# CHAPTER – 1

# INTRODUCTION

Radars have been mainly used in military operations like target detection, recognition of target devices, and used for surveillance purposes. It is high in cost and its target scanning range is also high when compared to the other radar. Each radar has its own applications and data is fed back to the radar and the location of target device is acquired. Radars has been used in many applications but Software Defined Radar (SDRadar) is different from other radars in cost and the target detection range. [14]

Radars have been used in many large applications and to meet the new challenges of technology, software defined radar is the suitable for the operation. SDRadar uses the technology of range detection and uses the transmitting antennas for sending the signals. These Electromagnetic (EM Waves) signals reach the target such as aeroplane, missiles etc., and reflect back to the receiving antenna and the data to be analysed. [1]

The reflecting EM waves touch the target and it calculates the time and the direction in which the target is present [1]. Slant range is defined as the distance between the source and the target in which the parameters include the angle of elevation and the position of the target. The slant range value is calculated and the value indirectly defines the distance in meters above the ground level. This project helps to increase the slant range resolution so that, the image resolution is increased. [14]

A low-cost software radio peripheral can be obtained by Universal Software Radio Peripheral (USRP) transceivers [3]. National Instruments has successfully combined the two versions of USRP transceivers. In this project, USRP N210 [18] has been chosen by our requirements and the results can be achieved after experimental calculations.

The main goal of the system is not only to reduce cost of the system, but also to increase the slant range resolution and bandwidth enhancement. The total setup is controlled by using LabVIEW application.

Radar can be used in many military operations in day and night weather and can works in all-weather capabilities. Traditionally, radars can be designed using many dedicated hardware blocks [1]. Radars possibilities can be extended to very broad and cover different fields like short and long range in ground and air surveillance, target recognition, target detection and classification and finally it can be also used in weapons control radar, which should be able to detect the targets which is present adjacently. These radar applications demand for the diverse radar capabilities, many antennas, specialised radar systems are developed on the same platform which is leading in the radar technology field.

Furthermore, many new platforms came into existence with containing with large number of RF sensors, which includes electronic counter measure, communication systems, navigation systems and electronic support measure systems. As radar contains many blocks and occupies the space and gain weight for various applications in which it is used in it, that space is limited and contains many constraints. Future radars also should contain the specification for the radar which supports the multifunctional capabilities and accuracy can be increased in the radars. [19]

In order to solve these contradicting constraints, a new technological radar has been evolved for the use of resolving the constraints which is called as SOFTWARE DEFINED RADAR (SDRadar). This SDRadar is a type of radar which is versatile in nature, where processing is done at the most. It includes signal generation, up and down conversions and also filtering which is performed by a software. This software is adapted easily and gives the software defined radars has many advantages as follows: [19]

- *creating a multipurpose* / *multifunctional radar*
- *re-use the same hardware*
- *advanced signal processing algorithms*
- *reduced price*
- *faster development*

Principles of software defined radar is same as the principles of software defined radio where the components have been implemented in the hardware which includes mixers, filters, modulators, demodulators and detectors etc. [19]

### ➢ *Multifunctional Radar*

The processing algorithm is implemented in the design section part of software which is easily loaded during the operation. It has the ability to switch between modes of the different radars or in between the application and the other radar. The antenna which can be used in this transmission and the same antenna can be used in the receiving antenna is used in many different radio frequency applications [19]. The same antenna can be used for different applications of software defined radar which includes:

- SAR
- Inverse SAR
- Weather radar
- Tracking of artillery shells
- Weapon location for the detection
- Electronic Counter Measures (ECM)
- Electronic Support Measures (ESM)
- Communication, navigation
- Identification system include: Satellite communication(SatCom), Radar Altimeter.

The possibility for creating the multipurpose radar which combines the different RF applications in one transmitting and receiver module and using one and only one antenna is especially interested in aircrafts. Examples of the multipurpose software defined radars include ARS-800-2 Multi-Purpose RF System Demonstrator and Reconfigurable Maritime Patrol Radar. [19]

The above maritime patrol radar is used as an airborne software defined radar in which it fluctuates between the different modes of the radar during the operation. In this maritime patrol radar, every time when it changes the mode, one algorithm is loaded on a FPGA which is operated by Personal Computer (PC).

The currently available modes of the Maritime patrol radar can be the following:

- *Real-time unfocussed SAR*
- *Real-time oil slicks and pollution detection (using SAR)*
- *Real-time representation of AIS (Automatic Identification System) Targets*

The multipurpose radio frequency system demonstrator presented in [7] in which it combines the two radio frequency applications on the same hardware includes pulse compression radar and a jammer. Two main challenges remain for creating the multifunctional software defined radars are:

- Designing the adapted antennas
- Increase in processor speed

In addition to the above challenges, it will also be important to

- Reduce the data flow rate to help improve the processing speed
- Design faster A/D converters in order to increase the bandwidth of software-defined radars.

## 1. *Antennas*

The software defined radars can use any kind of antennas in the application, but in order to satisfy the above parameters, multifunctional software defined radars use the antenna which supports all the above parameters and to satisfy the various needs given below [19]:

- Wideband or multiband capacity in order to accommodate the different functions.
- Availability of standard building blocks to simplify the design of new systems.

## 2. *Processing Speed*

Processing speed is the main factor in computer implementation of designing the software defined radar. One solution might be the use of graphics processing units (GPU) which is specialized in 3D graphics. GPU has highly parallel structure which makes it more effective than general purpose processors for some types of algorithms. [19]

| | **Intel Core i7 965 Extreme Edition** | **NVidia GTX 285** |
|---|---|---|
| Cores | 4 cores | 240 shaders, also called CUDA Cores |
| Frequency | 3200 MHz | 648 MHz |
| Processing Power | 70 GFLOPs | 1062 GFLOPs |

Table 1. Comparison of cores [19]

The above table compares the CPU (Intel Core) and modern GPU (Nvidia) and shows that GPU can be very useful for parallel applications such as radar applications, rather than considering CPU (Intel Core). The two biggest manufacturers of GPU are NVidia and AMD, developed libraries that allow programmers to use GPU for non-graphic applications. This is also called as general-purpose computing on graphical processing units (GPGPU) or stream processing.

Library of NVidia is called as Compute Unified Device Architecture (CUDA) and library of AMD is called as FireStream [8]. But previous studies show CUDA speeds up the radar pulse compression computing by the factor of 4 and SAR processing by the factor of 15 w.r.t., the workstation.

Recently, CUDA cards is only available to the servers and desktop computers, while real radar systems are using the chip which is mainly designed for embedded systems. CUDA was not available for real life radars. This is changed in the year 2009 when GE Fanuc released board containing 3U-VPX based board featuring with NVidia GT 240 CUDA enabled GPU processor. This kind of boards in future definitely increase the performance and allow the creation of the software defined radar in running with advanced algorithms. [19]

- ***Re-use of hardware***

Re-using of radar parts can be seen in the implementation of the software defined radar. This hardware can be either new usable blocks or can be taken from the old radar parts. In considering the both cases, the radar can be built by choosing the appropriate building blocks and the right software. There exist some projects which is taken for the creation of Scalable Multifunctional Radio Frequency (SMRF). This kind of building blocks can be designed to be compatible between the nations and the companies. [19]

Ideally, designing of software defined radar consists of choosing the right software's and appropriate building blocks used for designing. Hardware from the previous radars can also be used for designing the software defined radar. Based upon this, Very High Frequency (VHF) radar is built by using the antennas and the mechanisms of previous old radar named P-18 radar, made by Russia.

- ***Advanced signal processing algorithms***

In radar technology, researchers have developed many algorithms and tested new advanced signal processing algorithms. Some of them include Space-Time Adaptive Processing (STAP), Synthetic Aperture Radar (SAR), or Inverse Synthetic Aperture Radar (ISAR) is developed in the computer but in real world, processing can be done by adapting specialized hardware circuits.

Real challenge is when converting the algorithm from software to the hardware of real radars. The algorithm of software defined radar is implemented in software, facilitates for the test, further improvement and developing the algorithm. [19]

- ***Faster development and reduced price***

The possibility of using the blocks from the previous radars and using in the new radar leads to the faster development and the cost of the radar designing also reduces as many of the blocks is already arranged/ acquired from the previous radar application. Hardware parts is already existing and only task is to develop the software part for designing software defined radar.

The initial investment in development and research and development, the initial price of the blocks might be high and it will certainly drop the prices when the usage is increased for building blocks. Ultimately, this will reduce the production cost of the radar system.

Additionally, the possibility of testing the radar which is under development by taking the algorithm in which no prototype is required in it. This will allow faster and reduction in the price is obtained. Overall, the creation of multifunctional radar reduces the cost when compared to the building of individual systems individually for different applications. [19]

## 1.1. Motivation

The motivation of this project is to increase the slant range resolution of the radar and to detect the target in which direction it is present.

## 1.2. Literature Survey

In this paper [21], Synthetic Aperture Radar (SAR) is used as an airborne radar in which mapping technique is used for generating the high-resolution maps of surface target area. High resolution can be obtained by coherently combining the returns from a number of radar transmission and resolution of image is determined by the aperture of the radar where large aperture provides greater resolution. Resolution of the target images is determined by the parameters of emission with more data giving greater resolution. In this paper, it presents a technique for enhancing the slant range resolution in SAR images by dithering the carrier centre frequency. The procedure controls the radar waveforms so they optimally perform the classification function rather than providing the image of best quality. Knowledge based approach is best for determining the waveform of radar which can be able to differentiate the targets present near to each other.

Slant range resolution for a SAR system is inversely determined by the frequency. The frequency extent of transmitted signal is limited by the bandwidth of the analog to digital converters. This limitation can be solved by involving the dithering the carrier centre frequency of the SAR transmitted waveform. Limitation of the SAR is to increase the slant range resolution by combining measurements with differing carrier centre frequencies.

Authors in [14] explains about enhancing the range resolution and slant height. It uses stretch processor algorithm in which linear modulated waveform of 2MHz is used as input equation waveform frequency and fast fourier transform technique is used to transforming into frequency domain. Algorithm is used to increase the slant range resolution value where the results obtained from the implementation of first generation USRP devices. It shows 72m in first generation USRP 2920 device and later techniques and further development in the USRP devices and in algorithms obtained 12m and reduced to 6m. Range resolution can be found out by inversely proportional to the bandwidth value. This bandwidth value can be found out by obtaining the FFT waveform. The main limitation of this paper is that SDRadar operates at 2MHz frequency but not in nano frequencies. This limitation can be solved by developing the algorithms which operates at nano frequencies.

In the reference paper [22], authors demonstrate a six-port receiver technique for increasing the range resolution. Generally, Frequency – modulated continuous-wave (FMCW) based measurement technique is deployed to give an approximate range value of target. Six-port circuit is used for the receiver as a precision phase detector in Continous Wave (CW) function and at the same time as a mixer in FMCW function. The switching between the modes is controlled by software to improve the range resolution. FMCW based range resolution mainly depends on the baseband signal transmitted. A very broadband and linear frequency sweeping signal is needed in this case to achieve better range resolution for practical applications.

The above proposed software defined radar operates with the frequency of 2MHz is the main limitation of the project as it cannot operate the greater frequencies i.e., Giga Hertz. Algorithms can be developed by taking reference of signal processing algorithm to operate Giga Hertz (GHz) frequencies which indirectly increases the slant range and resolution will also be increased rather than before.

## 1.3. Problem Statement

Develop slant-high resolution SDRadar for efficient target detection in low power wireless applications.

## 1.4. Objectives of the work

The main objective of this work is to find the slant range resolution of the software defined radar (SDRadar) for low power emerging technologies.

## 1.5. Organization of thesis

The whole document is comprised of chapters in which project work is divided into sections named as chapters. The chapter-1 describes about the introduction of the project, literature survey, limitation and objectives of the work.

In chapter-2, it describes about the existing system of software defined radar which operates at the frequency of 2MHz. It also explains about the blocks existing and the functionality of each blocks is briefly explained.

