OBJECT DETECTION USING WIRELESS SIGNALS

by

Gorla Praveen

A special study submitted in partial fulfillment of the requirements for the degree of Master
of Engineering in Telecommunications

Examination Committee: Dr. Teerapat Sanguankotchakorn (Chairperson)
Dr. Poompat Saengudomlert (Member)
Dr. Attaphongse Taparugssanagorn (Member)

Nationality: Indian
Previous Degree: Bachelor of Engineering in Electronics and Communication
Engineering
Jawaharlal Nehru Technological University, India

Scholarship Donor: AIT Fellowship

Asian Institute of Technology
School of Engineering and Technology
Thailand
September 2017

Acknowledgments

I would like to express my profound gratitude to my esteemed advisor, Dr. Teerapat Sangankotchakorn, Professor & Head of Telecommunication Engineering field of study, for his advice throughout this course.

I would like to take this opportunity to thank Dr. Poompat Saengudomlert for his timely guidance on the report and Dr. Attaphongse Taparugssanagorn for his comments and suggestions on the report.

Finally, I thank my parents and friends for their support.

Gorla Praveen
November 2017

Abstract

Wireless signals play major a role not only in establishing communication between the node to node but also for providing information about the other end of the destination node. Wireless signals especially used in radar engineering are used to detect the target eliminating the use of large number sensors.

RF wireless signals which are generated from the networking (WiFi routers) devices can be used for remotely detecting the object. And nowadays networking devices installed in the household and the companies are the part of modern communication and by using these devices for the above said would greatly reduce the use of sensors for object sensing. A person away from his home can detect the changes during his absence with the routers that are installed in his home.

This study aims at studying different techniques that are used for object detection using wireless signals at different scenarios.

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List of Abbreviations

CFAR	Constant False Alarm Rate
CFR	Channel Frequency Response
CIR	Channel Impulse Response
CSI	Channel State Information
CSI	Channel State Information
DBPSK	Differential Binary Phase Shift Keying
DQPSK	Differential Quadrature Phase Shift Keying
DSI	Direct Signal Interference
DSSS	Direct Sequence Spread Spectrum
FMCW	Frequency Modulated Continuous Wave
GHz	Gigahertz
GPS	Global Positioning system
kHz	kilohertz
LOS	Line-of-Sight
MAC	Media Access Controller
MATLAB	Matrix Laboratory
MBPS	Megabytes Per Second
Mbps	Megabits per second
MHz	Megahertz
MSPS	Mega Samples Per Second
NLOS	Non-Line-of-Sight
OFDM	Orthogonal Frequency Division Multiplexing
PHY	Physical layer
PIR	Passive Infrared
PLCP	Physical Layer Convergence Protocol
PPDU	PLCP Protocol Data Unit
QAM	Quadrature Amplitude Modulation
RADAR	RAdio Direction And Ranging
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
TOF	Time Of Flight
WiFi	Wireless Fidelity

List of Symbols

c	Velocity of light
R_x	Receiving antenna
T_x	Transmitting antenna
V	Velocity of target
α	Non-negative arbitrary real number that determines Kaiser-Bessel window shape
χ	Basic ambiguity function
ΔT	Time of flight
τ	Time delay
Br	Bistatic range
D_{rx}	Distance between R_x and target
D_{tx}	Distance between T_x and target
f_b	Beat frequency during FMCW analysis
f_{Dp}	Doppler Shift in frequency
F_{rx}	Frequency of received signal
F_{tx}	Frequency of transmitted signal
$G_n(w)$	Gain response of Chebyshev filter in dB
I_0	Zeroth-order modified Bessel function
$s(t)$	Represents DSSS modulated signal
T_m	Time period of modulating signal in FMCW analysis
$w[n]$	Represents response of Kaiser-Bessel window in dB
B	Bandwidth of a signal
f	Frequency of a signal
L	Distance between transmitter and receiver
R	Range of object from the system during FMCW analysis
T	Time period of observation during low clutter analysis

Chapter 1

Introduction

1.1 Overview

Wireless communications had paved way for establishing communication from place to place and from node to node with data rates ranging from bits per seconds to gigabytes per second. It has not only been used as a means of communication but also for localization of things. Localization by using wireless signals is the most advanced and promising technology in this era of the Internet of Things which can be used for detecting the objects within the shortest range but with the most accuracy. In general, Global Positioning System (GPS) helps in tracking the objects only in outdoor positioning with a meter level accuracy and for indoor positioning of objects we need a varied type of sensors that to be employed for tracking the object moments. When sensors such as Ultrasonic and PIR are used there is a great probability of occurrence of an error while tracking multiple objects when there is a presence of multiple bodies. These sensors fail in making an optimal decision in distinguishing the direction of motion of multiple objects. When the accuracy is the most priority then a large number of sensors can be deployed but it increases the bulkiness with only a little improvisation of accuracy. As wireless signals are prone to interference many digital signal processing techniques can be used to reduce their effect increasing the efficiency of detection. However, Indoor positioning using wireless signals is the promising one for localization in this era of the Internet of Things. A lot of research from the past to the present has been done on Wireless Indoor localization by many scholars, in which their work will be discussed in detail in the later stages of this report.

1.2 Problem Statement

Indoor Localization in this era of the Internet of Things has been in raise to detect the objects with most accuracy. But it greatly needs a large number of sensors and many networking devices to be employed for object sensing with a direction of motion and connecting them to the rest of the world.

1.3 Objectives

- To study about the techniques of object detection using Wireless signals.
- To study on improving the accuracy of detecting objects when WiFi(802.11 b/g/n/ac) and FMCW signals are used.

1.4 Limitations and Scope

These systems are capable of detecting the objects in various environments but these lack portability to use for regular use and the cost of the system is very expensive. Further scope is to develop these scenarios in single board computers.

1.5 Organization of the report

To compare different methods that work in different environments with accuracy and cost as a major criterion.

Chapter 1: Introduction: Overview, problem statement, objective, scope and limitations, and organization of the report.

Chapter 2: Literature review on the current state of research.

Chapter 3: Basic research methodologies that are used in localization from the past.

Chapter 4: Basic experimentation for Object detection.

Chapter 5: Conclusions

Chapter 2

Literature Review

This chapter includes basic concepts evolved during the course of research from the past to the present on Indoor localization for object detection with certain parameters like the distance between the object(s) from the reference point, the velocity of an object, direction and the phase of motion of an object. This also includes an explanation of some digital processing techniques and algorithms which are used for effective analysis of signal at the receiver.

2.1 Radar systems

Radar systems consist of transmitters and receivers for object tracking in which these components are used for calculating Velocity, distance from a reference point, angle of arrival and time of arrival of the object. Generally, these systems are large in size and find its applications for military purposes but nowadays tiny radar systems are designed for native purpose using available sensors and wireless signals of unlicensed band.

2.2 Bistatic Radar and Bistatic Range

Bistatic radar as shown in Figure 2.1, is a system having a transmitter and the receiver. The separation between them is almost correspondingly comparable to the approximated target range. In opposite to this, there are other radar systems, where these are different from Bistatic radar in a way of separate Tx Rx, the range of detection, the principle of detection, type and number of antennas used.

Figure 2.1: Block diagram of Bistatic radar

(NickYoung.NATS, 2017)

Basic determination of range using separate transmitter and receiver by calculating time of arrival of the object is called as Bistatic range. Bistatic range as shown in Figure 2.2 is equivalent to $D_{tx} + D_{rx} - L$ where D_{tx} , D_{rx} and L are distance between transmitter target object, target object receiver and transmitter receiver respectively.

