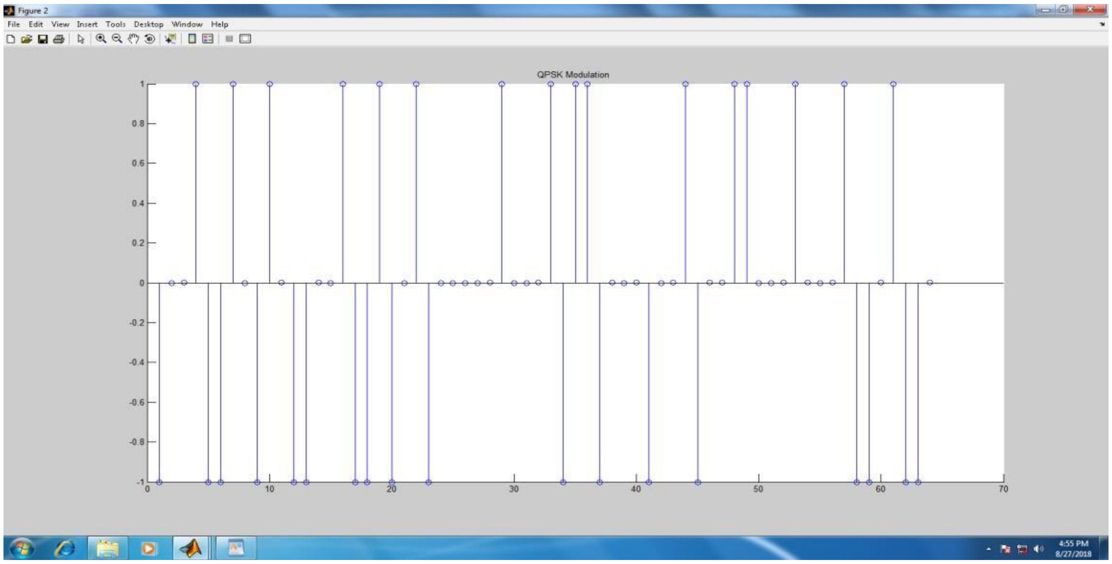


Figure11: BPSK Demodulation

Original Data:

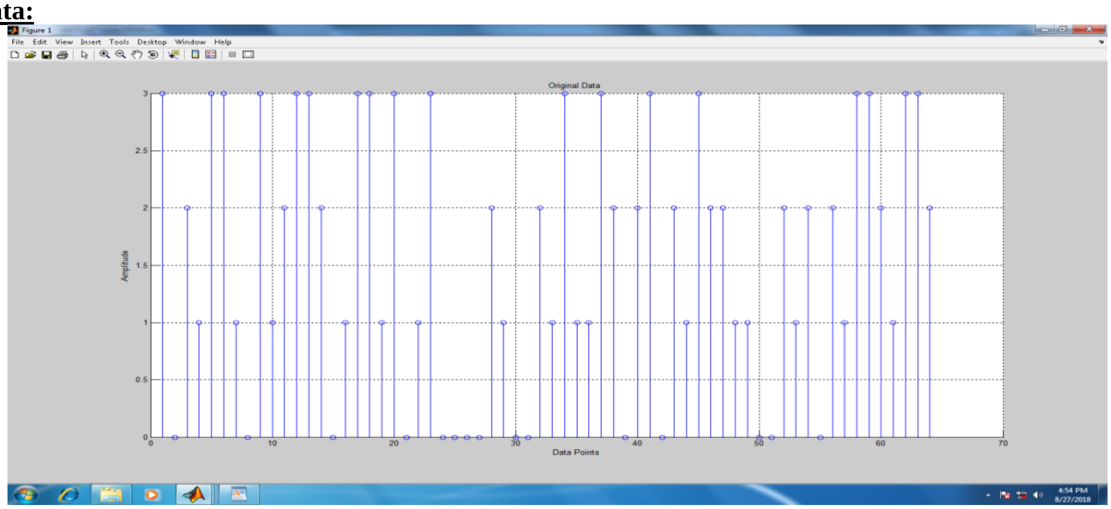


Figure 12: Original Data

Result:

MATLAB code for the given data: Number of bits 64, Number of subcarrier 4; Total number of bits to be transmitted256, Block size of OFDM 16 using PSK Modulation and simulate the transmitter and receiver blocks of OFDM is performed.

EXPT.10: SIMULATION OF MIMO SYSTEM USING MATLAB

Aim:

To write a MATLAB code for the 2X2 MIMO system using 16QAM modulation.

Software Used:

- MATLAB Version 7

Theory:

MIMO is an acronym that stands for Multiple Input Multiple Output. It is an antenna technology that is used both in transmission and receiver equipment for wireless radio communication. There can be various MIMO configurations. For example, a 2x2 MIMO configuration is 2 antennas to transmit signals (from base station) and 2 antennas to receive signals (mobile terminal). MIMO takes advantage of multi-path. MIMO uses multiple antennas to send multiple parallel signals (from transmitter). In an urban environment, these signals will bounce off trees, buildings, etc. and continue on their way to their destination (the receiver) but in different directions. "Multi-path" occurs when the different signals arrive at the receiver at various times. With MIMO, the receiving end uses an algorithm or special signal processing to sort out the multiple signals to produce one signal that has the originally transmitted data.

Types of MIMO

MIMO involves

1. Space Time Transmit Diversity (STTD)
2. Spatial Multiplexing (SM)
3. Uplink Collaborative MIMO.

1. **Space Time Transmit Diversity (STTD)** - The same data is coded and transmitted through different antennas, which effectively doubles the power in the channel. This improves Signal Noise Ratio (SNR) for cell edge performance.

2. **Spatial Multiplexing (SM)** - the "Secret Sauce" of MIMO. SM delivers parallel streams of data to CPE by exploiting multi-path. It can double (2x2 MIMO) or quadruple (4x4) capacity and throughput. SM gives higher capacity when RF conditions are favorable and users are closer to the BTS.