In chapter-3, it describes about the measurement of target altitude for radar in which techniques used and the formulation used for calculating the target altitude is explained. Equations can be formulated for finding the target altitude and various propagation models is also explained.

In chapter-4, it describes about the proposed work which includes block diagram, individual components can be explained individually and comparison of previous work to the proposed work also explained in detail.

In chapter-5, it explains about the various algorithms to be used in software defined radar and describes the operation of algorithm which includes various blocks like input, Local Oscillator, mixer, low pass filter, and Fast Fourier Transform technique is used for transforming the output into frequency domain at the end of stages of operation.

In chapter-6, it explains about the simulated results which is obtained when the algorithm is processed by LabVIEW platform and waveforms is generated for 2MHz frequency to each section in the algorithm.

In chapter-7, it describes about the future scope of radar where it is used to design the other application and conclusion of software defined radar (SDRadar) is explained. The whole data is collected from various sources and their references is produced in chapter-8.

# CHAPTER – 2

# EXISTING SYSTEM

As explained in chapter-1, increasing the range resolution value is the main motivation in existing system which uses USRP N2920 board and it achieved the values which is comparatively different from the first-generation transceivers. It has the bandwidth frequency up to 2GHz. The setup consists of Single Board Computer, Controller, Low Noise Amplifier, Power Amplifier, Circulator, Motor, Antenna and the USRP transceiver. The whole setup is controlled by the LabVIEW application which is controlled by the single board computer. [14]

The motor is controlled by the controller where the instructions is given by the LabVIEW application. The inputs given to the transceiver say, USRP N210 is connected to the power amplifier then connected to the circulator, which acts as a block for sending and receiving paths. The output of the circulator is connected to the antenna which is placed at the last section of the block diagram. [14]

Power amplifier is present in the transmitting path, which increases the signal power in the transmitting path. The antenna presents at the last acts as both transmitting and receiving. The signals sent through the transmitting antenna is allowed to pass into the atmosphere, touches the target and reflects back to the same antenna, but now, it acts as a receiving antenna. Analog signal, which reflects back to the receiving antenna, contains the data in the signal. While in the receiving path, the signal is allowed into the low noise amplifier section, which has the operating voltage of 5 Volts. [14]

Low noise amplifier block helps the data signal to remove the unwanted signals or noise which is present in the received signal. The noises present in the signal is completely removed and the noise free signal is allowed to pass into the USRP N2920 board and then sent into the LabVIEW application and the results are observed [14]. Generally, the low noise amplifiers are arranged near the detection blocks. The whole setup is arranged outside and the results are observed by arranging the metal plates at certain distances and check the procedures repeatedly.

## 2.1. SLANT RANGE

Slant range is the length of the path between radar and the target, not the distance which is measured on the earth surface. The radar measures for different ranges of two targets which placed one above the other. This might result in false measurement which corrected by the software module in the latest radar units called as RRP-117 [5].

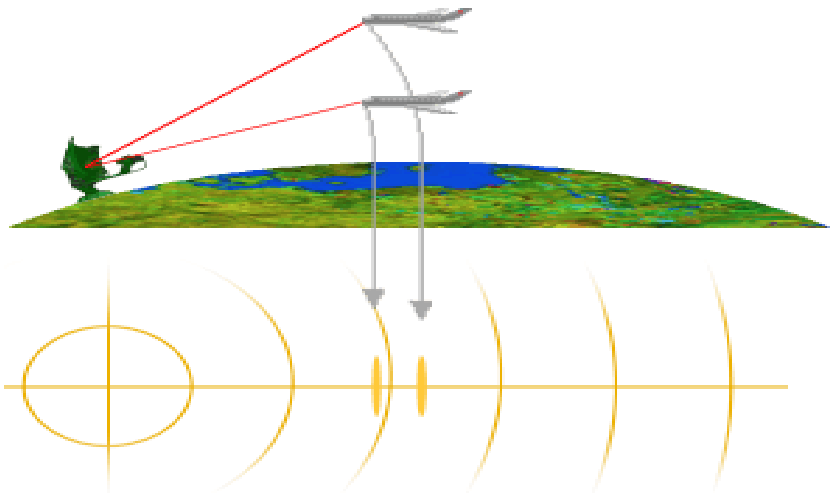


Figure 2.1. Slant range for two targets [20]

These software modules can be used in the geographical calculations and the calculation is difficult and complicated. This also requires some weather data for correction. Previously, old radars like 2D radar, ASR-910 is still used in the air traffic management cannot be used for calculating the slant range.

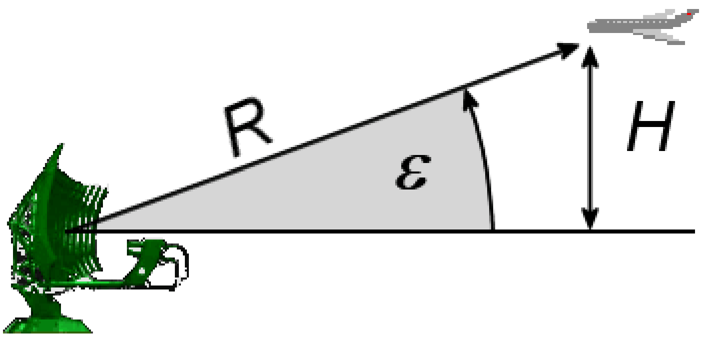



Figure 2.2. Trigonometric connections without consideration of the earth’s bend. [19]

The range between a ground projection and ground radar of the target is called the Down range. It is very important to know at what geographical position the target is detected. The calculation of the topographical range is very complicated in a radar unit. The calculated topographic trigonometric connections shown in the above figure is given as

$$R_{topogr.} = R. \cos \varepsilon$$

This would be valid if the flat earth is taken into consideration and the earth radius is also taken into account. In addition, the actual distance to the slant range is measured by the radar unit proportionally depends on

- The measured slant range
- The actual height of the target
- The actual earth radius valid for the radar unit site

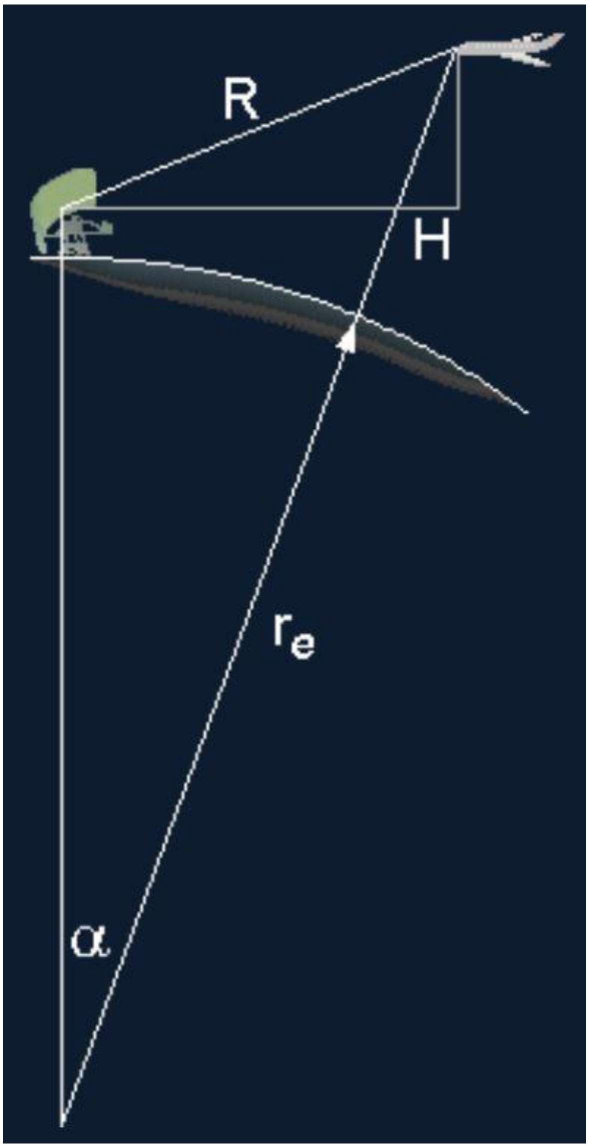



Figure 2.3. Trigonometrical connections including the consideration of the earth's bend. [19]

From the above diagram, triangle can be considered between the points: centre of the points, the position of the aircraft, and the radar sites. The sides of the triangle are described by the cosine theorem and by equation

$$R^2 = r_e^2 + (r_e + H)^2 - 2r_e\,(r_e + H).\cos\boldsymbol{\alpha}$$

($r_e$ is the equivalent earth radius here).


Figure 2.4. Determination of angle $\boldsymbol{\alpha}$ [19]

Assume that earth is sphere, the section of circumference of the sphere is calculated with help of simple ratio from the complete circumference of the earth from the angle $\boldsymbol{\alpha}$:

$$360^o.\,R_{topogr.} = \boldsymbol{\alpha}\,.\,2\pi.\,r_e$$

Circumference of the earth can be considered approximately for the actual topographical range which is illustrated in this section. The propagation of the electromagnetic waves is subjected to refraction, that mean, the transmitted beam is not in a straight line of the triangle, and this side is also bent in addition to the dependence of

- The transmitted wavelength
- The barometric pressure
- The air temperature
- The atmospheric humidity.

Slant range is defined as the line of sight between the target and the radar which is used to calculate the slant range resolution for better resolution of the target. As the slant range resolution is increased, the resolution of the target is increased. Basically, this is implemented in the space-borne or air-borne navigation where targets present in the space or airborne. Improving the slant range resolution can be done by implementing with multiple SAR (Synthetic Aperture Radar) surveys. [19]

This SAR system is limited by power and data rate constraints of the synthetic aperture radar. Strip mapping is an imaging system using microwaves for generating high resolution from echoes which collected by a small antenna. But azimuth resolution is obtained through time-delay measurements in which time-dispersed linear frequency modulated pulses is compressed into very short pulses. Areas of images can be easily imaged with higher azimuth resolution i.e., up to 1-2 m using the Synthesized Aperture Radar (SAR) systems and on the other hand, transmitted signal bandwidth is limited up to 20 MHz by power constraints.

Slant range is explained earlier with implementation of USRP boards and taking only one antenna for transmitting and receiving the modulated signal. The transmitted signal travels with the electromagnetic waves and touches the target and loses the energy and scatters in all directions and also reflects back in the same direction and receives the echo signal and determines the energy of received signal. This can be useful to track the target and in which the direction the target is present by performing the calculations on the received echo. Then it allowed to pass into the low pass filter where cutoff frequency is given and only allows the frequencies to allow below that frequency. Higher frequencies above the cutoff frequency is neglected. [19]

The obtained waveform can be seen in the application which is used to control the whole software and the system. Output of low pass filter is allowed to pass into the Fast Fourier Transform section where it analyses the low pass filter waveform and peaks is formed at the strongest signal frequency, i.e., the detection range can be found by considering the lower and higher frequencies of the FFT output signal. Then the value of slant range resolution can be found by taking the parameters from the output waveform and calculate the range resolution. This operation is finished indoor and outdoor testing is also done. As the targets as placed at a certain distance, such as 6mts, 8mts, 12mts. [14]

The transmitted signal is allowed to pass the electromagnetic signal through the antenna and reflects back the echo signal receives at the same antenna which is used as transceiver. The same operation is carried out for the other distance like 8meters and 12 meters. The same procedure is carried out and the reflected echo signals are also shows the output waveform. The main aim of the project is to find the range and the distance of the target. This distance can be calculated by the above process and received echo signals are analysed and allowed to pass into the low pass filter and again tend to send into FFT section.