Figure 2.2: Bistatic range block diagram

(Willis, Nicholas.2007.BistaticRadar)

2.3 Chebyshev filters

As wireless communications are more prone to noise and interference, filters are used to reduce their effect in the final output of the received signal. Chebyshev filters are used for minimizing the error between the idealized filter and the realized filter over the particular range. Generally, these characteristics are mathematical and inherited from Chebyshev polynomials. As these filters are passband ripple they show the smooth response for passband and irregular response in the stop band.

The gain response $G_n(\omega)$ as shown in figure 2.3 of Chebyshev is most commonly used filter of Type I which is represented in (2.1).

$$G_n(\omega) = |H + n(j\omega)| = \frac{1}{\sqrt{1 + \epsilon^2 T_n^2(\frac{\omega}{\omega_0})}} \quad (2.1)$$

Figure 2.3: Frequency response when filter type I order of four and $\epsilon = 1$
(Willams, B., et al. (2006). Electronic Filter Design Handbook)

2.4 Kaiser-Bessel window

Kaiser window (Kaiser-Bessel window) as shown in figure 2.4 is one of the window filter used for processing the signal in digital signal processing. This is defined as follows.

$$w[n] = \frac{I_0(\beta \sqrt{1 - (\frac{2n}{N-1} - 1)})}{I_0(\Pi\beta)}, 0 \leq n \leq N - 1 \quad (2.2)$$

$= 0, \text{ otherwise.}$

Where in (2.2) N is the length of the sequence in odd numbers, I_o is the zeroth-order modified Bessel function of the first kind, $\beta = \pi\alpha$ and α is an arbitrary and non-negative real number that determines the shape of the window.

Figure 2.4: Parametric family of Kaiser-window

(Smith III. (2011) *Spectral Audio Signal Processing: CCRMA*)

2.5 Algorithm

Constant False Alarm Rate (CFAR) and CLEAN algorithm

CFAR is an adaptive algorithm for detecting the target object by calculating the threshold value of the power at the receiver. When the received power level is above the threshold then it is considered to be originated from the target and the object is detected. As the threshold level decreases then there is a possibility of detecting more targets with an increase in a number of false alarm rate. In general, a threshold is calculated by cell- averaging method by taking a set of block of cells around the cell under test (CUT) as shown in figure 2.5 and calculating the average of the power.

Figure 2.5: CFAR by taking two adjacent cells around CUT

CLEAN is a computational algorithm used for deconvolution of images by iteratively considering the highest point value of the image and subtracting it from the small gain of this point source system

impulse function until the highest point value is less than the desired threshold.

2.6 Some basic system models

Here we use concept of bistatic range, basic concept used in radar systems as shown in figure 2.6 in deducing the target range.

Figure 2.6: Basic radar detection using bistatic range

(Willis, Nicholas. 2007. *BistaticRadar*)

From the figure 2.6, sum of distances of D_{rx} and D_{tx} remains same when the object is detected on the ellipse where D_{tx} and D_{rx} are the distance of target from Tx and RX respectively. Here L is the separation between the Tx and RX

When transmitter generates the signal with a frequency of F_{tx} , then it gets reflected by object with a frequency of F_{rx} and it is processed by the receiver.

$$F_{tx} - F_{rx} = \frac{1}{\Delta T} \quad (2.3)$$

$$D = \frac{c}{\Delta T}; \quad (2.4)$$

Where c in (2.4) is the speed of light and D is almost equal to the sum of D_{rx} and D_{tx}

$$D \approx D_{tx} + D_{rx} \quad (2.5)$$

Hence from (2.4) the target range which is equals to bistatic range B_r is represented in (2.6)

$$B_r = D - L \quad (2.6)$$

2.7 Wireless passive radar system models (s)

In passive radar-based detection, there is no dedicated transmitter (Tx), instead, receiver (Rx) uses some third party transmitted data from available transmitter(Tx) by estimating the arrival time.

Low clutter environment

The first experiment to detect humans using wifi signal was done by Guo et al.,2008 Using WiFi Beacon transmission for wireless based passive radar in low clutter environment[1].Beacon signals as one frame which is emitted periodically by the transmitter can be used to detect the presence of objects. Emitted signals consist of two parts (DBPSK coding with 1 Mbps and DQPSK coding with 2 Mbps) is modulated by DSSS modulation with a barker code of eleven elements.

Barker code eleven element series : [+1, -1, +1, +1, -1, +1, +1, +1, -1, -1, -1]

General equation of DSSS modulation is represented in (2.7)

$$s(t) = \exp(j2\pi f_0 t) \sum_n^N \exp(j\psi) p(t) \quad (2.7)$$

Where n is number of bits and $p(t)$ is the pulse strain function.

The below (2.8), (2.9), (2.10) represents the 1 Mbps DSSS DQPSK, 2 Mbps DSSS DQPSK and rectangular pulse respectively.

$$s(t) = \exp(j2\pi f_0 t) \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} \exp(j\psi_{n,m}) p(t - mT - 11nT) \quad (2.8)$$

$$s(t) = \exp(j2\pi f_0 t) \sum_{n=0}^{(N-1)/2} \sum_{m=0}^{M-1} \exp(j\psi_{n,m}) p(t - mT - 22nT) \quad (2.9)$$

$$\begin{aligned} p(t) &= 1, 0 \leq t \leq T \\ &= 0, \text{otherwise} \end{aligned} \quad (2.10)$$

Ambiguity function analysis is done to verify the received signal and the amount of distortion, 11 MHz [1] signal bandwidth is used in simulating in Matlab. The basic ambiguity function is expressed in (2.11).

$$|\chi(\tau, f_{Dp})| = \left| \int_{-\infty}^{\infty} x(t)x(t - \tau)\exp(2\pi f_{Dp}t)dt \right| \quad (2.11)$$

Substituting (2.8) and (2.9) in (2.11) we can obtain DSSS DBPSK and DSSS DQPSK ambiguity functions respectively. Upon theoretical calculation and the simulation results from *Guo et al.*, 2008 as shown in figure 2.7 and figure 2.8 which are represented in table 2.1

Figure 2.7: Ambiguity diagram, Zero Doppler and range outs for DSSS/DBPSK Beacon signal

(*Guo et al.*, 2008)

Figure 2.8: Ambiguity diagram, Zero Doppler and range outs for DSSS/DQPSK Beacon signal.

(Guo et al., 2008)

Modulation	Resolution	Simulation	Theory
DSSS/DBPSK	Range	15.9m	13.6
DSSS/DBPSK	Doppler	4.61kHz	5.2kHz
DSSS/DBPSK	Range	15.9m	13.6m
DSSS/DBPSK	Doppler	9.21kHz	10.4kHz

Table 2.1: Simulated and theoretical results of DSSS/DBPSK and DSSS/DQPSK signals.

(Guo et al., 2008)

Practical implementation

Following conclusions from theoretical ambiguity function analysis in low clutter region. Experimentation is done in Guo et al., 2008 by using WiFi transmitter (DWL-200AP) with 2.437 central frequency having 20 dBm peak EIRP theoretical assumption with a transmitting antenna gain of 5dbi and zero loss.

Figure 2.9: Geometrical representation of WiFi based passive radar.