3. **Uplink Collaborative MIMO Link** - Leverages conventional single Power Amplifier (PA) at device. Two devices can collaboratively transmit on the same sub-channel which can also double uplink capacity.

Two transmit antennas, two receive antennas (2x2)

Under some circumstances, when the air channel presents bad characteristics, or when it is possible to implement more than one antenna at the receiver, the use of a higher order of diversity could be interesting. A detailed view of the two-transmit and two receive antennas is given, with the aim of simplicity, but the generalization can easily be done in the case of using any number of antennas.

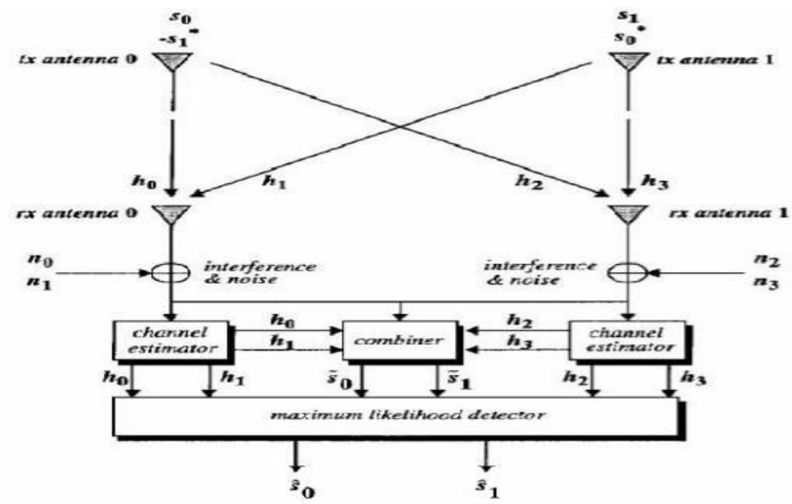


Figure 4.2 Two-branch transmit with two receive antennas scheme

The Encoding and Transmission Sequence

The encoding and transmission sequence for this configuration is identical. The channel at time t can be modeled by complex multiplicative distortions,$h_0(t)$, $h_1(t)$, $h_2(t)$, $h_3(t)$ between transmit antenna zero and receive antenna zero, transmit antenna one and receive antenna zero, transmit antenna zero and receive antenna one, transmit antenna one and receive antenna one, respectively. Table shows the signal notation for each antenna in each symbol time.

Notation of received signals at the receive antennas

	Antenna 0	Antenna 1
Receiving antenna 0	h_0	h_2
Receiving antenna 1	h_1	h_3

$$\begin{bmatrix} r_0 \\ r_2 \end{bmatrix} = \begin{bmatrix} h_0 & h_1 \\ h_2 & h_3 \end{bmatrix} \begin{bmatrix} s_0 \\ s_1 \end{bmatrix} + \begin{bmatrix} n_0 \\ n_2 \end{bmatrix}$$

$$\begin{bmatrix} r_1 \\ r_3 \end{bmatrix} = \begin{bmatrix} h_0 & h_1 \\ h_2 & h_3 \end{bmatrix} \begin{bmatrix} -\bar{s}_1 \\ \bar{s}_0 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_3 \end{bmatrix}$$

The received signals can then be expressed as

$$r_0 = h_0 s_0 + h_1 s_1 + n_0 \qquad (4.11)$$

$$r_1 = -h_0 s_1^* + h_1 s_0^* + n_1 \qquad (4.12)$$

$$r_2 = h_2 s_0 + h_3 s_1 + n_2 \qquad (4,13)$$

$$r_3 = -h_2 s_1^* + h_3 s_0^* + n_3 \qquad (4,14)$$

The complex random variables, n_0, n_1 , n_2 and n_3 represent the receiver thermal noise and interference.

The Combining Scheme

The combiner builds the following two combined signals, which are sent to the maximum likelihood detector

$$\begin{bmatrix} \bar{s_0} \\ \bar{s_1} \end{bmatrix} = \begin{bmatrix} \overline{h_0 h_2} & h_1 & h_3 \\ \overline{h_1 h_3} & -h_0 & -h_2 \end{bmatrix} \begin{bmatrix} r_0 \\ r_2 \\ \bar{r_1} \\ \bar{r_3} \end{bmatrix}$$

$$\tilde{s_0} = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 + h_3 r_3^* \qquad (4.15)$$

$$\tilde{s_1} = h_1^* r_0 - h_0 r_1^* + h_3^* r_2 - h_2 r_3^* \qquad (4.16)$$

The combined signals seen above are equal to those obtained using a four-branch MRRC. Hence, the diversity order obtained with the two schemes is the same. Another property is that the combined signals of the receive antennas are simply the addition of the combined signals from each receive antenna, so it is possible to implement a combiner for each antenna and then simply sum the output of each combiner.