Then the signals are analysed and at the value of 6, 8 and 12 meters, the peaks are observed, i.e., the distance of the target is calculated and expressed in terms of meters. The range resolution value for the above waveforms is given equal to 6meters. In first generation of USRP, this value is calculated up to 75m and gradually reduced to the 12m and finally to 6m. [14]

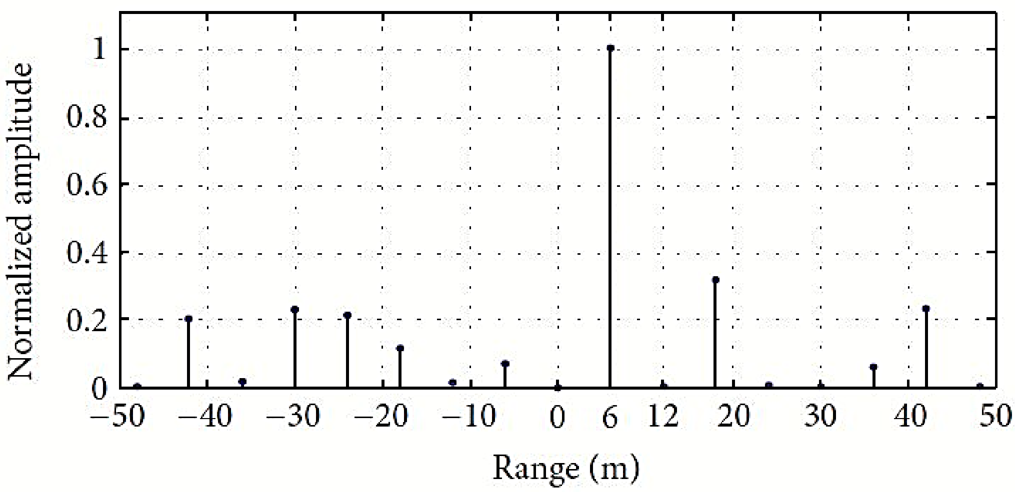



Figure 2.5. Retrieved signal peaks with target placed at 6m [14]

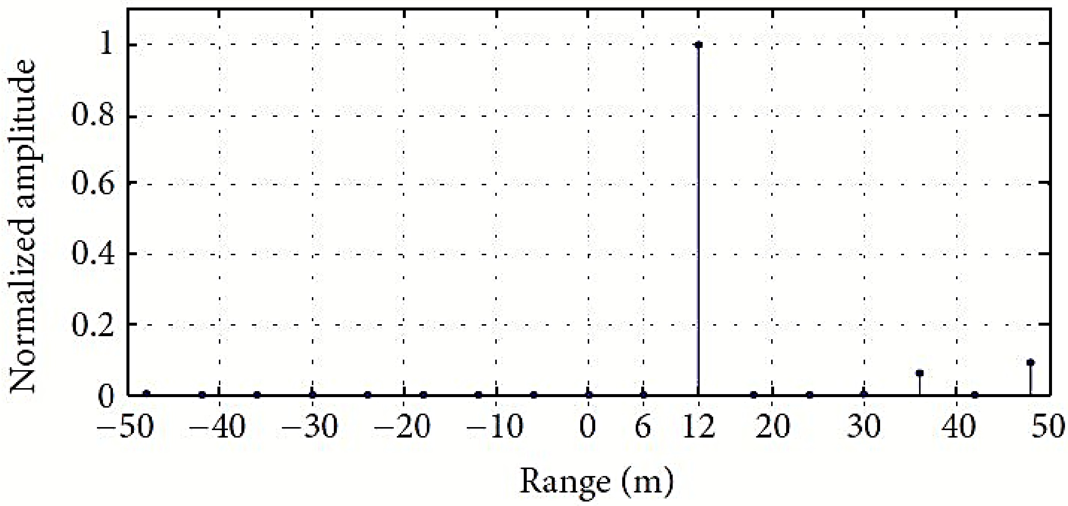



Figure 2.6. Retrieved signal peaks with target placed at 12m [14]

The above data explain for only one target which is present at some unknown distance and this distance can be seen or observed in the final FFT analysis of the signal. In the same procedure, there can be many targets in between the range and all the targets respond to the transmitted signals. The targets can be of any number and all the distances can be observed in the software section of the system in which having the LabVIEW platform. In this project, by taking all the experimental calculations, the above range resolution value can be reduced to less than 6mts (<6m) is main aim of this work. [14]

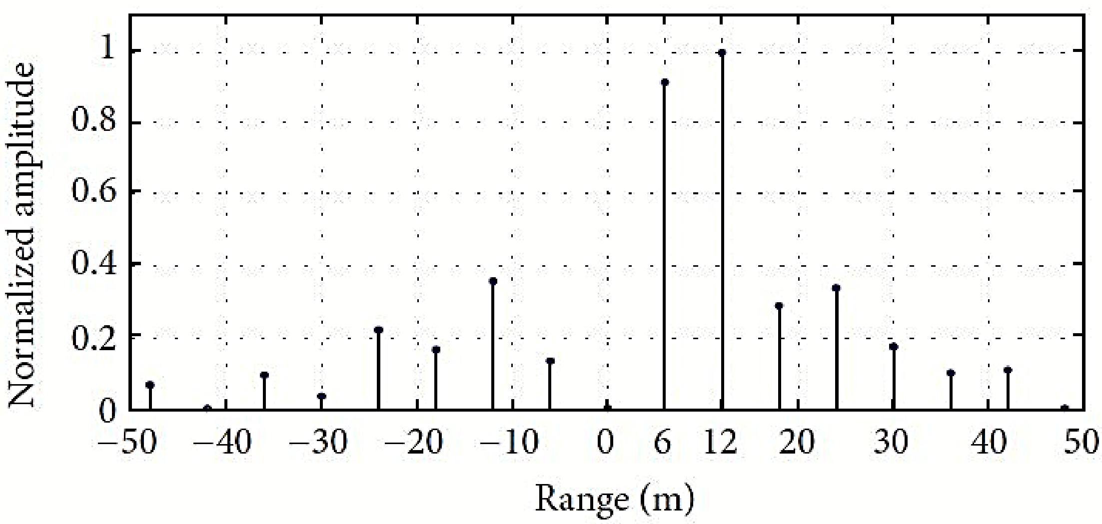



Figure 2.7. Retrieved signal peaks with two targets placed between 0 and 12m. [14]

## 2.2. RANGE RESOLUTION

The sample signal is taken and allowed to transmit and receives the signal back with adding some noise like white noise or gaussian noise. Noise is also present in the incoming signal in both imaginary and real channel which assumes white noise and gaussian noise respectively. To detect the incoming signal, a special type of matched filter is commonly used in the communication. This filter detection can be optional when known signal is to be detected.

The target resolution of the radar is its ability to distinguish between the two targets even they are present very closely in either ranging or bearing. Weapon controlling radar for which great resolution is required to differentiate between the targets which are present in yards away. Search radar is usually used and it can distinguish the target which is present over hundred yards away. This resolution can be derived into two types. They are Range Resolution and Bearing Resolution.

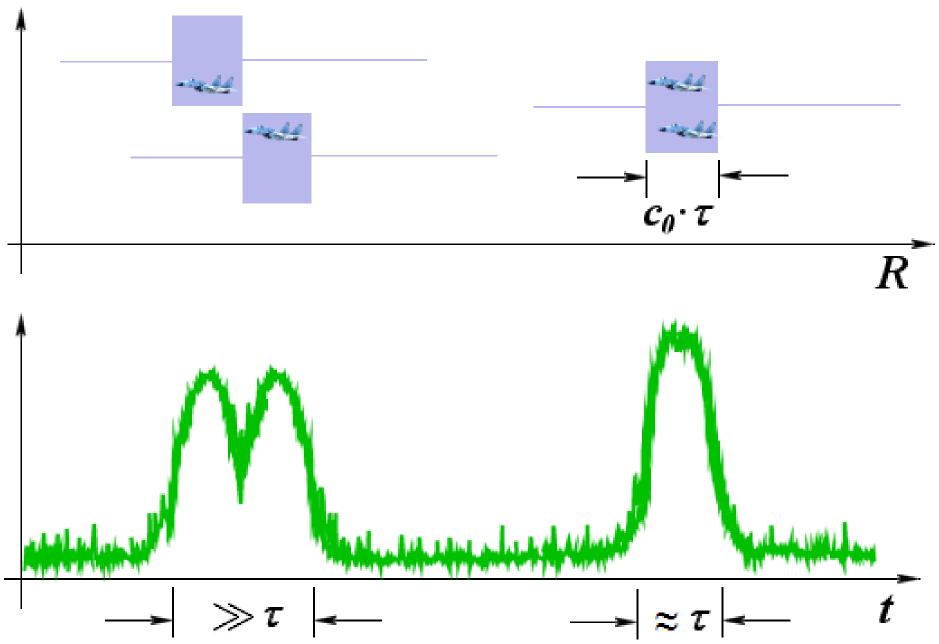



Figure 2.8. Minimum distance of targets in range

Range resolution can be defined as the ability to distinguish between two or more targets on the same bearing but present at different stages. The degree of range resolution is purely dependent on the size of the targets, and types of targets, and the efficiency of the receiver and indicator. Pulse width is the main primary factor in range resolution. A well-designed radar system with all the factors having maximum efficiency and should be able to distinguish targets separated by one-half the pulse width $\tau$. The range resolution of a radar system can be calculated from the following equation

$$S_r \geq \frac{c \,.\, \tau}{2}$$

## a. Radar using Intrapulse – Modulation

In a pulse compression system, the range resolution of the radar is given by the length of the pulse. The ability of compressing the pulse purely depends on the bandwidth of the transmitted pulse not by its pulse width. The receiver should also have the almost same bandwidth to process the full spectrum of echo signals.

$$S_r \geq \frac{c}{2 \,.\, BW}$$

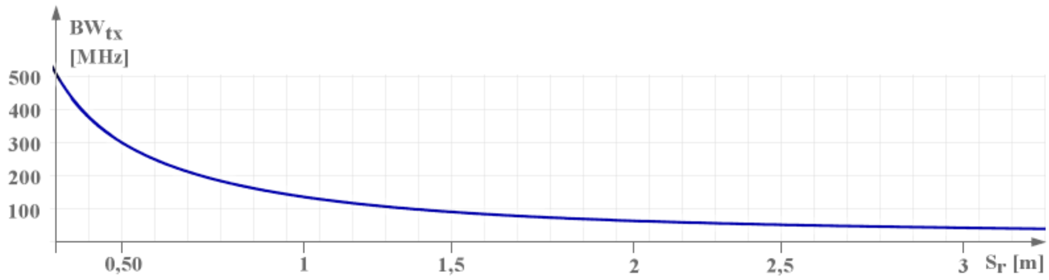



Figure 2.9. Range resolution as a function of transmitters bandwidth

High resolution can be obtained with the long pulses, thus with a higher average power. The above figure shows the variation of the slant range resolution with bandwidth.

## 2.3. DISTANCE – DETERMINATION

The radar transmits radio pulse with very high pulse power, transmits in only one direction which is directed by the directivity of the antenna and propagates in the given direction with the speed of light. If obstacle is present in the direction, then some part of the energy is scattered in all the directions. A small portion of the energy is reflected back and received by the radar. The received pulse energy by the radar antenna is evaluated by the radar.

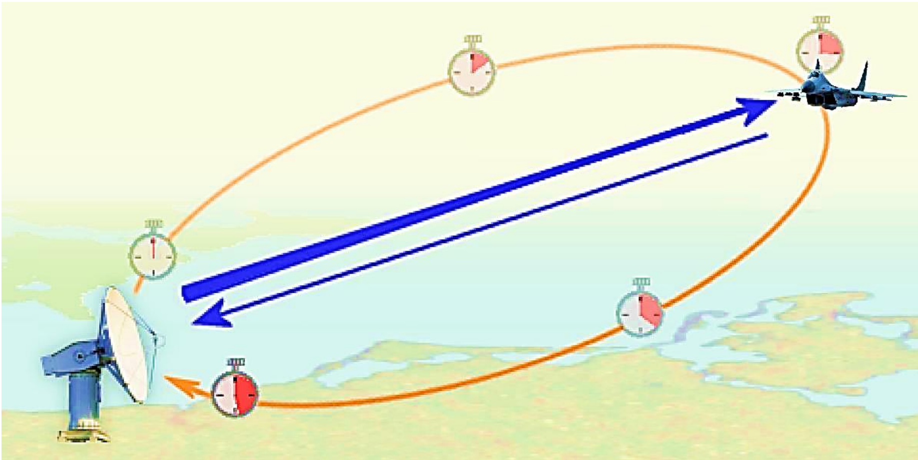


Figure 2.10. Distance determination by time

The distance calculation is measured with simple oscilloscope. The radar sends a strong pulse energy and moves with synchronous leaving a spot at the transmitting time. The deflection starts with the transmitting pulse in synchronously. The pulse in the oscilloscope also moves with the transmitting signal and receives the echo signal by the radar. Then at this moment, short pulse is denoted in the oscilloscope. The distance between the radar and the target is calculated by the time taken by the signal for to and fro radar signal. Otherwise, the distance between the two pulses in the oscilloscope is calculated for the distance between the radar and the target i.e., aircraft.