(Guo et al., 2008)

Experimentation is conducted in Guo et al., 2008 using the configuration represented in the figure 2.9 with two antennas having narrow beam width of 24dBi gain. Received signal is processed in Matlab with 100 MHz sampling frequency using NetRad in [1] by calculating doppler resolution in the equation (2.12) and using (2.11) the following results shown in figures 2.10, 2.11 and 2.12 are obtained.

$$\Delta f = \frac{1}{T} < f_{dp} = \frac{V \cos \frac{\beta_i}{2} \cos(\alpha_i)}{\frac{c}{f}} \quad (2.12)$$

Where Δf is doppler resolution, f_{dp} is doppler shift, T is period of observation, V target velocity, c is speed of light, f is transmitter frequency which is 2.4 GHz, $\beta_i = 60$ deg and α_i is 30deg from figure 2.9.

Transmitting antenna which transmits Beacon signal is initiated, first a single target at a distance of 12m from the receiver is made to move towards the receiver with 100ms reception span. Figure 2.10 shows the target detection range.

Figure 2.10: Ambiguity function diagram when target (12m)is moving towards receiver with 100 ms time of reception

(Guo et al., 2008)

As there are many side lobe from the figure 2.10 and to reduce them the time reception is increased to 300ms and the following results as shown in figures 2.11 and 2.12are obtained when two targets are at near(12m from receiver) and far (35 m from receiver) distances .

Figure 2.11: Ambiguity function diagram when two target (35m)is moving towards receiver with 300 ms time of reception

(Guo et al., 2008)

Figure 2.12: Ambiguity function diagram when two target (12m)is moving towards receiver with 300 ms time of reception

(Guo et al., 2008)

So the above experimentation *Guo et al., 2008* show that 802.11 Beacon signals can be used for detection of targets using WLAN. But this works in an low clutter environment where the desired results may vary when done in high clutter environment.

High clutter environment

In section 2.7 of low clutter we discussed target detection in low clutter environment but when comes to high clutter environment where walls, floors, concrete buildings are the instruments of noise and interference which results in an error in detection. So we employ digital processing techniques for reducing the noise and error in detecting the targets.

WiFi transmitter simulated with 64- QAM OFDM signal is used to transmit the signal at 54 Mbps data rate with 16 Mhz bandwidth in [2] by Chetty et al., and the configuration of antennas is shown in the figure 2.13.

Figure 2.13: Geometrical configuration for object detection in high clutter environment with bistatic baseline, bistatic range and bistatic angle was 7.6m, 17.5m and 460.

(Chetty *et al.*, 2009)

As this experiment is done in high clutter region then the received signal is prone to noise, Here in Table 2.2 represents the experimental measurements of system noise and the clutter response by Chetty *et al*

Test	Target	Target Pace	Notes
1[System noise and clutter response]	No	-	Noise measurement with no antenna
2[System noise and clutter response]	No	-	Noise measurement of antenna connected
3[System noise and clutter response]	No	-	Antenna connected with idle WLAN
4[System noise and clutter response]	No	-	Antenna connected with Data transfer by WLAN
5[Passive WiFi radar capability]	Metal Cylinder	At stationary	Target holding metal cylinder
6[Passive WiFi radar capability]	Metal Cylinder	When walking	Target holding metal cylinder
7[Passive WiFi radar capability]	Metal Cylinder	When running	Target holding metal cylinder
8[Passive WiFi radar capability]	Single Person	At stationary	
9[Passive WiFi radar capability]	Single Person	When walking	
10[Passive WiFi radar capability]	Single Person	When running	

Table 2.2: Experimental measurements are taken as mentioned

(Chetty *et al.*, 2009)

Ambiguity function using (2.11) is measured in Chetty *et al.*, 2009 for a time period of about 100ms is analysed and the simulated results are presented in the figures 2.14 and 2.15. It is observed from both the figures that the bistatic range resolution is 14m with -19db of sidelobes of highest peak from the mainlobe and the resolution of 8 Hz with -8db of sidelobes of highest peak from the main lobe.

Figure 2.14: Zero Doppler cut of the ambiguity function
(*Chetty et al., 2009*)

Figure 2.15: Zero range cut of the ambiguity function
(*Chetty et al., 2009*)

After analyzing the cross ambiguity function, a test is conducted when there is no presence of target using measurements from table 2.2(1-4). This intention is to cancel DSI (Direct Signal Interference) using the self-ambiguity from the cross ambiguity function when target detection data is received. Then again experimentation is done in *Chetty et al.*, using measurements from table 2.2 (9-10) with figure 2.16 representing Doppler range plots when there is single person presence.

Figure 2.16: Doppler-range plot with target and bistatic range response

(Chetty *et al.*, 2009)

On analyzing figure 2.16 clearly shows that range resolution is less due to the narrow band but multiple object detection accuracy can be improved by using more number of transmitters and the receivers and also with the increase of time integration for data collection. So there is a great possibility of target detection in low clutter and also in high clutter regions using self-ambiguity and the cross ambiguity function analysis.

Concept of using CSI based techniques over RSSI

Received Signal Strength (RSS), a MAC layer feature, is used for localizing the object using RSS power of the reflected received signal. But for long-range detection of a target, there is a monotonically decrease in received signal strength in which object detection is not accurate. When there is a multipath propagation there is a fluctuation in RSS of 5db per 600 milliseconds (Zimu Zhou *et al.*), using RSS as a parameter does not guarantee the location accuracy. So moving to some robust solution, Channel State Information(CSI) using Channel Impulse Response (CIR), a PHY layer feature, is the best to depict multipath propagation under the time-variant assumption. .

The frequency response of CIR from CSI can be obtained from the present day OFDM based Wireless (IEEE 802.11a/g/n) network cards using custom firmware. Each CSI is able to estimate amplitude and phase of each OFDM subcarrier.

Figure 2.17: Graphical representation of RSS vs CSI

(Zhou *et al.*, 2015)

Illustration of RSS vs CSI in as shown in figure 2.17 represents that RSS is a single valued function (amplitude) superimposed of multipath, but CSI estimates each subcarrier with coarse-grained distinction using CIR in the time domain. Recent studies by many scholars have investigated several methods for amplitude (Zhou *et al*) and phase (Wu *et al*) extraction using CSI which can detect the target in LOS and NLOS(using phase orientation).

2.8 Literature review of the research

- Guo *et al.*, 2008 - This is the first experiment to detect objects with WiFi signals by using Beacon transmissions such as two parts of DBPSK and DQPSK with DSSS modulation used for transmission for wireless based passive radar. Self-ambiguity function analysis and cross ambiguity analysis is done upon reception of signals for detection.
- Ahamed *et al.*, 2008 - Tracking system for the pervasive environment, linear approximation with RSSI is used by collecting samples by measuring distance and direction of WiFi APs.
- Chetty *et al.*, 2009 - Detection of target using Passive Bistatic WiFi radar when system and target are in high densified echo environment. By using Wifi Access point, reference receiver and surveillance receiver with OFDM, 64 QAM transmission, ambiguity analysis is done for location approximation using bistatic radar concept with the nullification of DSI (Direct Signal Interference). A similar work by the same author (Chetty *et al.*, 2011) is through the wall sensing of personnel using passive bistatic WiFi radar at standoff distances. In this targets are monitored from outside the wall so as to detect the target satisfying the concept of seeing through the walls.
- Falcone *et al.*, 2012 - Tracking of non-stationary objects is done with WiFi-based radar by using Global Positioning System (GPS) for accurate positioning.