MATLAB Code:

```
clc;
clear all;
close all;
ndata=2; % number of randam data
x=randint(ndata,1,1); % input data generated
x=[2 3];
%y=[x];

%INPUT DATA BITS

Data_input_bit(1,1)=x(1,1)
Data_input_bit(1,2)=x(1,2)
figure;plot(Data_input_bit);title('Input Bits');

%PERFORMING 16 QAM MODULATION ON THE INPUT DATA

z=qammod(Data_input_bit,4);
```

```
%CHANNEL COEFFICENTS MATRIX

h=[0.3 -.2 ;.1 .11];
%h11=1; h12=1; h21=1; h22=1;

%NOISE COEFFICENTS

e=[.1 .1;.1 .1];
%e11=1; e12=1; e21=1; e22=1;

out=zeros(10,1);
for i=1;%:ndata-1;

% SYMBOLS AT TIME PERIOD T;


out(i,1)=z(i);
out(i+1,1)=z(i+1);

% SYMBOLS AT TIME PERIOD T+1;

out(i,2)=-conj(z(i+1));
out(i+1,2)=conj(z(i));
%time_t2(i,1)=-conj(z(i+1));
%time_t2(i+1,1)=conj(z(i));
end

s1=out(i,1);
s2=out(i+1,1);
%for j=1:100
for i=1;

% RECIEVED DATA BY RX1 ANTENNA AT TIME INTERVAL T

r(1,1)= (h(1,1)*s1) + (h(1,2)*s2) + e(1,1);

% RECIEVED DATA BY RX1 ANTENNA AT TIME INTERVAL (T+1)

r(1,2)= ((-h(1,1))*conj(s2)) + (h(1,2)*conj(s1)) + e(1,2);

% RECIEVED DATA BY RX2 ANTENNA AT TIME INTERVAL T

r(2,1)= (h(2,1)*s1) + (h(2,2)*s2) + e(2,1);

% RECIEVED DATA BY RX2 ANTENNA AT TIME INTERVAL (T+1)

r(2,2)= ((-h(2,1))*conj(s2)) + (h(2,2)*conj(s1)) + e(2,2);
end


t(1,1)=((conj(h(1,1))*r(1,1)));
t(1,2)=h(1,2)*(conj(r(1,2)));
t(2,1)=((conj(h(2,1)))*r(2,1));
t(2,2)=((h(1,2)*(conj(r(2,2)))));

c(1,1)= ((conj(h(1,2)))*r(1,1));
```

```
c(1,2)= h(1,1)*(conj(r(1,2)));
c(2,1)= ((conj(h(2,2)))*r(2,1));
c(2,2)= ((h(2,1)*(conj(r(2,2)))));

%MAXIMUM LIKELEHHOD DETECTION SCEHME

s1_e =t(1,1) + t(1,2) + t(2,1) + t(2,2);
s2_e= c(1,1) - c(1,2) + c(2,1) - c(2,2);
%s1_e= ((conj(h(1,1))*r(1,1))) + ((h(1,2)*(conj(r(1,2))))+ ((conj(h(2,1)))*r(2,1)) + ((h(1,2)*(conj(r(2,2)))));
%s2_e= ((conj(h(1,2)))*r(1,1)) - ((h(1,1)*(conj(r(1,2)))) + ((conj(h(2,2)))*r(2,1)) - ((h(2,1)*(conj(r(2,2)))));

%PERFORMING 16 QAM DEMODULATION
%FINAL OUTPUT BITS


final_output_Bits(1,1)=qamdemod(s1_e,4)
final_output_Bits(1,2)=qamdemod(s2_e,4)
figure;plot(final_output_Bits);title('final output Bits');
```

Result:
Input:

Input bits:

x = 2 3

Input data bits:

Data_input_bit = 2
Data_input_bit = 2 3

Performing 16 QAM modulation on the input data:

z =1.0000 + 1.0000i 1.0000 - 1.0000i

Channel coefficients matrix:

h = 0.3000 -0.2000
0.1000 0.1100

Noise coefficients:

e = 0.1000 0.1000
0.1000 0.1000

Out matrix:

out = 0
0
0
0
0
0
0
0
0
0

Symbols at time period T:

out = 1.0000 + 1.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i

out = 1.0000 + 1.0000i
1.0000 - 1.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i

Symbols at time period T+1:

out = 1.0000 + 1.0000i -1.0000 - 1.0000i
1.0000 - 1.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i

out = 1.0000 + 1.0000i -1.0000 - 1.0000i
1.0000 - 1.0000i 1.0000 - 1.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i

s1 = 1.0000 + 1.0000i

s2 = 1.0000 - 1.0000i

Received Data By Rx1 Antenna At Time Interval T:

r = 0.2000 + 0.5000i

Received Data By Rx1 Antenna At Time Interval (T+1)

r = 0.2000 + 0.5000i -0.4000 - 0.1000i

Received Data By Rx2 Antenna At Time Interval T

r = 0.2000 + 0.5000i -0.4000 - 0.1000i
0.3100 - 0.0100i 0.0000 + 0.0000i

Received Data By Rx2 Antenna At Time Interval (T+1)