The propagation of the radio waves happens at the constant speed, i.e., speed of light, $3x10^{8}\ ^{m}/_{s}$ and distance can be determined by the runtime of high frequency transmitting signals. Slant range is defined as the actual range of a target from the radar. Slant range is also defined as the line of sight between the radar and the target.

To calculate the horizontal distance between the target and the emitter, target elevation's knowledge is required. Since the waves propagate i.e., travel to target and comes back to radar, the total distance is divided by two inorder to calculate the time taken by the signal to reach the target.

The formula for calculating the slant range is given by

$$R = \frac{c \cdot t}{2}$$

where c is speed of light = $3 \times 10^{8}\ ^{m}/_{s}$, t is the measured running time in seconds, R is slant range. The distances are expressed in kilometres or nautical mile and it's conversing value is 1.852 km.

## *2.4. Software Defined Radar: Synchronization Issues*

In recent years, research and development has been carried out in the radar technology in which focussed on the software defined radio (SDR). The main aim of the SDR research is to shift the radio engineering problem from the hardware to the software domain. The main advantage of this problem transition is that Software domain provides more flexible, repeatable, accessible solution space than provided by the hardware domain.

The open source software defined radio project is known as GNU Radio and Universal Software Radio Peripheral (USRP) is the hardware specially designed to be used with the GNU Radio software. The combination of the above two technologies produce the low cost and very sophisticated software defined radios. Software defined radar and software defined radio are the two technologies present in the same technology, GNU Radio and USRP can be used to form a low-cost radar sensor.

In practical, the software defined radar is a particular radar which replaces the hardware with the software, by including all the concepts of SDRadar. In Software Defined Radar, mostly it is used for signal generation, target detection, range resolution of the target and processing of radio signal processing is also carried out by the FPGA and or DSP. Radar can easily switch between the modes as it is completely software defined, for modifying the transmitting and receiving signal when it is in operating stage also.

Depending on the applications of the radars, the firmware of the radar can be changed and radar transceiver can act as linear/non-linear chirp radar, traditional pulse radar with phase encoded modulation. By the above approach, this reduces the components and the size of the system, weight and the power consumption.

The main advantage of the software defined system is having with great flexibility and accessibility is related to the hardware systems. The universal fact is that a single SDR system can implement many radio or radar systems with different hardware and only have to change the software part of the system. The software part has to be designed for various systems and the main issue of this kind of system is Software Implementation.

The radar sensor can be useful only when the transmitting and receiving signal pulse width is known. The time between the transmission of pulse and reception of the pulse can be known exactly. In order to characterize this system, time coherence and time synchronization is analysed. Time coherence is nothing but the time values assigned to any two samples is equal to the difference between the actual time at which the samples are converted to analog signal or from analog signal.

Whereas, time synchronization must exist between the transmit and the receive data streams. It shows the capability to obtain high level precise information which includes the velocity of the vehicle, direction of the vehicle, and the distance of the vehicle is used to improve the security in the automotive field. This experiment close to the concept of cognitive radar which is explained in the above section. It also shows the important issues and limitations related to the combination of the SDR with radar systems and able to design a multifunctional software defined unit with well suited for radar sensor networks which can be used for range measurements, data communications and the radar imaging.

### A. *Implementation of SDRadar*

Basic principle of the SDRadar is to transmit a high energy pulse signal which travels in the form of electromagnetic waves and touches the target and scatters in all the directions, and it also travels back in the same direction in which the power of signal is reduced and received by the same antenna which is used for transmitting. This received pulse contain low energy and calculates the received pulse.

The obtained pulse describes the distance of the target by the energy it reflects in the opposite direction. The energy can be lost in various factors like the size of the system and the distance of the system. The received echo signal describes the location of the target and the direction of the target in which it is present. In order to recognize the echo signal, the transmission doesn't occur continuously, but it can be recognized with using the rectangular pulse having pulse width $\tau$. Slant range can be indicated with the notation of $R_{sr}$, which is the distance between the target and the radar.

$$R_{sr} = c * t/2$$

where c represents the speed of light and t is the time interval between the transmitting and the receiving instants of pulsed signal. T is also can be converted into the frequency domain just by taking the inverse of time is known as frequency. This can be shown as

$$T = 1/f$$

T represents the time and f represents the frequency. The above equation can be also modified and given as

$$R_{sr} = c/2*B$$

c is speed of light and B represents the Bandwidth of the frequency. Bandwidth is known as the difference between the higher frequency and the lower frequency.

In order to have a system which works without any errors, then it should contain the good level of synchronization. The synchronization is guaranteed when the time interval between the first pulse transmitted and the pulse of first received is determined.

## 2.5.MODEL

Model is classified into different areas. They are Matrix Definitions, Environmental and Simplifications.

### 1. ENVIRONMENTAL MODEL

While estimating the altitude, it's important to develop the model which satisfies the environmental conditions such as reflection properties and radar hardware and software geographic conditions.

### 2. TARGET MODEL

The target can also be modelled as a quantity of scatters over the extent of target geometrics. Each of the reflectors can be considered as the input waves and consists large amount of signal. Addition of waves can be performed w.r.t relative phase. The reflectors will interfere both destructively and constructively. If the surface of the earth surface is rough or is in complicated geometrical shape, the target scattering positions cannot be described as deterministic.

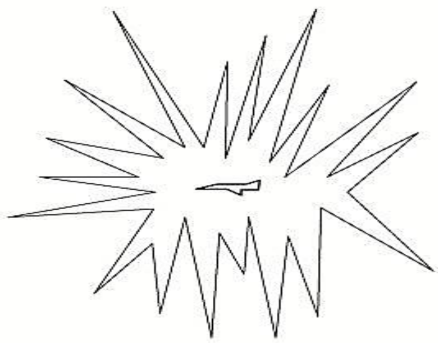


Figure 2.11. Target reflectors must be expressed in the model in terms of probabilities [19]

In the case, when the target contains the quantity of random scattering reflectors, the distribution function for the complex target amplitude is normal $N\,(0, \boldsymbol{\sigma}_S)$ in imaginary and real part which gives the radar cross section (RCS), which is square of target amplitudes and becomes exponential distributed. It also follows that the target amplitude with different radar wavelength is independent.

## ANGLE CORRELATION

The total RCS is dependent on individual reflectors relative position and the target area will fluctuate sharply with respect to the radar carrier maintaining the angle to the target.

Radar will detect the target from incoming and outgoing angles with effect of multipath echoes.

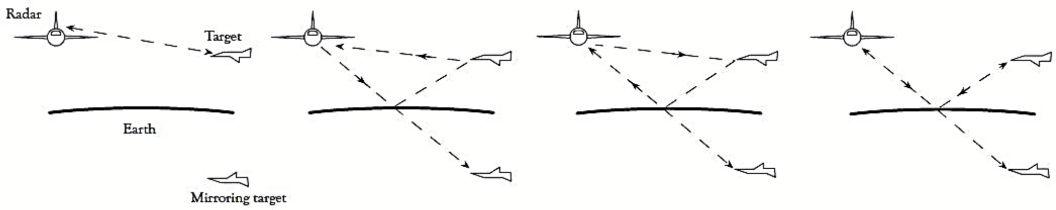



Figure 2.12. Four different possibilities for the radar wave path. [19]

The RCS in case 2 and 3 is considered to be identical while the target amplitudes for the other cases must not necessary be correlated.

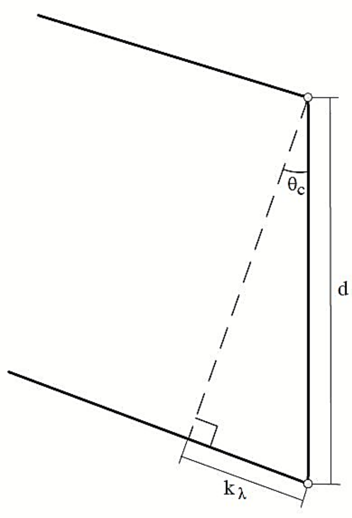



Figure 2.13. Targets main reflectors separated in altitude with range d. [19]

This angle correlation can be estimated roughly with the illustrated Figure 8. As described earlier, the model will give a pattern of RCS in Figure 6. If the target has two main reflection points separated with difference in length is $k\lambda$, altitude with range d, and the angle between the points is $\theta_c$, as shown in Figure 8. The angle difference is calculated between the incoming waves from the two different reflection points is estimated to large, the correlation for the target area is considered to be zero. The points are considered always as un-correlated because of the size of target when compared to the wavelength. This means that new random value is obtained for every new pulse.

## 3. Geometric Model

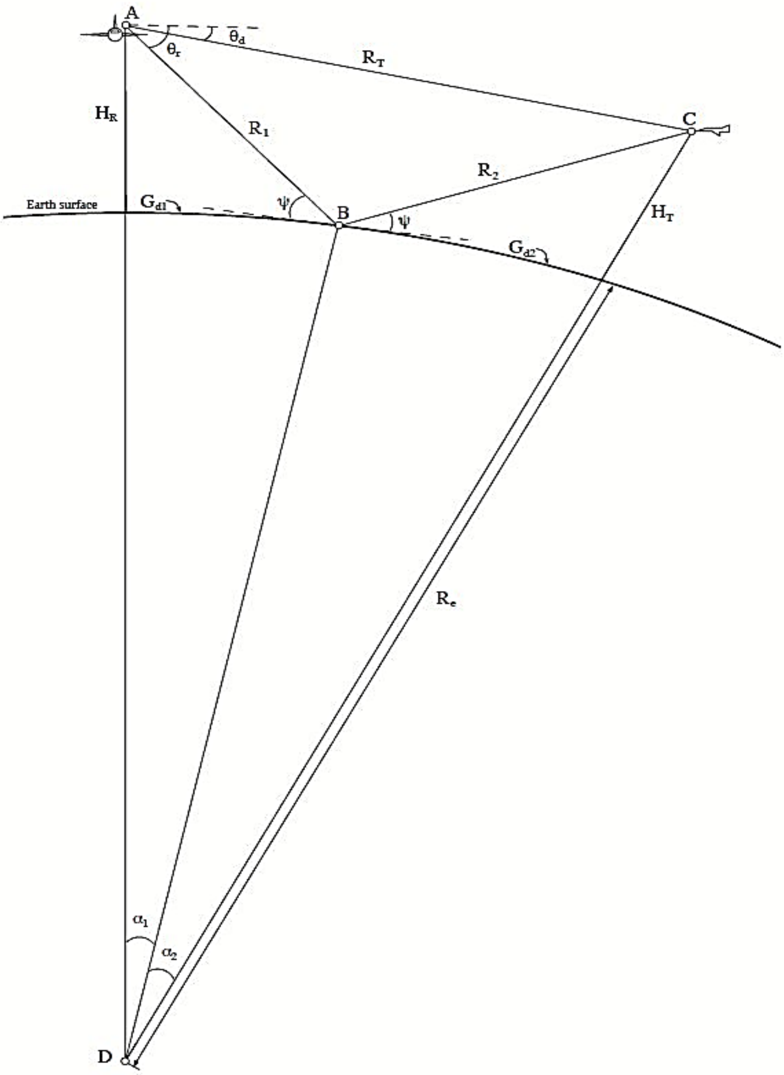



Figure 2.14. Geometry of spherical Earth reflection without restriction on altitude and range of target relative to the radar [19]

The above geometric model is used to derive the estimated altitude. To do this, a spherical earth model is used instead of using the simplified earth model. Basic problem to define in this geometric model is to find the correct reflection point on the ground surface $G_d$ and should contain the knowledge of how to make partition between $G_{d1}$ and $G_{d2}$. Assuming the target and the radar altitude is smaller than the effective radius of the earth, $R_e$ is given by

$$2G^3_{d1} - 3G_dG^2_{d1} + [G^2_d - 2R_e\,(H_R + H_T)]\,G_{d1} + 2R_eH_TG_d = 0 \qquad (1)$$

Where $R_e = \frac{4}{3}.\ 6370$ km. The constant $\frac{4}{3}$ is used as correction for the atmospheric refraction.