- Rzewuski and Kulpa, 2011 -Designing of system concept for localization using PPDU (PLCP Protocol Data Unit) of MAC address to locate the destination.
- Zhou et al., 2015 - Explained the concept of using Channel State Information (CSI), a PHY feature for extracting CFR and CIR with amplitude and phase detection of the reflected signal. CSI can be obtained from the WiFi network cards with a constraint of using CSI of only 40 MHz (802.11n) bandwidth.
- Wu et al., 2015 - Examined the use of CSI for tracking humans, phase, and frequency diversity is used to map body with use of chest motion of a human. The experiment is done for LOS and NLOS detection.
- Van Dijk et al., 2008 - Design of FMCW antenna Array for radar applications with independency in transmitter and receiver reception with Direct Digital Synthesis Technology.
- Adib et al., 2013 - See-Through walls with WiFi, a wall gesture-based communication using inverse sympathetic detection (using only one receiver). Algorithm based detection by calculating the correlation matrix and eigenvalues for separating the signal from the noise along with the indication of direction.
- Adib et al., 2014 - Based on RF Reflections of the body by using static frequency modulated continuous wave (FMCW) where different parts of the body responds for reflecting signals at different frequencies. Here FMCW is operated for some duration, so different body parts reflect at different frequencies and the shape forming of the body is done.
- Adib et al., 2014 - A similar work by using RF reflections for multi personnel localization by using multi-shift FMCW.
- Adib et al., 2015 - Based on variations in reflected signal from the stationary human body monitoring of heartbeat is done. Without loss in generality that these variations are due to heartbeat reflections of a stationary human body at particular reflected frequency of heart with narrow bandwidth.

2.9 Discussion

Literature study on several existing methods has shown significant development in designing indoor positioning systems. Some of the methods discussed in 2.8 used RSSI and CSI(Zhou *et al.*, 2015) of the signal for determining characteristics of a signal. Wireless beacon transmission such as DSSS & DBPSK, DSSS & DQPSK modulated signal described in Geo *et al.*, 2008 is the first method used for target detection. This shows that beacon transmitted signal changes its characteristics upon reflection from the target and these changed characteristics are used for signal analysis especially with the use of ambiguity function, change in signal characteristics with the transmitted signal is analyzed and this led to determine the characteristics of the target.

Latest research reveals that use of chirp generator described in Adib *et al.*, 2014, Adib *et al.*, 2015 finds its application not only in target detection but also its shape forming. When chip generator

generates signals with varying frequency in which different body parts of human reflect at different frequencies and these are captured by receiving antennas, upon sample collection and signal processing techniques. This method also improves the accuracy of detection with moderate accuracy in shape forming.

All these systems are capable of detecting target but these methods find difficult in integrating with the existing system because of a closed system and interpretability. However, these methods are the foundation for research in radar engineering, especially in indoor localization.

In the following chapter(s) we discuss some of the basic experimental results done in Telecommunication Laboratory at Asian Institute of Technology, that led to the scope of object detection using narrowband wireless signals is illustrated.

2.10 Software Validation

Practical simulation of ambiguity function using (2.11) for DSSS/DBPSK and DSSS/DQPSK using MATLAB is shown in following Figures 2.18, 2.19, 2.20 and 2.21

Figure 2.18: Generation of Barker code, Spread signal (DSSS), DBPSK modulated signal and power Spectral density (fft) DSSS/DBPSK signal.

Figure 2.19: Ambiguity function - Doppler shift and delay of DSSS/DBPSK signal

Figure 2.19 represents ambiguity function analysis of a DSSS/DBPSK modulated signal with signal from barker code sequence of bits generated as shown in Figure 2.18.

Figure 2.20: Generation of Barker code, spread signal (DSSS), DBPSK modulated signal and power spectral density (fft) DSSS/DQPSK signal.

Figure 2.21: Ambiguity function - Doppler shift and dely of DSSS/DQPSK signal

Figure 2.21 represents the ambiguity analysis of a DSSS/DQPSK modulated signal with basic signal from barker sequence of bits as shown in Figure 2.20.

Analysis of ambiguity function from figures 2.19 and 2.21 reveals that peak value is found to be at when there is no Doppler shift and when the delay between the transmitted and the received signal is very less.

Chapter 3

Methodology

3.1 Power analysis

At this level, we examine the feasibility of using received power levels to detect object when there is presence of object by transmitting and receiving the reflected signal by using available transmitting(Tx) and receiving(Rx) antennas which work in the MHz up to GHz frequency ranges. By considering the transmitted signal power level and received signal power level and by implementing digital signal processing techniques we can obtain the distance at which the object is located. For this, we need to do the following.

1. Tx Antenna : A transmitting antenna which is readily available for experimentation and which generates from MHz to GHz frequencies is needed for physical experimentation.
2. Rx Antenna : An antenna capable of detecting the signal having frequencies from MHz to GHz frequencies.
3. Signal generator which is connected to Tx antenna and Oscilloscope connected to Rx antenna as shown in figure 3.1 is used to primarily transmit and receive the signal.

Figure 3.1: Basic model using signal generator and spectrum analyser for feasibility test (Tx and Rx antennas of 2.4 GHz are available in AIT TC Lab)

Experimentation

Basic experimentation is done in Telecommunication laboratory of Asian Institute of Technology to demonstrate the scope of object detection using wireless signals of narrowband frequency. Experimentation procedure follows the later stages of the chapter.

For object detection, primary experiment using Signal generator (0 - 3GHz), Spectrum analyzer (0 - 3 GHz), one transmitting(Tx) antenna and one receiving(Rx) is performed.

1. Transmitting (Tx) antenna is attached to the RF output of the signal generator and receiving (Rx) is attached to the RF input of the Spectrum analyzer.
2. Antennas are kept at a nominal distance of 3 cm as shown in figure 3.2 to test the signal transmission and receiving capabilities. RF signal is transmitted with -10dBm amplitude and varying frequency as shown in table 3.1 to see at which frequencies that the antennas have higher gain. Two values of the received signal are recorded. Generally, Tx and Rx antennas are designed to work optimal at 2.2 GHz to 2.6 GHz with center frequency 2.4 GHz.

Tx Frequency in GHz	Tx amplitude in dBm	Rx Frequency in GHz at peak amp	Rx amplitude in dBm
1.5	-10	1.5013	-44.9
			-45
1.75	-10	1.7508	-50
			-49
2	-10	2.003	-44.5
			-43
2.2	-10	2.198	-41.23
			-41.58
2.4	-10	2.40004	-38.241
			-37.6
2.6	-10	2.5981	-38.45
			-38.61
2.8	-10	-2.8005	-46
			-47.74
3	-10	2.9982	-49.62
			-50.48

Table 3.1: Rx and Tx values at -10dBm Tx amplitude with varying frequency with 3cm distance apart between Tx and Rx when no obstacle is introduced

Figure 3.2: when Tx-Rx are at 3 cm apart and when no obstacle is introduced

3. Tx and Rx are placed at 30cm apart and the RF signal is generated with 2.4 GHz , -10dBm amplitude. Spectrum analyser clearly shows peak values (are recorded as shown in Tables 3.2, 3.3, and 3.4 when experiment is repeated for 3times) at 2.4Ghz where other values are noise signals with negligible amplitude as shown in the Figure 3.3

Tx Frequency in GHz	Tx amplitude in dBm	Rx Frequency in GHz at peak amp	Rx amplitude in dBm	Average Rx amplitude in dBm
2.4	-10	2.40	-41.2	
2.4	-10	2.40	-41.84	
2.4	-10	2.40	-41.43	
2.4	-10	2.40	-41.21	
2.4	-10	2.40	-41.26	
2.4	-10	2.40	-41.15	-41.4414

Table 3.2: Receiver (Rx) observations recorded first (1st) time with distance between Tx and Rx as 30cm, no obstacle introduced