r = 0.2000 + 0.5000i -0.4000 - 0.1000i
0.3100 - 0.0100i 0.1100 - 0.2100i

t = 0.0600 + 0.1500i

t = 0.0600 + 0.1500i 0.0800 - 0.0200i

t = 0.0600 + 0.1500i 0.0800 - 0.0200i
0.0310 - 0.0010i 0.0000 + 0.0000i

t = 0.0600 + 0.1500i 0.0800 - 0.0200i
0.0310 - 0.0010i -0.0220 - 0.0420i

c = -0.0400 - 0.1000i

c = -0.0400 - 0.1000i -0.1200 + 0.0300i

c = -0.0400 - 0.1000i -0.1200 + 0.0300i
0.0341 - 0.0011i 0.0000 + 0.0000i

c = -0.0400 - 0.1000i -0.1200 + 0.0300i
0.0341 - 0.0011i 0.0110 + 0.0210i

Maximum Likelehhod Detection Scehme

s1_e = 0.1490 + 0.0870i

s2_e = 0.1031 - 0.1521i

Final Output Bits :
final_output_Bits = 2

final_output_Bits = 2 3

<u>Original Data:</u>

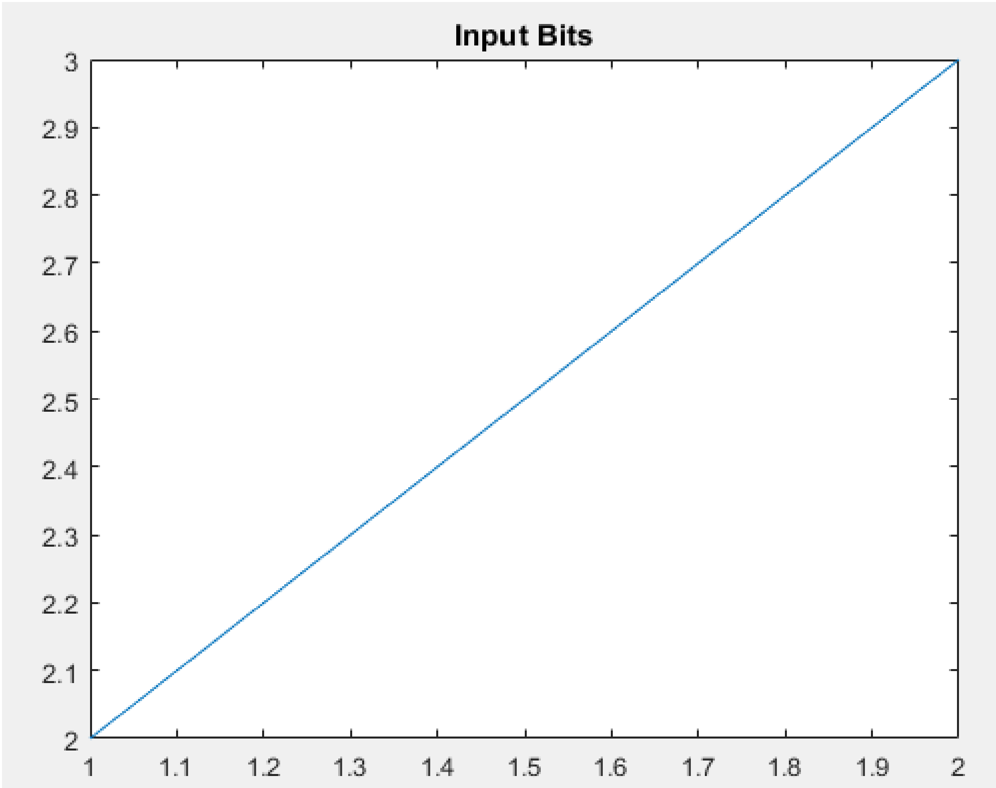


Figure 1 : Original Data

Final output bits:

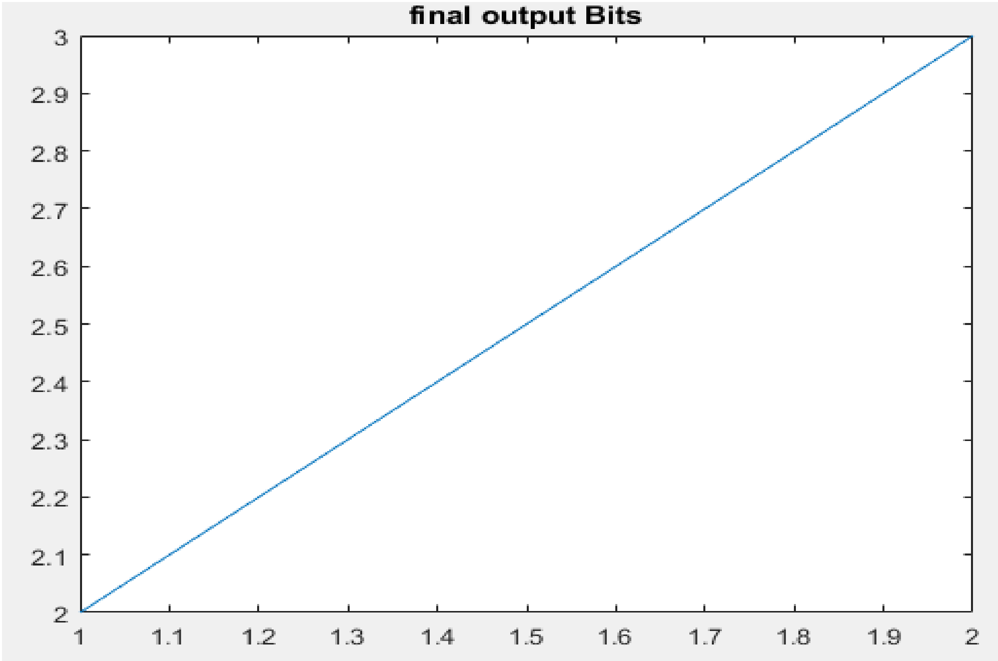


Figure 2 : final output bits

Result:

MATLAB program for 2X2 MIMO with 16 bit QAM is performed.

EXPT. 11: CALCULATE THE LINK BUDGET FOR SATELLITECOMMUNICATION

Aim :

To write a MATLAB program to calculate the link budget for satellite communication.

Theory :

A link budget is an accounting of all the gains and losses in a transmission system. The link budget looks at the elements that will determine the signal strength arriving at the receiver. The link budget may include the following items:

- Transmitter power.
- Antenna gains (receiver and transmitter).
- Antenna feeder losses (receiver and transmitter).
- Path losses.
- Receiver sensitivity (although this is not part of the actual link budget, it is necessary to know this to enable any pass fail criteria to be applied.

Where the losses may vary with time, e.g. fading, and allowance must be made within the link budget for this - often the worst case may be taken, or alternatively an acceptance of periods of increased bit error rate (for digital signals) or degraded signal to noise ratio for analogue systems.

Received power (dBm) = Transmitted power (dBm) + gains (db) - losses (dB)

The basic calculation to determine the link budget is quite straightforward. It is mainly a matter of accounting for all the different losses and gains between the transmitter and the receiver.

Losses = FSL + AML + RFL + PL + AA

FSL = Freespace loss AML = Antenna Misalignment loss

RFL=Receiver Feeder loss PL=Polarization Loss AA

= Atmospheric Absorption.

Carrier to Noise Ratio – Uplink

$CNR_u = EIRP_u + GTR_u - Loss_u + 228.6$

Carrier to Noise Ratio – downlink

$CNR_d = EIRP_d + GTR - Loss_d + 228.6$

Overall Carrier to Noise Ratio

Overall Carrier to Noise Ratio

$CNR_{overall} = CNR_u \text{ X } CNR_d / (CNR_u + CNR_d)$

Program:

```
clc;
clear all;
close all;
 % Input parameters
pt = input('Enter the input power in watts: ');
Pt = 10 * log10(pt);  % Convert transmitted power to dB
 gt = input('Enter the transmitting antenna gain in dB: ');
gs = input('Enter the receiving antenna gain in dB: ');

% Calculate EIRP (Effective Isotropic Radiated Power)
EIRP = Pt + gt;

% Display EIRP
fprintf('The EIRP is: %.2f dB\n', EIRP);

% Path loss calculation inputs
d = input('Enter the distance in km: ');
f = input('Enter the frequency in MHz: ');

% Calculate free space loss (FSL)
fsl = 32.4 + 20 * log10(d) + 20 * log10(f);

% Display free space loss
fprintf('The free space loss is: %.2f dB\n', fsl);

% Additional loss inputs
rfl = input('Enter the receiver feeder loss in dB: ');
aa = input('Enter the atmospheric absorption in dB: ');
aml = input('Enter the antenna misalignment loss in dB: ');
pl = input('Enter the polarization loss in dB: ');

% Calculate total losses
```

```
losses = fsl + rfl + aa + aml + pl;

% Display total losses
fprintf('Total losses: %.2f dB\n', losses);

% Calculate received power
P = EIRP + gs - losses;

% Display received power
fprintf('Total received power: %.2f dB\n', P);
```