When the range $R_T$ is known instead of ground range $G_d$ the following approximations need to be solved

$$G_d \cong sqrt\ (R^2_T - (H_T - H_R)^2 / 1 + ((H_R + H_T)/R_e \qquad (2)$$

The range $G_{d1}$ in (1) is given by

$$Gd1 = \frac{Gd}{2} - p\,sin(\frac{\xi}{3}) \qquad (3)$$

Where

$$\mathrm{P} = \frac{2}{\sqrt{3}}\sqrt{Re(HR + HT) + \left(\frac{Gd}{2}\right)^2} \qquad (4)$$

$$\xi = \sin^{-1}\left(\frac{2ReGd\ (HT-HR)}{p^3}\right) \qquad (5)$$

With $G_{d1}$ given and if $G_{d2} = G_d - G_{d1}$, the angles $\boldsymbol{\alpha}_1$ and $\boldsymbol{\alpha}_2$ in Fig 9 can be derived as

$$\boldsymbol{\alpha}_1 = \frac{Gd1}{Re} \qquad (6)$$

and

$$\boldsymbol{\alpha}_2 = \frac{Gd2}{Re} \qquad (7)$$

and

$$R_1 = \mathrm{sqrt}\ [H^2_R + 4R_e\,(Re + H_T)\,\sin^2(\boldsymbol{\alpha}_1/2)] \qquad (8)$$

$$R_2 = \mathrm{sqrt}\ [H^2_R + 4R_e\,(Re + H_T)\,\sin^2(\boldsymbol{\alpha}_2/2)] \qquad (9)$$

The elevation angle, $\boldsymbol{\theta}_d$, from the direct ray is exact calculated by applying the law of cosine to the triangle $\overline{ABC}$

$$\boldsymbol{\theta}_d = \sin^{-1}[(2R_e\,(H_T - H_R) + H^2_T - H^2_R - R_T)/(2(R_e + H_R)R_T)] \qquad (10)$$

An approximation of $\boldsymbol{\theta}_d$ can be used if $H_T << R_e$ and $H_R << R_e$ as

$$\boldsymbol{\theta}_d \cong \sin^{-1}\left(\frac{HT-HR}{RT} - \frac{RT}{2Re}\right) \quad (11)$$

The depression angle of the reflected ray, $\boldsymbol{\theta}_r$, is found by similar analysis of triangle $\overline{ABD}$ and can be approximated to

$$\boldsymbol{\theta}_r \cong \sin^{-1}\left(\frac{HR}{R1} - \frac{R1}{2Re}\right) \quad (12)$$

$\boldsymbol{\theta}_r$ is given by the angle with correct gain according to the geometrical model shown in Fig. 9 but must be negated to be used in the calculation of the antenna diagram.

$\delta_R$ can then be derived by

$$\delta_R = R_1 + R_2 - R_T \quad (13)$$

but to avoid numerical calculation problems that may occur when large numbers are subtracted, the law of cosine is used and the final form of $\delta_R$ is

$$\delta_R = \frac{4\left(H_R + \dfrac{H_R^2 - R_1^2}{2R_e}\right)\left(H_T + \dfrac{H_T^2 - R_2^2}{2R_e}\right)}{R_1 + R_2 + R_T} \quad (14)$$

At first sight, it's like a simple problem to derive $H_T$ from (17), but note that $R_1$ and $R_2$ contains highly nested expressions of $H_T$. The final target altitude can be derived from the equation $\delta_R$.

## 4. REFLECTION MODEL

In this model, it is explained that the reflection arises from surface of sea and is purely specular. It contains the reflection coefficients magnitude $\boldsymbol{\rho}$ which refers to the product if three factors which are $\boldsymbol{\rho}_0$, $\boldsymbol{\rho}_s$ and D. Their individual contribution is a number with ranges from 0 to 1. The total specular reflection coefficient has a magnitude represents in the equation [19]

$$\boldsymbol{\rho} = \boldsymbol{\rho}_0 \boldsymbol{\rho}_s D \quad (15)$$

where

$$0 \le \boldsymbol{\rho} \le 1 \quad (16)$$

$\boldsymbol{\rho}_0$ is defined as the coefficient of electromagnetic reflection that appears at the reflected surface. $\boldsymbol{\rho}_s$ is spreading factor indicates how the components of the reflection wave is reduced as a result of the surface of roughness. D is the divergence factor caused by the fact that reflecting surface is always convex.

The angle which appears on the point of reflection between the tangent to surface and the beam is called grazing angle, represented as $\psi$. This angle is used when calculating the reflection factor and found by analysis of the relations in Figure 9 as

$$\psi \cong \sin^{-1}\left(\frac{HT}{R1} - \frac{R1}{2Re}\right) \tag{17}$$

Further, calculation of $\boldsymbol{\rho}_0$ as

$$\boldsymbol{\rho}_0 = \frac{\sin(\psi) - \sqrt{\varepsilon c - \cos 2(\psi)}}{\sin(\psi) + \sqrt{\varepsilon c - \cos 2(\psi)}} \tag{18}$$

where

$$\varepsilon_c = \varepsilon_r - j\,\varepsilon_i = \varepsilon_r - j60\,\lambda_r\,\sigma_e \tag{19}$$

and $\varepsilon_r$ is the ordinary dielectric constant, $\lambda_r$ is wavelength in meters and $\sigma_e$ is referred to conductivity in units mho/m. $\boldsymbol{\rho}_s$ is then derived from the following equation

$$\boldsymbol{\rho}_s = e^{-z}\, I_0(z) \tag{20}$$

where $I_0$ denotes modified Bessel Function of zero order and the equation is represented as

$$z = 2\left(\frac{2\pi\sigma_h \sin(\psi)}{\lambda}\right) \tag{21}$$

Here, $\sigma_h$ is the standard deviation, STD, of the amplitude distribution of the sea waves and $\boldsymbol{\rho}_s$ is valid on the intervals of $0 \leq \frac{\rho s \sin(\psi)}{\lambda} \leq 0.3$.

Due to this, the point where reflection occurs is always curved rather than flat, this means that the curvature of the reflected wave front will be different to the incident wave when compared which affects the field intensity at that point. The divergence factor is derived as

$$D \approx (1 + 2G_{d1}\, G_{d2} / R_e\, G_d \sin(\psi))^{-1/2} \tag{22}$$

This is referred to just an approximation.

## 5. RADAR MODEL

The radar is assumed to carry with a beam changing system with fixed positions. When the signal is allowed to transmit, the beam is always in horizontal position but the receiving antenna is just adjusted in elevation position. Therefore, the transmitting and receiving signals are computed in pairs and the received signal adjusts the angle up or down. So, it is called up-and-down beam. [19]

The antenna diagram can be derived by the following equation

$$A_k = 1 - 2(\frac{\theta_b}{4\lambda_r})^2 \cos(0.81\frac{\theta_b}{\lambda_r} + k\frac{\pi}{6}). \tag{23}$$

Here $A_k$ is the normalized amplitude gain factor. The values of $k \in \{0, 1, -1\}$ represents the transmitted beam and the received up and down beam. $\boldsymbol{\theta}_b$ is represented as elevation angle, where $b = \{r, d\}$ and $\lambda_r$ is the radar wavelength.

To increase the resolution in range without reducing the duration of the pulse, where pulse compression is used. Approximate gaussian function is used to derive the impulse response function which represents as

$$h_{pc}(r) = 10^{-0.6(r/r3)2} \tag{24}$$

where r is a vector with each sample value and $r_3$ the pulses of bandwidth 3dB.

The pulse compression in radar systems is implemented in digital domain in which only a discrete-time version of the compressed pulse is obtained. [19]

### a. Least-Square Estimate (LSE)

LSE do not require any statistical knowledge about observed data vector x, which is determined from many other methods. The only requirement is that their existing model how depends on the theta $\boldsymbol{\theta}$.

The equation which is to be minimized of LSE-loss function can be given [19]

$$\mathbf{L}(\theta, s) = \| x - A(\theta)s\|^2$$

If s is seen as linear parameter in this model, analytically it can be substituted by a LSE of s. It is shown as

$$\hat{s} = (A^T A)^{-1} A^T x$$

which gives LSE-loss function as

$$L(\theta) = \|x- A (A^T A)^{-1} A^T x\|^2 = \epsilon^T (\theta)\, \epsilon(\theta)$$

where the least-squares residual represented as

$$\epsilon (\theta) = (I - A(A^T A)^{-1} A^T)\, x = P^{\perp} x$$

and the matrix A depends on the vector parameter $\theta$. The projection matrix $P^{\perp}$ is the orthogonal projection of A's complement. It is possible to presave the data for each estimate values. When s is substituted with its estimate. There is possible to neglect the impact created on the reflection parameter $\boldsymbol{\rho}$, and this can be applied to a constant value of one. The final solution is to find the $\theta$ which minimises the unknown nonlinear parameters in $\theta$.

From the above data, x is a complex vector and $\epsilon$ is complex valued. The normal in the loss function is needed to be given as

$$\mathbf{L}(\theta) = \|\epsilon(\theta)\|^2 = \epsilon^H (\theta)\, \epsilon(\theta) = (\mathrm{Re}\, \epsilon(\theta))^2 + (\mathrm{Im}\, \epsilon(\theta))^2 = \left\|\begin{bmatrix}\mathrm{Re}\, \epsilon(\theta) \\ \mathrm{Im}\, \epsilon(\theta)\end{bmatrix}\right\|^2$$

The characteristic is achieved when algorithms are executed with different values of $\theta$.

## 2.6.MEDIAN OF SEVERAL ESTIMATIONS

Every input signal is a collection of one up beam and one down beam, but to analyse, there do not contain only one signal, but multiple. This is done several times on signal and much more information can be collected about the target. From this calculation, a final median value is collected as estimation for measuring the target altitude. [19]

## 1. QUALITY INDEX

To check how good the estimation results are, there exists a technique called as quality index, which is abbreviated as QI. This quality index is calculated for each measurement. To calculate this index, one should have the knowledge about the LSE-Loss matrix and global grid minimum is found as in TGS. The estimation result is good when the deviation is high from mean of every derived LSE-Loss value which results the high Quality Index (QI). [19]

Quality Index is derived by

$$QI = |\overline{\mathbf{L}(\theta)} - \mathbf{L}(\theta_{\mathrm{gmin}})\,|$$

where $\bar{\mathbf{L}}$ represents the mean of derived LSE-Loss value for each derived value. $\mathbf{L}(\theta_{\text{gmin}})$ represents lower LSE-Loss value. [19]

For algorithms and the optimization methods, knowledge about the loss function is missed, this can be covered by taking the two lower local minima values taking into account. Quality index can by derived by

$$QI = |\ ||x||^2 - \mathbf{L}(\theta_{\text{gmin}})\ |.\ [\mathbf{L}(\theta_{\text{gmin}}) - \mathbf{L}(\theta_{\text{1min}})] / \mathbf{L}(\theta_{\text{gmin}})$$

where $\bar{\mathbf{L}}$ is replaced with $||x||^2$ and second lowest minima represents with $\mathbf{L}(\theta_{\text{1min}})$. the energy in the input signal can be shown with $||x||^2$ and estimation of the total loss function is given with $||\boldsymbol{x} - \hat{\boldsymbol{s}}||^2$.