Tx Frequency in GHz	Tx amplitude in dBm	Rx Frequency in GHz at peak amp	Rx amplitude in dBm	Average Rx amplitude in dBm
2.4	-10	2.40	-43.70	
2.4	-10	2.40	-43.30	
2.4	-10	2.40	-43.07	
2.4	-10	2.40	-43.92	
2.4	-10	2.40	-43.27	
2.4	-10	2.40	-44.10	
2.4	-10	2.40	-43.60	
2.4	-10	2.40	-42.83	
2.4	-10	2.40	-43.76	
2.4	-10	2.40	-44.15	
2.4	-10	2.40	-43.88	-43.689

Table 3.3: Receiver (Rx) observations recorded second (2nd) time with distance between Tx and Rx as 30cm, no obstacle introduced

Tx Frequency in GHz	Tx amplitude in dBm	Rx Frequency in GHz at peak amp	Rx amplitude in dBm	Average Rx amplitude in dBm
2.4	-10	2.40	-44.59	
2.4	-10	2.40	-43.57	
2.4	-10	2.40	-44.99	
2.4	-10	2.40	-43.64	
2.4	-10	2.40	-44.34	
2.4	-10	2.40	-45.04	
2.4	-10	2.40	-45.21	
2.4	-10	2.40	-43.61	
2.4	-10	2.40	-44.05	
2.4	-10	2.40	-43.89	-44.292

Table 3.4: Receiver (Rx) observations recorded third (3rd) time with distance between Tx and Rx as 30cm, no obstacle introduced

Figure 3.3: Received Peak value observation when Tx signal frequency is 2.4GHz, -10dBm

4. Experimentation scenario is shown in figure 3.4. Now the obstacle is introduced at different distance (LOS) ranging from left of transmitter(Tx) to the receivers(Rx) right scaling from -15cm to 45 cm as shown in Figure 3.4 and observations are recorded in Tables 3.5, 3.6 and 3.7 (when experiment is repeated for 3 times) with a stamp for every 3cm.

Figure 3.4: Experimentation scenario

Obstacle distance. From Tx to Rx	Rx amp dBm1	Rx amp dBm2	Rx amp dBm3	Rx amp dBm4	Rx amp dBm5	Rx amp dBm6	Rx amp dBm Avg
-15	-43.17	-43.2	-43.57	-43.77	-43.13	-43.29	-43.355
-12	-43.67	-42.9	-43.15	-43.56	-43.14	-42.97	-43.231
-9	-42.56	-42.57	-43.15	-42.03	-42.18	-42.33	-42.47
-6	-44.8	-45.61	-45.36	-44.34	-44.72	-45.12	-44.9916
-3	-41.75	-41.88	-43.21	-43.35	-43.1	-42.95	-42.706
0	-52.8	-51.42	-53.7	-54.08	-54.42	-55.6	-53.67
3	-46.71	-47.01	-47.64	-47.5	-47.05	-46.63	-47.09
6	-45.25	-44.64	-46.64	-46.29	-47.07	-46.23	-46.02
9	-46.32	-45.05	-46.11	-46.48	-46.5	-47.73	-46.365
12	-49.83	-46.97	-46.79	-47.02	-47.3	-46.14	-47.3416
15	-44.39	-44.63	-44.68	-44.24	-45.08	-44.61	-44.605
18	-46.84	-46.84	-46.25	-46.49	-46.1	-47.14	-44.61
21	-43.3	-43.34	-43.73	-43.57	-44.1	-43.07	-43.5183
24	-42.75	-43.96	-44.91	-44.31	-44.9	-44.95	-44.2966
27	-48.69	-48.12	-49.91	-47.79	-48.39	-47.31	-48.368
30	-51.31	-49.67	-52.17	-50.86	-52.56	-52.02	-51.4316
33	-42.41	-41.81	-42.38	-42.5	-41.44	-42.15	-42.511
36	-43.27	-43.2	-43.28	-43.31	-43.53	-43.51	-43.35
39	-44.58	-45.96	-45.7	-46.21	-45.79	-46.37	-45.7688
42	-43.56	-43.39	-43.43	-43.81	-43.26	-43.4	-43.475
45	-43.14	-42.79	-43.07	-43.67	-42.74	-43.14	-43.091

Table 3.5: Receiver (Rx) dBm recorded first (1st) time at various distance of obstacle position from the Tx

Obstacle distance. From Tx to Rx	Rx amp dBm1	Rx amp dBm2	Rx amp dBm3	Rx amp dBm4	Rx amp dBm5	Rx amp dBm6	Rx amp dBm Avg
-15	-45.79	-44.47	-44.73	-46.57	-45.33	-44.54	-45.22666
-12	-45.3	-44.9	-44.58	-44.07	-44.54	-45.33	-44.7869
-9	-46.6	-44.63	-47.18	-46.5	-45.52	-46.21	-46.1066
-6	-45.16	-45.13	-45.23	-44.18	-45.03	-44.83	-44.9266
-3	-45.21	-45.2	-46.13	-47.2	-45	-45.23	-45.6616
0	-55.9	-55.25	-54.63	-55	-54.68	-55.37	-55.1383
3	-51	-50.29	-50.87	-50.76	-50.72	-50.81	-50.74166
6	-49.21	-50	-48.79	-50.06	-50.13	-50.15	-49.7233
9	-48.16	-46.7	-47.06	-49.13	-47.02	-47.6	-47.6116
12	-50.74	-51.17	-48.18	-49.47	-50.09	-50.46	-50.01833
15	-47.22	-48.69	-47.9	-48.4	-47.79	-48.42	-48.07
18	-48.83	-50	-49.79	-50.69	-51.55	-50.51	-50.2833
21	-48.69	-47.33	-49.63	-50.17	-50.7	-49.52	-49.3
24	-50.18	-51.45	-52.83	-53.58	-51.21	-51.98	-51.87
27	-53.8	-52.85	-52.22	-51.41	-54	-53.8	-53.0133
30	-55.58	-55.68	-54.73	-55.52	-55.29	-55.35	-55.3583
33	-46.7	-47.13	-48.29	-46.31	-47.61	-48.3	-47.39
36	-44.9	-44.21	-45.17	-45.13	-45.09	-45.3	-44.9666
39	-46.78	-46.57	-46.51	-46.15	-46.16	-46.17	-46.39
42	-44.6	-44.36	-44.74	-44.74	-45.11	-44.1	-44.6083
45	-46.11	-45.9	-45.32	-45.29	-45.77	-45.38	-45.6833

Table 3.6: Receiver (Rx) dBm recorded second (2nd) time at various distance of obstacle position from the Tx

Obstacle distance. From Tx to Rx	Rx amp dBm1	Rx amp dBm2	Rx amp dBm3	Rx amp dBm4	Rx amp dBm5	Rx amp dBm6	Rx amp dBm Avg
-15	-45.09	-45.41	-45.46	-45.42	-45.69	-45.4	-45.4116
-12	-43.05	-43.21	-43.76	-42.73	-42.86	-43.21	-43.3166
-9	-45.1	-44.79	-45.13	-44.12	-44.57	-44.52	-44.705
-6	-44.4	-43.52	-42.09	-43.51	-43.55	-43.44	-43.41833
-3	-46.52	-47.88	-47.74	-46.24	-45.96	-47.61	-46.9916
0	-50.56	-51.13	-52.71	-50.35	-49.35	-52.61	-51.1183
3	-47.43	-47.03	-47.08	-47.98	-47.49	-46.5	-47.2561
6	-48.54	-49.72	-49.5	-49.13	-50.46	-49.35	-49.45
9	-45.75	-46.92	-47.03	-45.95	-46.2	-46.7	-46.425
12	-46.99	-47.33	-48.88	-47.54	-48.57	-47.16	-47.745
15	-45.81	-46.92	-47.03	-45.95	-46.2	-46.7	-46.435
18	-45.73	-47.17	-46	-46.97	-46.44	-46.62	-46.4883
21	-46.99	-47.07	-47	-46.62	-46.67	-46.61	-46.8266
24	-46.88	-47.59	-48.4	-48.21	-47.29	-47.18	-47.5916
27	-49	-48.88	-49.94	-49.1	-49.49	-48.9	-49.21833
30	-51.84	-51.16	-49.55	-50.21	-49.71	-50.25	-50.4533
33	-46.7	-47.13	-48.29	-46.31	-47.61	-48.3	-47.39
36	-44.9	-44.21	-45.17	-45.13	-45.3	-45.09	-44.9666
39	-46.79	-46.57	-46.51	-46.51	-46.15	-46.16	-46.44833
42	-44.65	-44.36	-44.74	-44.74	-45.11	-44.1	-44.61666
45	-46.11	-45.9	-45.32	-45.29	-45.77	-45.58	-45.66166