Inputs:

Enter the input power in watts: 0.001

Enter the transmitting antenna gain in dB: 10

Enter the receiving antenna gain in dB: 5

The EIRP is: -20.00 dB

Enter the distance in km: 10

Enter the frequency in MHz: 2000

The free space loss is: 118.42 dB

Enter the receiver feeder loss in dB: 2

Enter the atmospheric absorption in dB: 0.5

Enter the antenna misalignment loss in dB: 1

Enter the polarization loss in dB: 0.5

Total losses: 122.42 dB

Total received power: -137.42 dB

Result:

The Matlab program for calculating the link budget was simulated successfully.

EXPT 12 : CALCULATION OF THE LINK BUDGET FOR SATELLITECOMMUNICATION AND ALSO TO CALCULATE THE CARRIER TO NOISERATIO FOR UPLINK AND DOWNLINK AND ALSO THE OVERALL CARRIER TO NOISE RATIO.

Aim :

To write a Matlab program to calculate the link budget for satellite communication and also to calculate the Carrier tonoise ratio for uplink and downlink and also the overall carrier to noise ratio.

Theory :

A link budget is an accounting of all the gains and losses in a transmission system. The link budget looks at the elements that will determine the signal strength arriving at the receiver. The link budget may include the following items:

- Transmitter power.
- Antenna gains (receiver and transmitter).
- Antenna feeder losses (receiver and transmitter).
- Path losses.
- Receiver sensitivity (although this is not part of the actual link budget, it is necessary to know this to enableany pass fail criteria to be applied.

Where the losses may vary with time, e.g. fading, and allowance must be made within the link budget for this - oftenthe worst case may be taken, or alternatively an acceptance of periods of increased bit error rate (for digital signals) or degraded signal to noise ratio for analogue systems.

Received power (dBm) = Transmitted power (dBm) + gains (db) - losses (dB)

The basic calculation to determine the link budget is quite straightforward. It is mainly a matter of accounting for allthe different losses and gains between the transmitter and the receiver.

Losses = FSL + AML + RFL + PL + AA

FSL = Freespace loss

AML = Antenna Misalignment loss

RFL=Receiver Feeder loss

PL=Polarization Loss AA

= Atmospheric Absorption.

Carrier to Noise Ratio – Uplink

CNR_u=$EIRP_u$+GTR_u-$Loss_u$+228.6

Carrier to Noise Ratio – downlink

CNR_d=$EIRP_d$+GTR-$Loss_d$+228.6

Overall Carrier to Noise Ratio

$$CNR_{total} = 10 \cdot \log_{10}(10^{CNR_u/10} + 10^{CNR_d/10})$$

Program:

```
clc;

clear all;
```

```
close all;

% Input parameters
EIRPu = input('Enter the uplink EIRP: ');
EIRPd = input('Enter the downlink EIRP: ');
GTRu = input('Enter the uplink G/T: ');
GTRd = input('Enter the downlink G/T: ');
FSLu = input('Enter the uplink FSL: ');
FSLd = input('Enter the downlink FSL: ');
RFLu = input('Enter the uplink RFL: ');
RFLd = input('Enter the downlink RFL: ');
AAu = input('Enter the uplink AA: ');
AAd = input('Enter the downlink AA: ');
AMLu = input('Enter the uplink AML: ');
AMLd = input('Enter the downlink AML: ');

% Calculate total losses
Lossu = FSLu + RFLu + AAu + AMLu;  % Uplink total losses
Lossd = FSLd + RFLd + AAd + AMLd;  % Downlink total losses

% Calculate CNR for uplink and downlink
CNRu = EIRPu + GTRu - Lossu + 228.6;  % Uplink CNR
CNRd = EIRPd + GTRd - Lossd + 228.6;  % Downlink CNR

% Display the uplink and downlink CNR
fprintf('Total carrier-to-noise ratio for uplink is: %.2f dB\n', CNRu);
fprintf('Total carrier-to-noise ratio for downlink is: %.2f dB\n', CNRd);

% Calculate the total CNR (in dB)
CNRt = 10 * log10(10^(CNRu / 10) + 10^(CNRd / 10));

% Display the total CNR
fprintf('Total carrier-to-noise ratio is: %.2f dB\n', CNRt);
```

Inputs

Enter the uplink EIRP: 50

Enter the downlink EIRP: 30

Enter the uplink G/T: 12

Enter the downlink G/T: 15

Enter the uplink FSL: 190

Enter the downlink FSL: 195

Enter the uplink RFL: 2

Enter the downlink RFL: 3

Enter the uplink AA: 0.5

Enter the downlink AA: 0.7

Enter the uplink AML: 0.5

Enter the downlink AML: 0.7

Total carrier-to-noise ratio for uplink is: 97.60 dB

Total carrier-to-noise ratio for downlink is: 74.20 dB

Total carrier-to-noise ratio is: 97.62 dB

Result:

The program for power received by an antenna and path loss in Free space propagation was simulated successfully.

Frequently Asked Question
Questions:

· Which are various spread spectrum modulation techniques?
· Why is spread spectrum modulation needed?
· Why is spread spectrum modulation more efficient?
· What is principle of DSSS?
· What is need of PN sequence?
· Which are different types of codes used in CDMA?