Quality index of TGS-s can be defined as the deviation between the global grid minimum and the LSE-Loss matrix mean value. Deviation between the lowest and the second lowest is calculated LSE loss values are considered for various optimization search methods. [19]

## 2. Performance of Pulse separation and Signal to Noise Ratio

Signal to Noise Ratio (SNR) is used and derived by

$$\text{SNR} = a^2 / \text{var}(n)$$

where a is pulse amplitude, n is Gaussian colored voice. The above equation describes how signal to noise ratio can be derived which explains as the ratio of pulses amplitude to the gaussian noise. The signal to noise ratio is calculated for amplitudes and mean of these is used. It is possible to detect when the algorithm is not able to solve multipath echoes for different SNR, is by reducing the $\delta_R$ towards zero. When continuously changing the values of $\delta_R$ and SNR for many times, then variance and normed bias error can be formed. [19]

## 3. Interaction between SNR and $\delta_R$

A test scenario is conducted to measure the interactions between the signal to noise ratio to $\delta_R$ when $\delta_R$ is reduced for different values of SNR. The bias error and the variance for the entire scenario is derived and the obtained results are roughly estimated and gives only the idea of LSE performance. [19]

$$Bias\ error = \frac{\sum_{i=1}^{100}(\delta_{R_{est}}(i) - \delta_{R_{true}})}{n} \cdot r_3^{-1}$$

$$Var = \sqrt{\frac{\sum_{i=1}^{100}(\delta_{R_{est}}(i) - \delta_{R_{true}})^2}{n-1}} \cdot r_3^{-1}$$

The above expressions [19] describe how bias and variance error are derived when they are normed with $r_3$.

## 4. COMPUTATIONAL BURDEN

The computational burden is affected when implementing the optimization search methods. To compute more scientifically, time is used in every optimization search methods and can be able to get a hint and floating-point operations are used which gives the correct measure and the computational performance of the compared algorithms and simulations are carried out in LabVIEW. [19]

## 5. CALCULATION OF TARGET ALTITUDE FROM $\delta_R$

The approximate equation for calculating $\delta_R$ is

$$\delta_R = \frac{2H_R H_T}{R_T}$$

where assumption is calculated for flat earth rather than more advanced [19]

$$\delta_R = \frac{4\left(H_R + \frac{H_R^2 - R_1^2}{2R_e}\right)\left(H_T + \frac{H_T^2 - R_2^2}{2R_e}\right)}{R_1 + R_2 + R_T}$$

The geometric parameters of spherical earth is raised. Note that $R_1$ and $R_2$ is highly contained with the nested expressions of $H_T$. The value of $H_T$ is calculated with or without considering the interpolation where time is consumed more than taking the approximate value of $H_T$ which is given as

$$H_T = \frac{\delta_R R_T}{2H_R}$$

Drift occurs in the sequence when the geometrical parameters are not considered and taken into account. Multiply the above $H_T$ equation with a factor and observe either the closer range values will be correct or the target present at the large distance. [19]

# CHAPTER – 3

# RADAR TARGET ALTITUDE MEASUREMENT

## 3.1. INTRODUCTION

Radars is used in airborne navigation over sea to detect the target present in the air. While transmitting the signal, pulse will be generated and it is allowed to travel through the airborne and main problem occurs when the transmitted pulse is received in multipath. Due to the multipath signals, if they are known and suppressed, then the target's altitude can be easily determined very accurately. After receiving the transmitted signal, processing has been done to the received signal considering the multipath characteristics. [19]

The signal is transmitted with consideration of beam angles and the received signal is in the combination of one up beam and one down beam. This represents that knowledge should be over input signal, which is the combination of pulses, and positions of the pulse, where the altitude can be calculated of the target. [19]

Apart from signal processing algorithm, there exists many different algorithms which is used to track the target and its altitude measurement. Choosing of algorithm should check that it satisfies the whole parameters which is considered for the altitude calculation. Previously, Least-Squares Estimate (LSE) method is used and it has been evaluated and it is extended with other algorithms also. Some of them are Total Grid Search (TGS), Gauss Newton with line search (GN), Steepest Descent with line search (SD) and Numerical Neighbourhood Search (NN). [19]

Loss function in LSE is derived several times with considering different characteristics, where each value is contributed to curve-fit error of the input signal. TGS is obtained if the values are calculated over the total specified estimated space. Then all values are applied to remaining algorithms and those values need not to be derived over estimated space. [19]

## 3.2. RADAR Background

RADAR use sensor for transmitting and receiving electromagnetic signals in the form of microwaves. These pulse signals are transmitted through directional antenna which receives the reflected energy between the pulses. Concentration in the radiation energy into narrow beam and sweep through expected region which is possible to detect the targets. This reflected energy can be either from sea, targets or land. The range can be calculated by time it takes for the microwaves signals to reach the target and from target to radar again is derived by the formula. [19]

$$R_T = \frac{c}{2\tau s}$$

c is microwaves propagation speed, i.e., speed of light and τ is time between the transmitted and received pulse. [19]

Targets can be of different types but hereafter, all are considered as air targets. Ideally the transmitting pulses should be very small to detect targets and at the same time, send out the maximum energy as possible which gives the highest probability of detecting targets. Practically, limitations of the peak power in which transmitting unit can deliver those prerequisites are inconsistent. For the above problem, pulse compression is the solution which is done by transmitting the modulated pulses having wider bandwidth to provide the required average power at an acceptable level of peak power. The received signal is compressed by decoding their modulation by a filter which fits the transmitted input pulse signal. [19]

Transmitting and the receiving signals is done simultaneously. These phase coherence acts as an important characteristic in which the targets can be estimated near ground reflections and the received signal is separated into two signals. One occurs with the phase of the transmitting signal and the another is 90 degrees phase shifted. This kind of separation is called as I/Q demodulation. When the pulse wave is reflected from the moving target, the changes made in the phase velocity due to the doppler shift in frequency. By sensing the frequencies of doppler shift, the radar can separate the echoes from clutter and land, where objects with high radial velocity is suppressed.

Pulse repetition frequency is defined as the number of pulses transmitted per second, abbreviated as PRF.  The range of PRF of airborne radars range from few hertz to several kilohertz. The choice of pulse repetition frequency is crucial because it determines the weather, range and to what extent the doppler frequencies are observed by the radar. Range ambiguities occur due to the radar that has no clarity to which the pulse belongs to an echo. When PRF is low enough for all echoes from one pulse to be received before next pulse is transmitted. But when the PRF is high, the scenario is different. When a target is moving or away from the radar, shift occurs in I and Q-channel. [19]

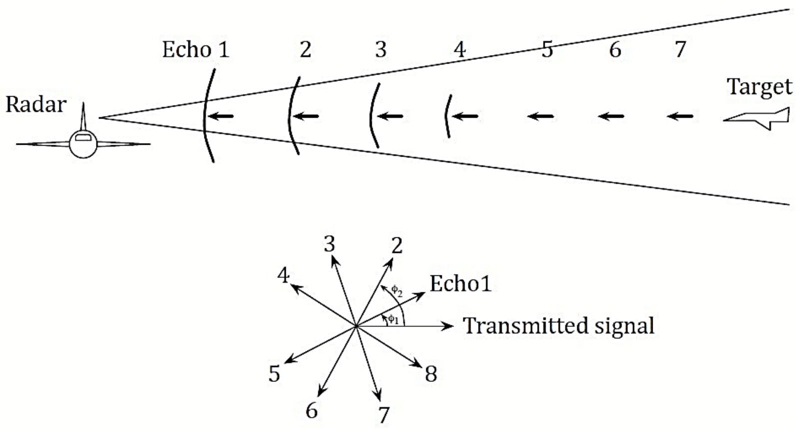



Figure 3.1: Target doppler frequency shows up as a pulse-to-pulse shift in phase [19]

Target doppler frequency results in a progressive phase shift in the frequency of the received echoes from the target. This phase shift of one echo to the other echo is shown in the below figure. After receiving the echoed signal, the phase shift produces a signal in which the amplitude fluctuates at the target. Depending on the doppler shift frequency value, whether it is positive or negative, Q will lag or lead respectively with phase shift of 90 degrees.

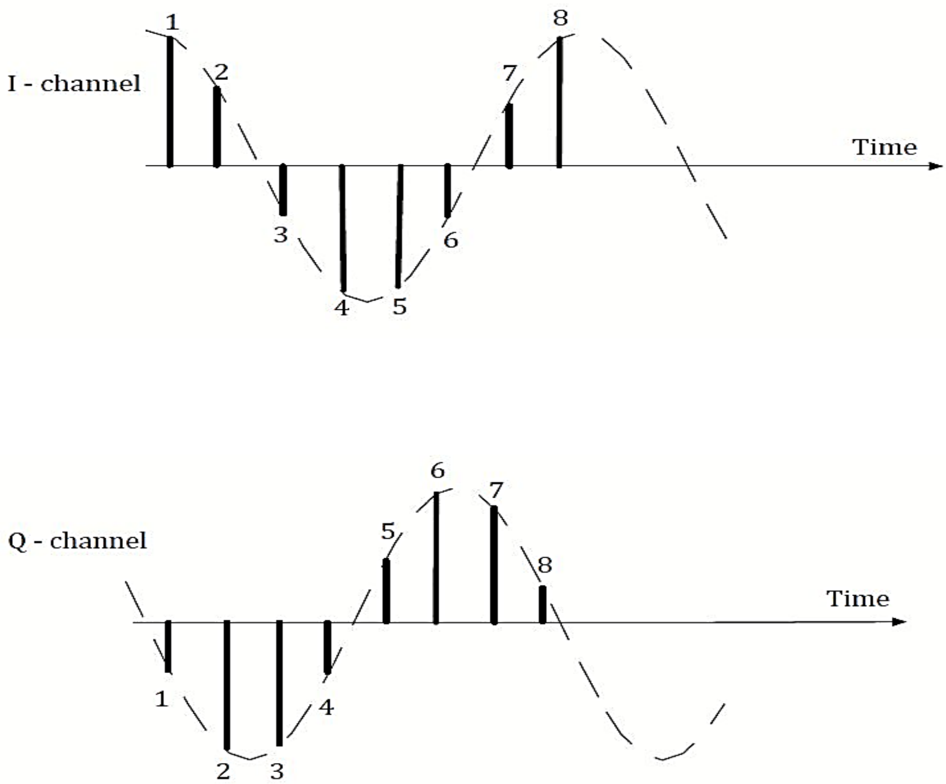



Figure 3.2: Doppler frequency with positive shift where both I and Q signal is provided. [19]

Representation of the received signal is done by a range doppler matrix where the signal is mapped into two dimensions. The range dimension can be evaluated by the matrix which is separated in range bins on which the range between the bins is equal to the sampling range given as

$$\tau_S = \frac{c}{2Ts}$$

where $T_s$ is the time between two samples. In doppler dimension, the signal is distributed into many doppler channels till the doppler filter-bank allows. [19]

The target properties can be extracted from the received signal is

- Range
- Radial velocity
- Elevation and azimuth direction
- Size

The result values of range and radial velocity will give exceptionally good and the measurement for the direction give acceptable values but we can't get the accurate values for the target size.