Table 3.7: Receiver (Rx) dBm recorded third (3rd) time at various distance of obstacle position from the Tx

5. At each value of distance for every 3cm of obstacle from the Tx , Six readings are recorded and average Rx amplitude dBm is calculated as Rx amplitude dBm average for every position. Graphs as shown in figures 3.5, 3.6 and 3.7(when experiment is repeated for 3 times) is plotted for Rx amp dBm avg v/s distance and analysis of graph is done before and after introducing obstacle.

Figure 3.5: Experiment 1: Graph comparing Rx amp dBm avg when obstacle is at different distances(LOS) b/w Tx and Rx, plotted for every 3cm of move

Figure 3.6: Experiment 2: Graph comparing Rx amp dBm avg when obstacle is at different distances(LOS) b/w Tx and Rx, plotted for every 3cm of move

Figure 3.7: Experiment 3: Graph comparing Rx amp dBm avg when obstacle is at different distances(LOS) b/w Tx and Rx, plotted for every 3cm of move

Figure 3.8: Experimentation Scenario

Graph Analysis

Figures 3.5, 3.6 and 3.7 is a graphical signal representation of experimentation scenario in Figure 3.8. For analysis we divide the scenario into four parts such as left of Tx(-15cm to 0 cm), right of Tx(0cm to 15cm), left of Rx(15 cm to 30 cm) and right of (30cm to 45 cm).

1. **Right of Tx(0cm to 15 cm) :** when obstacle is introduced and moved from 0cm to 15 cm we could see that Rx dBm increases till the mid value of right of Tx(0cm to 15 cm), about 7.5 cm then the graph starts decreases from that midpoint to endpoint of Right of Tx(0cm to 15cm), i.e mid point of Tx-Rx distance. Here the effect of small sidelobes are reduced till the quarter distance of 30cm due to which the graph increases and in the next quarter often sidelobes effect is not nullified and the signal reflection from obstacle can cause a decrease of signal level due to which graph falls down.
2. **Left of Rx(15cm to 30cm) :** from mid point of Tx-Rx, graph starts increasing till the mid point of Left of Rx(15cm to 30 cm), about at 21 cm and then the graphs start decreasing until the end point of Left of Rx(15cm to 30 cm), i.e at 30cm near the receiver. The value of received dBm is low at 30 cm point because of blockage of the signal from the transmitter(Tx) to the receiver(Rx) by the obstacle.
3. **Left of Tx(-15cm to 0 cm):** Similar effect, Transmitted power level is less when obstacle is at Tx(0 cm) and it increases as the obstacle moves from farther left of Tx and starts decreasing from the quarter point of (0 cm to -15cm) i.e the effect of side lobe is observed and it starts increasing from point the mid point when the sidelobe effect is reduced. And then the reflections from the main lobe due to the obstacle can cause the signal to interference and the signal attenuation is observed at the receiver.
4. **Right of Rx(30cm to 45 cm) :** Similar effect of sidelobe and main lobe reflection by the obstacle when it moves from right to farther right of Rx can cause increase and decrease of signal power.

Environmental conditions :

1. High clutter region having many computers in the lab.
2. Mobile phone signal interface.
3. Two air conditioners are switched on.
4. Several dielectric materials such as antenna under power off condition.

Conclusions on the power analysis

From the graphs figures 3.5, 3.6 and 3.7 are clearly symmetrical and clearly shows that the object detection parameters almost same when experiment is repeated for 3 times.

The ratio of Average received signal dBm when no object to the Received signal dBm when object is introduced at instantaneous distance from Tx is approximately equal for all the 3 experiments.

$$Experiment1(\frac{Avg Rx dBm received when no obstacle}{Rx dBm received instantaneously when obstacle is present}) \quad (3.1)$$

$$Experiment2(\frac{Avg Rx dBm received when no obstacle}{Rx dBm received instantaneously when obstacle is present}) \quad (3.2)$$

$$Experiment3(\frac{Avg Rx dBm received when no obstacle}{Rx dBm received instantaneously when obstacle is present}) \quad (3.3)$$

From this we can write that, $3.1 \approx 3.2 \approx 3.3$.

3.2 Time delay analysis

Object detection using FMCW signal

Simulation is performed using GNU Radio, a Software Defined Radio, for detecting object using FMCW signal.

The simulation includes generation of FMCW signal using sawtooth waveform with Voltage Controlled Waveform (Carrier signal). A signal is transmitted and delay is introduced after receiving the signal before processing the signal with the transmitted signal.

Chirp signal	Sawtooth
Chirp Frequency	1kHz
Band width of FMCW	750kHz
Sampling rate	3MSPS

Table 3.8: Simulation Parameters

Processing of signals are shown in figure 3.9 and Simulation parameters are implemented in GNU radio as shown in figure 3.10

Figure 3.9: System block diagram

Figure 3.10: GNU Radio Implementation

Assuming single target, a delay of 1000, 500, 250 and 100 samples are introduced respectively to study the scenario at varies TOF intervals. As we use 3Mega Samples per second, delay of 1000, 500, 250 and 100 samples experiences a delay of $0.33ms$, $0.16ms$, $0.08ms$ and $0.033ms$ respectively which can be treated as TOF(ΔT) of signal (creating the virtual delay in receiving a signal).

Note: Here in GNURadio, delay is introduced in terms of number of samples.

Equations (3.1) and (3.2) is used to determine the range of the target both theoretically and practically respectively. In (3.1) and (3.2) R is range of target from the system, T_m is the time period of modulating signal, B is the bandwidth of the chirp signal, c is velocity of light , ΔT is delay in the received signal and f_b is the beat frequency between transmitted signal and received signal which can be determined from the graph as shown in figures 3.11, 3.12, 3.13 and 3.14.

$$R(\text{theoretical range}) = \frac{c \cdot \Delta T}{2} \quad (3.1)$$

$$R(\text{practical range}) = \frac{c \cdot T_m \cdot f_b}{2 \cdot B} \quad (3.2)$$

Figure 3.11: Target with delay of 1000 samples

Figure 3.12: Target with delay of 500 samples

Figure 3.13: Target with delay of 250 samples

Figure 3.14: Target with delay of 100 samples

Observed beat frequencies f_b from graphs as shown in figure 3.11, 3.12, 3.13 and 3.14. are $250.88kHz$, $124.12kHz$, $62.4267kHz$ and $24.619kHz$ respectively.

Now, simulation as shown in figure 3.15 is done and the graph is obtained as shown in 3.16 when there is a presence of three targets with 1000, 500 and 250 sample delays respectively.