List Multiple Access Techniques?
Ans: There are three basic schemes:
• Frequency Division Multiple Access (FDMA)
• Time Division Multiple Access (TDMA)
• Code Division Multiple Access (CDMA)

Define Frequency Division Multiple Accesses (FDMA)?
Ans: In FDMA the bandwidth is divided into a number of channels and distributed among users with a finite portion of bandwidth for permanent. FDMA channels have narrow bandwidth (30 KHz) and therefore they are usually implemented in narrowband systems.

How adjacent channel interference is minimized?
Ans: Guard bands are introduced between frequency bands to minimize adjacent channel interference. Guard bands are unused frequency slots that separate neighboring channels.

What is the drawback of FDMA?
Ans: Guard bands are unused frequency slots that separate neighboring channels. This leads to a waste of bandwidth. When continuous transmission is not required, bandwidth goes wasted since it is not being utilized for a portion of the time.

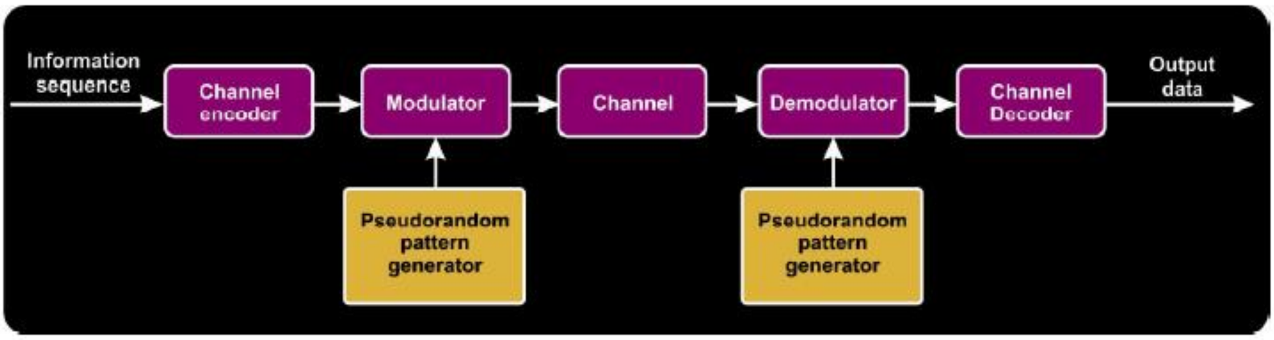
Define Time Division Multiple Access (TDMA)?
Ans: TDMA is a complimentary access technique to FDMA. In TDMA, the entire bandwidth is available to the user but only for a finite period of time. In most cases the available bandwidth is divided into fewer channels compared to FDMA and the users are allotted time slots during which they have the entire channel bandwidth at their disposal.

Define Code Division Multiple Access (CDMA)?
Ans: Code division multiple access (CDMA) is a form of multiplexing (not a modulation scheme) and a method of multiple access that does not divide up the channel by time (as in TDMA), or frequency (as in FDMA), but instead encodes data with a special code associated with each channel and uses the constructive interference properties of the special codes to perform the multiplexing.

How many types of CDMA techniques are there?
Ans: There are two basic types of CDMA: Synchronous CDMA, Asynchronous CDMA

What are the features of CDMA?
Ans: The features of CDMA are as follows: Narrowband message signal multiplied by wideband spreading signal or pseudo noise code Each user has his own pseudo noise (PN) code Soft capacity limit: system performance degrades for all users as number of users increases Cell frequency reuse: no frequency planning needed Soft handoff increases capacity Near-far problem Interference limited: power control is required Wide bandwidth induces diversity: rake receiver is used Extended battery life because of effective power control

Draw the block diagram of spread-spectrum digital communications system?
Ans:



Differentiate between BPSK and QPSK?

Ans: Quadrature Phase Shift Keying: In QPSK amplitude are not much. So the carrier is constant. Transmission rate is higher when compared with PSK. Keying of binary data or Morse code dots and dashes by ±90° phase deviation of the carrier. Abbreviated BPSK.

What is QPSK?

Ans: If we define four signals, each with a phase shift differing by 90 degree then we have Quadrature Phase Shift Keying (QPSK).

What do you understand by 2 PSK and 4 PSK systems?

Ans: In 2-phase PSK modulation, called 2-PSK, or Binary PSK (BPSK), or Phase Reversal Keying (PSK), the sine carrier takes 2 phase values, determined by the binary data signal. In 4-PSK, or Quadrature PSK (QPSK), the sine carrier takes 4 phase values, separated of 90° and determined by the combinations of bit pairs (Dibit) of the binary data signal. The data are coded into Dibit by a circuit generating:

· A data signal I *(In phase)* consisting in voltage levels corresponding to the value of the first bit of the considered pair, for a duration equal. To 2 bit intervals

· A data signal Q *(Quadrature)* consisting in voltage levels corresponding to the value of the second bit of the pair, for duration equal to 2 bit intervals.

What is Pseudo-random Noise (PN) sequence?