## 3.3. Multipath Background

This multipath effect occurs due to the multipath effect which arises when the earth surface is smooth, especially when using the airborne navigation over oceans, seas, and lakes. This effect is probably affected when the target is detected, if the multipath signals are well known, can be emphasized without suppressing which is useful for calculating the target altitude measurements. [19]

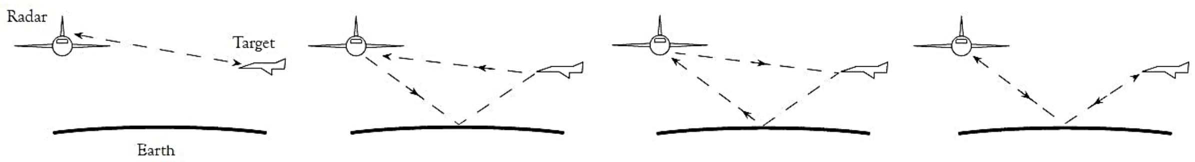
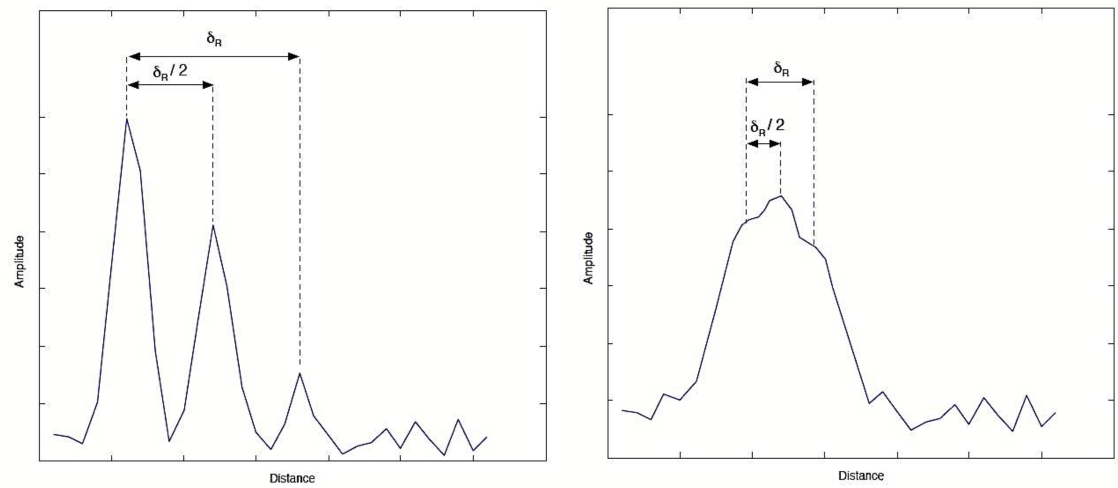



Figure 3.3: The four different cases of propagation for the radar signal using multipath effects. [19]

The above diagram represents the propagation of multipath signals in four different ways. This is shown in Figure 3.3 where the first diagram represents as the direct echo. Case 2 and Case 3 occurs at the same time, due to the same range for the propagation of the radar pulses, can be seen as one case which is called as first multipath echo. Case 4 contributes to the longest path and is called as second multipath echo.




(a) Dissolved echoes (b) Undissolved echoes

Figure 3.4: Two different signals received with multipath effect. Pulse 1,2 and 3 are the direct, first multipath and the second multipath echo respectively. $\delta_R$ referred as the range between first and the third pulse in each beam. [19]

The separation of the pulses is obtained depending on the distance away and the position of target altitude. Two main characteristics evolved in multipath propagation which is illustrated in the above Fig. (a) and Fig. (b). The first multipath is present in between the direct echo and the second multipath echo which is illustrated in the figure (a). In the figure (a), it represents the echoes resolved, but when the target is far away, and close to the earth surface, the signal becomes less resolved and can be in difficult case which is illustrated in Fig.(b).

Altitude can be determined by the detection of pulses and the estimated range between the second multipath echo and the direct echo for a flat earth surface model is given by

$$\delta_R \approx 2H_RH_T / R_T$$

where $R_T$ is the range to the target

$H_R$ the radar carrier altitude

$H_T$ the target altitude

Depending on the airborne radar and the position of the target, characteristic of $\delta_R$ is obtained. If the value of the $R_T$ is increased, the received signal from different echoes leads the pulses to overlap and impossible to determine the result. Relationships for the earth is much complicated and can be derived in geometrical model of the spherical earth.

## 3.4. Background for The Presaved Data

Simplification and the optimization methods are applied due to the high computational burdens for a TGS. Since the problem is discrete, this can be performed by adapting the matrices, used for deriving the computational values. Because of the problem i.e., discrete, which reduces the computational burden by saving as much as data before each calculation. More specifically, it is easy to extract the matrices instead of dealing with the complicated equations. [19]

## 3.5. Search Methods on Non-Linear Least Square Problem

The main use of the linear least square is curve fitting or data fitting. By finding the customized curve which matches the input data vector in the curve and the one which is possible to find the positions of the pulses. Clearly, this explains that the values obtained is fitted into the curve where the values are derived from the model function. LSE loss function is derived several times with various characteristics, and each value is contributed to the curve fitting error to input signal. If the total values are estimated over the total gridded estimation space, then TGS is performed. [19]

If all the values are provided in the matrix, this could be seen as the estimation grid with two unknown parameters which is to be estimated. Global optimum on the grid is obtained when the lowest value of the loss function over the discretized estimation space, the grid. This global optimum can be located in between the grid points on the continuous parameter space. The difference is calculated in between the global optimum and the grid optimum is thus upper bounded by the length of the grid points.

The next problem is to find the lowest grid value, global grid minimum which is obtained without deriving the Least square estimation loss function values. This leads to the highest computational burden and faster algorithm to be implemented instead. This optimization problem can be expressed in terms of the mathematical operations as the argument of given function having minimum or maximum value. Finding the global minimum is difficult unless the problem has some specific properties in TGS. In many techniques and methods, only global minimum is calculated by using such as derivates. For a one dimensional, global and local minimum value are represented in the following Figure 3.5. [19]

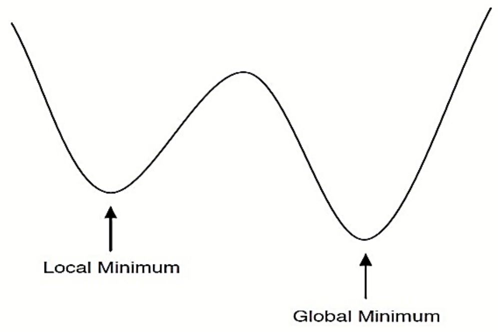



Figure 3.5. Local and Global Minima [19]

By implementing the conventional numerical methods, it is difficult to estimate the global minimum value. The best part is to start guessing near to the global minimum and to hope the iteration will converge to the result. The chance of finding the global minimum is increased by taking many different points throughout the feasible set, then if all the starting points produce the same result, then the global minimum is almost obtained else take the least value from all the results obtained for different starting points, consider it as the global minimum value. [19]

One more important step in optimized search methods, is how to define the magnitude of the step. Its best to adopt the fixed step length rather than altering the magnitude of the step using line-search. Minimization of minimum function is observed by choosing the step length reasonably. Most modern line-search implementations begin with a full Newton step i.e., the step length gain is taken to 1. Until the step length gain is found to be 1, estimates are carried out which satisfies the decrease on criterion function. Inspection has been made to check whether any type of convergence criterion has been met after each step. If it is found, local minimum is found. [19]

## CHAPTER - 4

## PROPOSED WORK

The above block diagram [14] represents the system setup of SDRadar system in which the transmitting and receiving paths are distinguished appropriately.

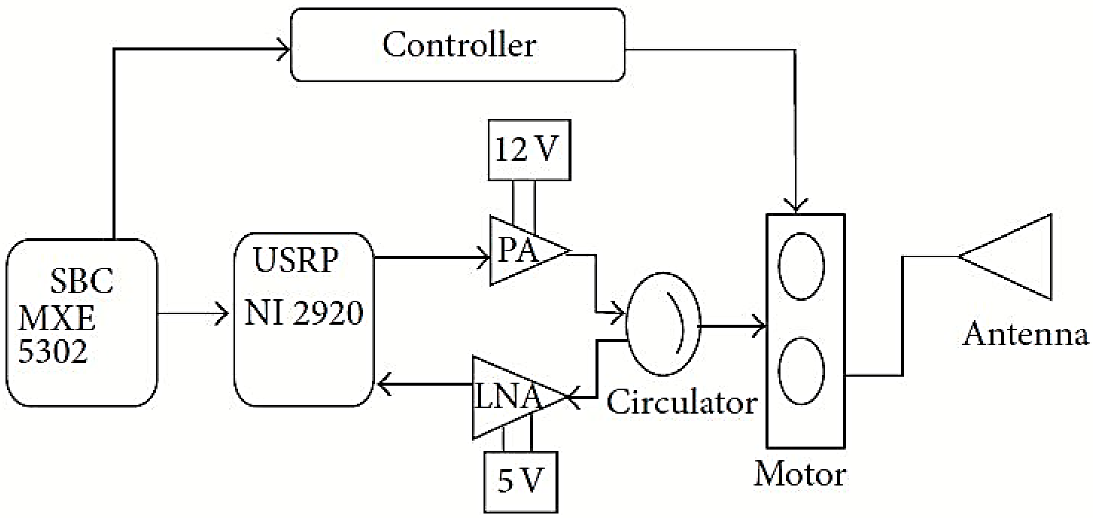



Figure 4.1. Block Diagram of existing SDRadar system [14]

### 4.1.SBC MXE5302

SBC is abbreviated as Single Board Computer. This computer is useful for controlling the whole system in which LabVIEW application is embedded into it and the signal data transmission values are also controlled and the frequency and the bandwidth also calculated. The values for bandwidth and the input frequency is provided in LabVIEW application. [14]

The data signals transmission and the received signal's output data waves can be observed in LabVIEW application. The another useful of single board computer is to control the motor which is present in the system which is useful for scanning the images of the target by the movement of the motor. This motor can be controlled by the use of the controller which is present in the system. [14]

### 4.2. CONTROLLER

Controller acts as the most important block in the system which controls the dc motor which is used for capturing the target images by moving around the object/thing placed at some distance. Controller takes the input from the LabVIEW application and movement of the dc motor captures the images and the matrix is filled by moving in various directions. According to this, absence of controller in system fails to capture the target images. [14]

## 4.3. POWER AMPLIFIER

Power amplifier is useful to increase the signal power along the transmitting paths. This block is kept near to the transmitted devices where the transmission takes place into the airborne navigation. So, the signal is allowed to reach the target with strong signal and has the ability to pass to the larger distances. Operating voltage of the power amplifier is 12 Volts.

## 4.4. LOW NOISE AMPLIFIER

Low noise amplifier is placed in the system in the receiving path. The transmitted signal is sent, touches the target and receives the signal through the receiving antenna. The received signal contains the data and it also comes in with the addition of noise into the system. Noise components are eliminated by allowing the signal into the low noise amplifier. Then the signal's noise components are eliminated and the signal power increases and the modulated signal is allowed to pass into USRP N2920 transceiver. The operating voltage of the noise amplifier has 5 Volts. [14]

## 4.5. CIRCULATOR

The SDRadar system setup contains the paths for transmitting and receiving paths. To reduce the system size, i.e., having separate paths for both transmitting and receiving paths, the both paths are reduced into one and that is called as Circulator. This has the functionality of acting as transmitting and receiving paths according to the system performance. By this adoption of circulator, the system size is reduced and the cost reduction also significantly reduced. It is compatible with all the systems where the circulator is required in the system.

## 4.6. MOTOR

Motor is placed into the SDRadar system for the use of capturing the images which is controlled by the controller, indirectly taking the inputs from the LabVIEW application from the single board computer. This motor is useful for moving around the objects and capturing the images from various directions. The captured images are allowed to fill into the matrix with the help of algorithms. Without using motor, the capturing or scanning the object is impossible. So that, the motor plays an important role in capturing the images. The operating voltage of the motor is 5 volts.

## 4.7. ANTENNA

A single antenna is placed at the last section of the system, and it acts as both transmitting and receiving antenna for sending and receiving signals. Generally, two antennas are adapted for sending and receiving, but that increases the cost and the size of the system. Then to reduce the size and cost, only one antenna is taken, say logarithmic antenna, which acts as transmitting and receiving antenna. This antenna setup can be controlled or used in outdoor setup and the incoming data also acquired by this antenna. This helps in reaching the targets and the reflecting signals is acquired by the same antenna. So, this type of requirement is satisfied by taking logarithmic antenna.