Figure 3.15: GNU Radio implementation for three target detection

Figure 3.16: Three target presence

In figure 3.16 it is clear that peak values represents beat frequencies(f_b) at $\approx 250kHz$, $125kHz$ and $62.5kHz$ which are almost equal when they treated independently.

Theoretical and practical ranges are calculated using (3.1) and (3.2) and are represented in 3.9

Step Time	Theoretical range(Km)	$f_b(kHz)$	Simulated range(Km)
1000	50	250.88	50.176
500	25	124.12	24.824
250	12,5	62.4267	12.485
100	5	24,619	4.923
1000,500,250	50, 25, 12.5	250.90, 124.12, 63.3803	50.180, 24.824, 12.676

Table 3.9: Theoretical and simulated values

Conclusion on time delay analysis

Theoretical range and practical simulated range values of targets are found to be equal stating that FMCW signals are capable of detection of about and its range when they are present at longer distances.

Chapter 4

Conclusion

Recent studies have shown that wireless signals have paved for designing low range radar systems in high clutter and low clutter environments with acceptable accuracy. These radar systems are used in indoor for detection of an object, especially for short-range detection. Investigation shows target location can be estimated from the CSI information which inter CSI information can also be traced by Physical Layer Convergence Procedure (PLCP)(*Stanislaw Rzewuski et al.*,)

Research scholars have involved in developing capturing the Human Figure through a Wall (*Adib et al.*,), Multi human tracking and 3D body shape forming (*Adib et al.*;) systems using Frequency Modulated Continuous Wave (FMCW) (*Dijk et al.*,) radars which works with a sweep frequency in Ultra Wide Band (3.1 GHz - 10.6 GHz) range. These systems are able to form full body image upon receiving reflections from the body at different frequencies transmitted by the FMCW transmitter. Further scope of research lies in designing a system which tracks objects and traces the 3D shape of an object using minimum networking devices such as the router(s) with an open architecture which works at central frequencies of 2.4 GHz(802.11n) and 5GHz(802.11n) with a bandwidth of 20Mhz and 40Mhz respectively.

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Appendix A

MATLAB Code

```
%-----"Generating . DSSS ./ DBPSK. Modulation"-----

%--"DSSS. ---Direct . Sequence .. Spread ... Spectrum .. Generation .. with .. Barker .

function [dbpsk_sig] = DSSS_DBPSK_Barker
clc
clear

%."Generating . the . bit .. pattern with each bit .28.. samples ..long.".

barker=[1 -1 1 1 -1 1 1 1 -1 -1 -1];% bits .
pattern_for_dss=[];% pat ..
for k=1:11%sample introducing ..
    if barker(1,k)==-1
        signal=-ones(1,28); %sample introducing ..
    else
        signal=ones(1,28);% sample introducing ..
    end

    pattern_for_dss=[ pattern_for_dss signal];
end
subplot(4,1,1)% subplotting ..
plot(pattern_for_dss);% plotting ..
axis([-1 308 -1.5 1.5]);% axis plot ..
title(' Original barker Bit Sequence ');% Naming ..

% "Generating .. the ... pseudo ... random .. bit ".
%.. "pattern .. for .. spreading ".
d=round(rand(1,121));%"randm gen of bits "...
pn_seq=[];
carrier=[]; %Carrier_introductionmn .
t=[0:2*pi/3:2*pi]; % "Creating 5 samples for one cosine".
for k=1:77
    if d(1,k)==0
        signal=-ones(1,4); %"Creating samples and ading them"..
    else
        signal=ones(1,4);%"Creating samples and ading them"..
    end
    c=cos(t);
    carrier=[carrier c];
end
```

```

        pn_seq=[pn_seq signal];

end

% ".. Spreadin.g... of.. sequence.".
spreaded_sig=pattern_for_dss.*pn_seq;
subplot(4,1,2)
plot(spreaded_sig)
axis([-1 308 -1.5 1.5]);
title(' Spreaded signal ');
display(size(spreaded_sig));
display(size(carrier));

%" BPSK .. Modulation... of ... the... spreaded .. signal".
%"dbpsk_sig=spreaded_sig.*carrier; % Modulating the signal
%differential encoding y[n]=y[n-1]=x[n]".
dbpsk_sig=mod( filter(1,[1 -1],spreaded_sig),2);%..
dbpsk_sig=dbpsk_sig.*carrier; %carrier mul....
subplot(4,1,3); %subplot_ting..
plot(dbpsk_sig)%plot_ting..
axis([-1 308 -1.5 1.5]);% Axis_naming.
title(' DBPSK Modulated Signal ');% Title_naming..
disp(size(dbpsk_sig));% disp_lying_sequence..

%"Plotting .. the ..FFT ... of.. DSSS.. signal".

y=abs( fft( xcorr( dbpsk_sig ) ) );
subplot(4,1,4)%.. subplot_ting..
plot(y/max(y))% Plot_ting..
xlabel(' Frequency')%lavbelingx..
ylabel(' PSD')% labeling_y..

%—"-----Generating.. DSSS./DQPSK. Modulation.-----"%.

%" DSSS.-- Direct.. Sequence.. Spread.. Spectrum.. Generation.. with.. Barker

function [qpsk_sig] = DSSS_DQPSK_Barker
clc
clear
M=4;

% "Generating the bit pattern with each bit 28 samples long".

barker=[1 -1 1 1 -1 1 1 1 -1 -1 -1]; %bar_kEr_bits...
pattern_for_dss=[];
for k=1:11

```



```

    if barker(1,k)==-1
        signal=-ones(1,28);%%% samp ling sig na l ,...
    else
        signal=ones(1,28);%%% samp ling sig na l ,...
    end

    pattern_for_dss=[ pattern_for_dss signal ];
end
subplot(4,1,1)% sub plotting ..
plot( pattern_for_dss );% plotting
axis([-1 308 -1.5 1.5]);%% Axis naming ..
title(' Original barker Bit Sequence ');% Title naming ..

%" Gene rating ... the .. pseudo .. ran dom . bit .. pat tern .. for . spread ing ".
d=round(rand(1,121));
pn_seq=[];% Pat tern for cos .
carrier=[];% Carrier mul for msg .
t=[0:2*pi/3:2*pi ]; % Creating 5 samples for one cosine
for k=1:77 %Creating samP..
    if d(1,k)==0
        signal=-ones(1,4); %Creating samples for zero ..
    else
        signal=ones(1,4);% Creating samples for one ..
    end

    pn_seq=[pn_seq signal];% Patt _ _ _ er _ _ en for cos

end

% " Spreading .. of .. sequence .. ".
spreaded_sig=pattern_for_dss.*pn_seq;
subplot(4,1,2)
plot( spreaded_sig )
axis([-1 308 -1.5 1.5]);
title(' Spreaded signal ');
display( size( spreaded_sig ));
display( size( carrier ))

len =length( spreaded_sig );
display( len );
for i=1:len
    if spreaded_sig(i)==-1
        spreaded_sig(i)=0.*spreaded_sig(i);

    else
        spreaded_sig(i)=1.*spreaded_sig(i);
    end
end