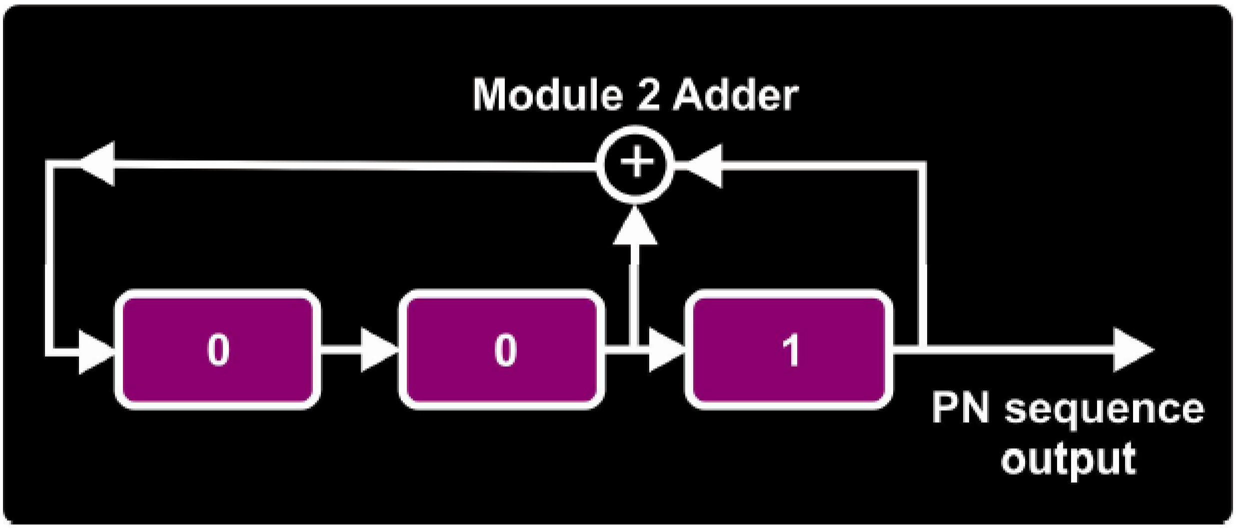
Ans: A Pseudo-random Noise (PN) sequence is a sequence of binary numbers, e.g. ±1, which appears to be random; but is in fact perfectly deterministic. The sequence appears to be random in the sense that the binary values and groups or runs of the same binary value occur in the sequence in the same proportion they would if the sequence were being generated based on a fair "coin tossing" experiment.

What are the uses of Pseudo-random Noise (PN) sequence?

Ans: They can be used to logically isolate users on the same frequency channel. They can also be used to perform scrambling as well as spreading and dispreading functions.

Draw the block diagram and explain how PN sequence can be generated?

Ans: A PN generator is typically made of N cascaded flip-flop circuits and a specially selected feedback arrangement as shown below. The flip-flop circuits when used in the cascaded manner is called a shift register, since each clock pulse applied to the flip-flops causes the contents of each flip-flop to be shifted to the right. The feedback connections provide the input to the left-most flipflop. With N binary stages, the largest number of different patterns the shift register can have is 2N. However, the all-binary-zero state is not allowed because it would cause all remaining states of the shift register and its outputs to be binary zero. The all-binary-ones state does not cause a similar problem of repeated binary ones provided the number of flip-flops input to the module 2 adder is even. The period of the PN sequence is therefore 2N-1, but IS-95 introduces an extra binary zero to
achieve a period of 2N, where N equals 15.



Q. Why you made it with Nokia, we need the one with Samsung/Motorola.
Ans. Let us clear something first, this is not to teach Nokia or Samsung. The concept is to give a working of GSM user end technology. We have chosen Nokia because it is more popular and easy to explain/expand. Whether it is of any make they have common GSM technology.

Q. Why there is no software section in the TechBook.
Ans. There is lot of scope for students to learn software many courses are being offered for J2ME, NET, and Symbian etc. and sooner or later he/she will acquire knowledge from professional field. We are considering customer feedback for software section.

Q. Why there is less No. of test points in the network section/ there are only (dead) block diagram not live circuits in network section.
Ans. The compactness and SMD components are the first phase of problems. Then as GSM utilizes both TDMA and FDMA it makes the task more complicated. The mobile phone should be in proper synchronization with the base station it shouldn’t be more/less. If more then it affects the other users, if less it will lead no network.
Q. Does the TechBook operate at 900MHz only?
Ans. The TechBook operates on both 900MHz & 1800MHz. But only the experiments concerning network section are limited to 900MHz band.

Q. Why does the TechBook need continuous charging or why there is high power consumption?
Ans. The battery needs continuous charging when there is a Tx/Rx operation. Because the operation consumes more power. There is power loss because of the added expansion and test points. Where as there is no need of charging during other section experiments.

Q. What is dual SIM?
Ans. Dual SIM means the phone can hold and use two SIM cards in the same handset. Each SIM card has its own phone number and may be from totally different networks. The phone keeps both SIMs - i.e. both numbers-switched on at all times, so you can make and receive calls on either of the two numbers.

Q. How does dual SIM work?
Ans. The answer to this question all depends on the phone. Some types of unlocked phone have two CPUs (central processing units, the part of the phone that does the ‘thinking’) which allow them to make two calls at the same time. You can receive signals for both numbers. Not all dual SIM card phones have two CPUs and this can have two results for consumers. If the phone has "call secretary" software, or your carrier has an "online call secretary" service, then when another call comes in, and you're busy, the incoming call will go to voicemail. If no such software or option exists on your GSM dual mobile then the other caller will just be told that your line is busy.

Q. What is 2G?

Ans. 2G is short for Second-Generation wireless telephone technology. The main differentiator to previous mobile telephone systems, retroactively dubbed 1G, is that the radio signals that 1G networks use are analog, while 2G networks are digital. Note that both systems use digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system.

Flavors of 2G

2G technologies can be divided into TDMA-based standard and CDMA-based standard depending on the type of multiplexing used.

The main 2G standards are:

- GSM (TDMA-based), originally from Europe but used worldwide
- iDEN (TDMA-based), proprietary network used in the United States and in Canada
- IS-136 aka D-AMPS, (TDMA-based, commonly referred as simply TDMA in the US), used in the Americas
- IS-95 aka cdmaOne, (CDMA-based, commonly referred as simply CDMA in the US), used in the Americas and parts of Asia
- PDC (TDMA-based), used exclusively in Japan

2.5G services, which enable high-speed data transfer over upgraded existing 2G networks, are widely deployed worldwide. Next-generation 3G, designed to allow the transmission of very large quantities of data, is also becoming increasingly popular. Work on 4G has already started although its scope is not clear yet. Higher data speeds enable new services for subscribers, such as picture messaging and video telephony.

Capacity

Using digital signals between the handsets and the towers increases system capacity in two key ways:

- Digital voice data can be compressed and multiplexed much more effectively than analog voice encodings through the use of various CODECs, allowing more calls to be packed into the same amount of radio bandwidth.
- The digital systems were designed to emit less radio power from the handsets. This meant that cells could be smaller, so more cells could be placed in the same amount of space. This was also made possible by cell towers and related equipment getting less expensive.