```

```

        end
    end

    qpsk_sig=dpskmod(spreaded_sig,M,pi/4);
    display(length(qpsk_sig));
    subplot(4,1,3);

    plot(qpsk_sig);
    title('DQPSK modulated signal');

    %"Plotting ... the FFT of DSSS .. signal".

    y=abs(fft(xcorr(qpsk_sig)));
    subplot(4,1,4)
    plot(y/max(y))
    xlabel('Frequency')
    ylabel('PSD')
    end

%-----CoordAxis function -----%
function [x,y] = coordinate_Axis(frequency, time, sample_Rate, pulse_Length)
%Function for coordinates axis for obtaining 3D axis.
half_floor = floor((time)/2);
x = -half_floor:half_floor;
x = x/sample_Rate;

half_floor = (frequency)/2;
y1=1:half_floor-1;
y2 = (-half_floor):0;
y = cat(2,y2,y1);
%normalize according to the pulse length
y = (y*sample_Rate*pulse_Length)/(frequency);

%-----ambiguity_function -----%..

function A2 = ambiguity_fun(xt1, xt2, normalize, fft_N)
% For bits 0 bit need to be represented as -1..
Cor_A=xcorril(xt1, xt2); % Cross correlation between two signals..
A1=fft(Cor_A,fft_N);
A2=abs(A1);
clear Cor_A A1;
size_A2 = size(A2);
length_A2 = size_A2(1);

```

```

halfLength=floor(length_A2(1)/2);
Cor_A1=A2(1:halfLength,:);
Cor_A2=A2(halfLength+1:length_A2,:);
A3=cat(1,Cor_A2,Cor_A1);
A2=A3;
clear Cor_A1 Cor_A2 A3;

string_cmparision = strcmpi(normalize,'true');
if string_cmparision == 1
    m1 = max(A2);
    m2= max(m1);
    A2=A2./m2;
end

%-----ambiguity---.. analysis---.. DSSS./DBPSK-----%.

clc;
clear;
close all;
normalize=true;
fftPoint=256;

[dbpsk_sig] = DSSS_DBPSK_Barker;
Z12=ambiguity_fun(dbpsk_sig, dbpsk_sig, normalize, fftPoint);
ambigSize=size(Z12);
pulseLength=length(dbpsk_sig);
[x,y]=coordinate_Axis(fftPoint, ambigSize(2), '1', pulseLength);
display(Z12);
display(ambigSize);
figure;
mesh(x,y,Z12);
title('Ambiguity function');
axes_handle = xlabel('Delay');
set(axes_handle, 'FontName', 'Symbol');
axes_handle = ylabel('Doppler Shift');
set(axes_handle, 'FontName', 'Symbol');
axes_handle = zlabel('|c(t,n)|');
set(axes_handle, 'FontName', 'Symbol');

%-----ambiguity analysis for DSSS/DQPSK-----%.

```

```

clc;
clear;
close all;
normalize=true;
fftPoint=256;

[qpsk_sig] = DSSS_DQPSK_Barker;
Z12=ambiguity_fun(qpsk_sig, qpsk_sig, normalize, fftPoint);
ambigSize=size(Z12);
pulseLength=length(qpsk_sig);
[x,y]=coordinate_Axis(fftPoint, ambigSize(2), '1', pulseLength);
display(Z12);
display(ambigSize);
figure;
mesh(x,y,Z12);
title('Ambiguity function');
axes_handle = xlabel('Delay');
set(axes_handle, 'FontName', 'Symbol');
axes_handle = ylabel('Doppler Shift');
set(axes_handle, 'FontName', 'Symbol');
axes_handle = zlabel('|c(t,n)|');
set(axes_handle, 'FontName', 'Symbol');

%—————Power analysis for object detection—————%

clc;
close all;

%The distance between the Tx antenna (at 2.4GHz, -10dBm amp)to..
%Rx is 30 cm..
%First the received values are observed when there is.
%obstacle between Tx.
%and Rx antennas.
% Certain values have been observed and avg is done.
rx_no_obs1 = [-41.84 -41.43 -41.21 -41.26 -41.15 -41.42 -41.78];
rx_no_obs2 = [-43.70 -43.30 -43.07 -43.92 -43.27 -44.40 -43.60
              -43.83 -43.76 -44.15 -43.88];

rx_no_obs3 =[-44.59 -43.57 -44.99 -43.64 -44.34 -45.04 -45.21
              -43.61 -44.05 -43.89];

len1=length(rx_no_obs1);
len2=length(rx_no_obs2);
len3=length(rx_no_obs3);
rx_no_obs1_sum = -290.09;
rx_no_obs2_sum = -480.58;
rx_no_obs3_sum = -442.92;

```

```

rx_no_obs1_avg =(rx_no_obs1_sum)/len1;
rx_no_obs2_avg =(rx_no_obs2_sum)/len2;
rx_no_obs3_avg =(rx_no_obs3_sum)/len3;
display(rx_no_obs1_avg);
display(rx_no_obs2_avg);
display(rx_no_obs3_avg);
% Generally obstacle distance is increased.
%3cm from start(-15cm) to end (-45cm)..
x=-15:3:45;
rx_obs1=[-43.3555 -43.231 -42.47 -44.9916 -42.706 -53.67 -47.09
-46.02 -46.365 -47.3416 -44.605 -44.61 -43.518333 -44.2966
-48.368 -51.4316 -42.511 -43.35 -45.7688 -43.475 -43.091];
rx_obs2=[-45.22666 -44.7869 -46.1066 -44.9266 -45.6616
-55.1383 -50.74166 -49.7233 -47.6116 -50.01833 -48.07
-50.2833 -49.3 -51.87 -53.0133 -55.3583 -47.39 -44.9666
-46.39 -44.6083 -45.6833];
rx_obs3=[-45.4116 -43.3166 -44.705 -43.41833 -46.9916 -51.1183
-47.2561 -49.45 -46.425 -47.745 -46.435 -46.4883 -46.8266
-47.5916 -49.21833 -50.4533 -47.39 -44.9666 -46.44833 -44.61666
-45.66166];

figure;

semilogy(x,rx_no_obs1_avg,'ks');
hold on;
semilogy(x,rx_obs1,'o-');
axis([-20 +50 -54 -40]);
grid on;
legend('Avg Rx_dBm when no obstracle is placed',
'Rx_dbm_received by receiver when obstracle moves from Tx to Rx');
xlabel('Distnce (in cm, 30 cm tx-Rx ditance) when Obstracle moves
from Tx to Rx taken for every 3cm from -15cm to 45 cm');
ylabel('Received Rx_dBm ');
title('1st experiments - When obstracle is placed at

different distances from Tx and Rx (LOS)');

figure;
hold on;
semilogy(x,rx_no_obs2_avg,'ks');
semilogy(x,rx_obs2,'o-');
axis([-20 +50 -54 -40]);
grid on;
legend('Avg Rx_dBm when no obstracle is placed',
'Rx_dbm_received by receiver when obstracle moves from Tx to Rx');
xlabel('Distnce (in cm, 30 cm tx-Rx ditance) when Obstracle
moves from Tx to Rx taken for every 3cm from -15cm to 45 cm');
ylabel('Received Rx_dBm ');

```

```

title('2nd time experiment is conducted – When obstracle is
placed at different distances from Tx and Rx (LOS)');

figure;
semilogy(x,rx_no_obs3_avg,'ks');
hold on;
semilogy(x,rx_obs3,'o-');
axis([-20 +50 -54 -40]);
grid on;

legend('Avg Rx_ dBm when no obstracle is placed',
'Rx_dbm_received by receiver when obstracle moves from Tx to Rx');
xlabel('Distnce (in cm, 30 cm tx–Rx ditance) when Obstracle
moves from Tx to Rx taken for every 3cm from –15cm to 45 cm');
ylabel('Received Rx_dBm ');
title('3rd time experiment is conducted – When obstracle is
placed at different distances from Tx and Rx (LOS)');
hold off;

%–”—————End of Matlab Codes”—————%

```