Advantages to 1G

Digital systems were embraced by consumers for several reasons.

- The lower powered radio signals require less battery power, so phones last much longer between charges, and batteries can be smaller.
- The digital voice encoding allowed digital error checking which could increase sound quality by reducing static and lowering the noise floor.
- The lower power emissions helped address health concerns.
- Going all-digital allowed for the introduction of digital data services, such as SMS and email.
- A key digital advantage not often mentioned is that digital cellular calls are much harder to eavesdrop on by use of radio scanners. While the security algorithms used have proved to not be as secure as initially advertised, 2G phones are immensely more private than 1G phones, which have no protection whatsoever against eavesdropping.

Disadvantages

The downsides of 2G systems, not often well publicized, are:

- In less populous areas, the weaker digital signal will not be sufficient to reach a cell tower.
- Analogue has a smooth decay curve, digital a jagged step one. This can be both an advantage and a disadvantage. Under good conditions, digital will sound much better. Under slightly worse conditions, analogue will have annoying static, while digital has occasional dropouts. As conditions worsen, though, digital will start to completely fail, by dropping calls or being unintelligible, while analogue just slowly gets worse and worse, generally holding a call longer and allowing at least a few words to get through.
- Despite the coverage maps provided by major phone companies, as of 2006 digital coverage in many areas is spotty at best.
- With analogue systems it was possible to have two or more "Cloned" handsets that had the same phone number. This was widely abused for fraudulent purposes. It was, however, of great advantage in many legitimate situations.

One could have a backup handset in case of damage or loss, a permanently installed handset in a car or remote workshop, and so on. With digital systems, this is no longer possible.

- While digital calls tend to be free of static and background noise, the lossy compression used by the CODECs takes a toll; the range of sound that they convey is reduced. You'll hear less of the tonality of someone's voice talking on a digital cell phone, but you will hear it more clearly.

Q. What is the difference between GSM and CDMA?

Ans. Before discussing and differentiating these two technologies we should know their separate meanings.

GSM:

Global System for Mobile Communication and popularly known as GSM. It is copyrighted term which refers to the use of Time-Division Multiple Access Technology known as TDMA. This technology is now globally available over 100 countries and is considered as the standard for communication especially in Asia and Europe. It functions on four distinct frequencies i.e. 900MHz and 1,800MHz bands in Europe and Asia while in North America and Latin America at 850 MHz and 1,900 MHz bands. Eight simultaneous calls on the same radio frequency are possible with GSM. It uses "Narrowband" TDMA which allows digital transmission between a cell phone and a base station. It is termed as narrowband because the frequency band, with TDMA is divided into numerous channels which are then piled together into a single stream. One plus point is that more than one caller can share the same channel at the same time.

CDMA:

Code Division Multiple Access abbreviated as CDMA is an entirely different technology. It particularly implicates multiplexing technology and technique used is for digital communication. After the channel is digitized, it spreads data out over the channel. It presents greater security as compared to GSM/TDMA as it is more efficient in analog transmission, has increasing battery capacity, greater frequency reuse and rate of dropped calls is improved. Because of its much reliable features, the experts favor its development across the globe. It is mostly found in United States, Canada and North and South Korea. The original CDMA is now called as CDMAoneTM.

Difference:

The basic difference between the two i.e. GSM and CDMA is regarding their frequency bands. In case of GSM, the end user doesn't have access to the entire frequency band whereas in case of CDMA the end user can access the entire frequency. So we can say that in CDMA frequencies re-use factor is 1. It's a debate that either GSM or CDMA is superior to the other but if we take account the users which need to the point information to attain the services and make choice out of it, following consideration will may help them.

Coverage:

It is consider being most important factor that is you find cellular services wherever you are but CDMA and GSM are the only carriers that provide cellular services everywhere. In this case there will not be any difference but the customers still have a choice.

Speed in Data Transferring:

People who use their phone more than making calls, it means use it as a streaming video device or email devices, speed is the most vital factor and in this area CDMA is said to be traditionally faster than GSM though both of these technologies claim 3rd Generation Standards. So people have choice in this case.

Subscriber Identity Module (SIM) Cards:

In United States, SIM cards are used by GSM only. Without carrier intervention, the removable SIM cards enable cell phone to get instantly activated, upgraded and swapped. GSM takes over CDMA in the case that the phones which are easily get enabled with card and are also useable with any of the present carriers but in case of CDMA phone, the old phone has to be deactivated by the carrier and then active the new one. Hence, the old phone turns out to be useless.

Roaming:

GSM carriers are having roaming contracts with other GSM carriers which enable wider and reliable coverage even in rural areas and the customers also do not have to bear the charges whereas charges, in case of CDMA networks, are significantly higher and they also do not cover rural areas but they may contract with GSM cells regarding roaming in rural areas.

Q. What is the difference Multiple Access Techniques used in GSM?

Ans. In cellular and cordless terminology the three main types of multiple access used to divide the radio frequency spectrum between the cell site radios and the mobile stations are:

· **Frequency Division Multiple Access (FDMA):**

Each call is carried on a separate frequency channel.

· **Time Division Multiple Access (TDMA):**

Each frequency channel is further divided into a set of timeslots; each timeslot carries the data of a voice call.

· **Code Division Multiple Access (CDMA):**

A Spread-Spectrum Technology is used, in which the radio signals associated with a call are spread across a single broad frequency spectrum (1.25 MHz). Each call in the spectrum is differentiated from other calls in that spectrum by assigning a unique code to each call's signal. At the receiving end (mobile station or cell site), the specific call's signal is isolated by decoding the full received signal using the code assigned to that call's signal.

Q. What is the difference Multiplexing technique used in GSM?

Ans. The two multiplexing techniques used in cellular and cordless terminology are:

· **Frequency Division Duplexing (FDD)**

In FDD two symmetric frequency bands are used, one contains the uplink channels and the other the downlink channels.

· **Time Division Duplexing (TDD)**

TDD means that the uplink of the voice call is time multiplexed on the same frequency channel as the downlink of the voice call.