## 4.8. USRP N210

USRP is expanded as Universal Software Radio Peripheral [3]. Generally, this boards are used in the radar communication which is sold by the National Instruments to develop the complex software defined radio systems. In this project, USRP is taken as part of the block diagram. In this software defined radar, this USRP boards is taken for use from its first generation. Developing the parameters from one to another boards, many USRP boards has been evolved and now currently it uses N210 version. It contains the specifications which is far better than the other USRP boards. [18]

This offers higher bandwidth and the higher dynamic range processing capability. High speed streaming capability is allowable by using the Gigabit ethernet interfacing with the USRP boards which help with the transmission of 50 Mega Samples(MS)/second(s) in both directions. It also has the additional feature which separates from all remaining boards is plug-and-play MIMO capability, which stands as the ideal with specific parameters and demanding performance with requirements. [18]

## 4.9. Comparison of Current USRP Device to the Previous USRP Device:

In previous work, the design of software defined radar is explained in the construction of the block diagram which includes the personal computer in which LabVIEW software is used to control the system and radar, USRP transceiver i.e., USRP N2920, power amplifier, low noise amplifier, circulator and a single antenna used for transmitting and receiving the electromagnetic signals, and controller is also used to control the motor in the design to capture the targets in various directions [2].

In this work, signal processing algorithm is used in the USRP transceiver in which Linear Frequency Modulated Waveform is used as the input equation and target distance is calculated when the signal is received at the antenna with containing the pulse width, which is calculated and the distance can be found out using the formulas and can also be found out experimentally using LabVIEW software. USRP board has the available bandwidth of 2MHz for the first generation USRP device and has the maximum bandwidth of 25MHz and range resolution value reduced to 6m from 72meters. [14]

In this current work, work is carried out in the USRP transceiver USRP N210 in which stretch processing algorithm is used, which is explained in the section of chapter 5. Stretch processing algorithm contains input block, local oscillator block, mixer block, low pass filter block, analog to digital converters, coherent detection, and Fast Fourier Transform blocks is present. The bandwidth of USRP transceiver is 20MHz. [18]

The input signal and local oscillator signal is mixed in mixer block and produces both the addition of frequency and subtraction of the frequency. The signal from mixer block is given to the low pass filter block where the frequency below cutoff frequency is allowed to pass and given to Fast Fourier Transform where peaks is observed for the strongest frequency signal.

| **USRP N2920** | **USRP N210** |
|---|---|
| 20MHz radio frequency bandwidth | 50 MHz of RF bandwidth |
| USRP Device Frequency range: 50MHz to 2.2GHz | 25 MHz of RF bandwidth with 16-bit samples |
| Gigabit Ethernet Connectivity | Gigabit Ethernet Connectivity |
| Onboard FPGA processing | Onboard FPGA processing |
| ADC: 14-bits 100MS/s | ADC: 14-bits 100MS/s |
| DAC: 16-bits 400MS/s | DAC: 16-bits 400MS/s |
| Frequency: 2 MHz | Frequency: 2 MHz |
| Range resolution value: 6m | Range resolution value: 5m |
| Bandwidth is limited | Bandwidth is increased |
| Cost is high | Cost is low |
| Single purpose | Multifunctional purpose |

| | |
|---|---|
| Hardware design blocks price is high | Hardware design blocks price is low |
| First generation USRP device blocks can be used | Hardware blocks can be used to design other radar |
| Signal Processing Algorithm | Stretch Processing Algorithm |
| Software: LabVIEW | Software: LabVIEW |
| Power: 6V 3A | Power: 6V 3A |

Table 2. Comparison of past and current work

# CHAPTER - 5

# ALGORITHMS

In this system, two types of algorithms are chosen. They are

1.Stretch Processing Algorithm [14]

2. Doppler shift Algorithm [14]

## 5.1. STRETCH PROCESSING ALGORITHM

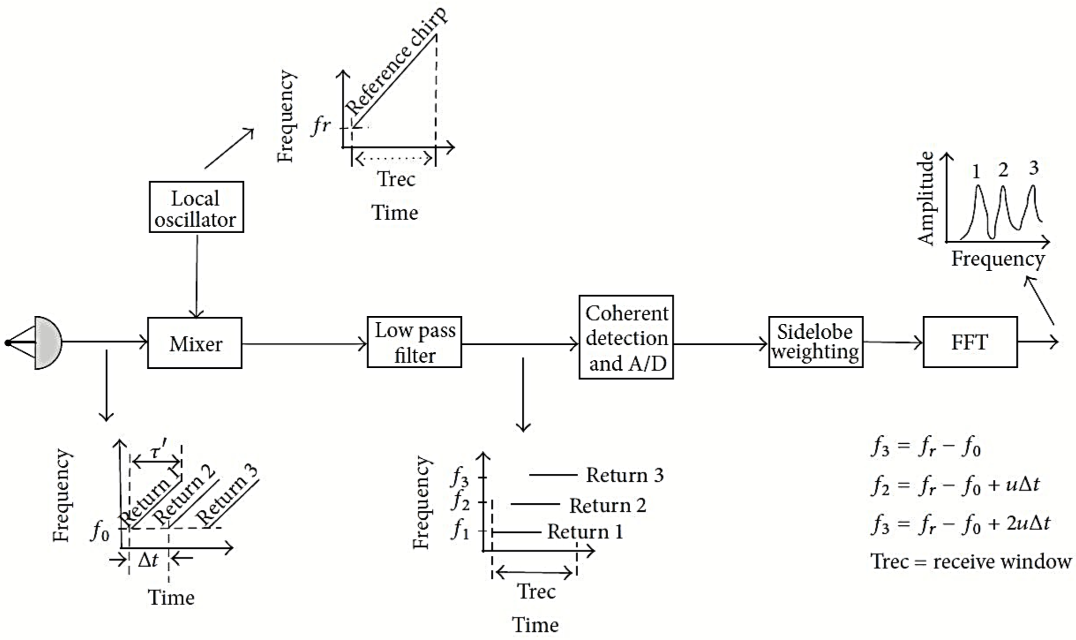



Figure 5.1: Block Diagram of Stretch Processing Algorithm [14]

In radar communication, there exists many signal processing algorithms [14] commonly used by radar and sonar to increase the range resolution and to increase the signal to noise ratio which can be achieved by modulating the input signal and correlating the received signal with transmitted.

### 5.1.1. Explanation of Stretch Processing Algorithm

Stretch processor algorithm [14] contains the blocks as

1. Input block
2. Oscillator block

3. Mixer block
4. Low pass filter block
5. Coherent detection and Analog to Digital converter
6. Sidelobe weighting
7. Fast Fourier Transform (FFT)

## 1. INPUT BLOCK

In this block, linear modulated equation is given as input. The equation is given in [14].

$$s(t) = \cos\left[2\pi\left(f_0 t + \frac{\mu}{2}t^2\right)\right], \quad 0 < t < \tau',$$

$$\mu = B/\tau'$$

The above equation taken from [14] is fed into the input block and the parameters included in this is chirp duration and f0 is the chirp start frequency, B gives the Bandwidth and t stands for time.

## 2. LOCAL OSCILLATOR BLOCK

In local oscillator block, the carrier signal is added to the frequency of the input signal. Generally, the local oscillator signal is 10 times larger than the input signal. The carrier signal is having with very large frequency and used for transmitting the signals. The input signal from input block is added to the local oscillator block signal and the combined output signal is generated with the changes in the input signal. The bandwidth can be taken approximately up to 2MHz. This local oscillator can be referred as carrier signal which produces the frequency more than the input signal. This is associated with the mixer to change the frequency of the input signal. After combining the signals, it produces the sum and the difference of the frequencies of the input signal. [17]

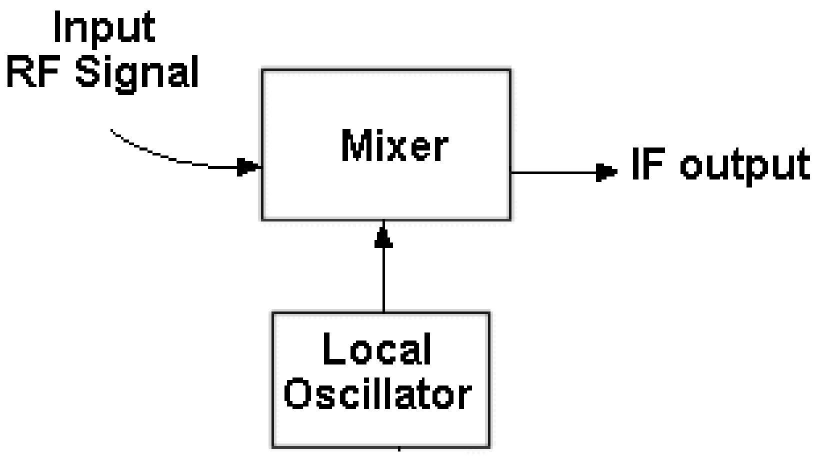



Figure 5.2. Local Oscillator Block [17]

This conversion process is called as heterodyning. In many applications, local oscillator is combined with the mixer called as converter and present at the receiver side which also reduces the cost, space, and power consumption acts as one device which produces the better performance. [17]

These local oscillators can be used in many other applications like super heterodyne receiver which is used in the radio receiving circuit. This local oscillator can be used in many other applications like modems, cable television's setup boxes and the frequency division multiplexing. One main application of the local oscillator is collecting the frequencies from the satellite where mixer is present at the antenna side and signals are converted to lower frequencies. These converted signals can be transmitted over a cable to the length before combining with the other signals. [17]

Crystal oscillator is one type of the local oscillator in which the frequency is fixed and to change the frequencies in the local oscillator, this has to be replaced with other. So, for multiple changes in frequency purpose, variable frequency oscillator is suggestable to use and it compromises stability and tunability.

## 3. MIXER BLOCK

In Mixer, the transmitted signals from the input block and the carrier signal from the local oscillator block is mixed in the mixer block shown in [16]. The replica of the transmitted waveform is mixed with the input signal. In mixer, the frequencies get added and subtracted, but in the output, it shows both the addition and the subtraction signals. For the further transformation of the signals, the mixed signal is carried forward and allowed to pass into the Low pass filter. [16]

The frequency mixer [16] which is a non-linear electrical circuit, creates the new signals when the input signal and the local oscillator signal is applied into it. Mixers is used in many applications and its operation is to produce sum and difference of frequency signals when input signal and the local oscillator signal is provided in the mixer which is also called as frequency mixer. Mainly, mixers are used to shift the frequencies of one to the another, which is called as heterodyning. In radio transmitters, frequency mixers are also used to modulate the carrier signals. [16]

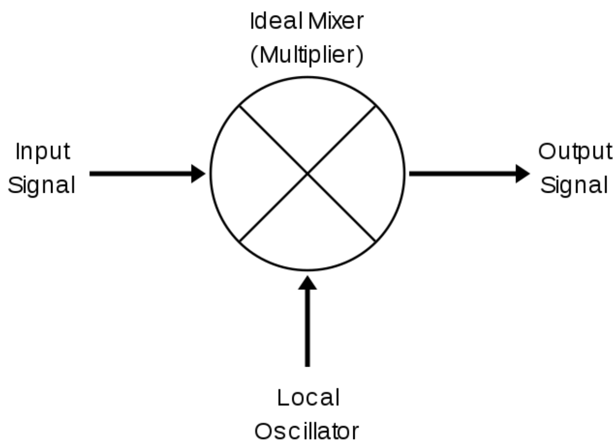



Figure 5.3. Mixer Block [16]

The main characteristic of the mixer is to produce the output combining the input signal and the local oscillator frequency. Device which is called as non-linear can act as mixer. Mixers are of active and passive type. In passive type mixers, it uses one or more diodes and obeys the non-linear relation between current and voltage to produce the multiplying element. The output signal power is always lower than the input signal power which is observed in the passive type mixers. Another type of mixer is active type mixer which is used as an amplifying device, such as transistor, to increase the strength of the transmitted signal i.e., input signal. Isolation between the ports is carried out by active mixers but it might have the higher noise and consumption of power is also high. [16]

In every application, the selection of the mixer is characterized by properties like conversion gain and noise figure. Non-linear components which is used as mixers contain diodes, transistors. The mixer circuit which is used not only to shift the frequency components of the input signal as in a receiver, but it can also use as product detector, modulator, phase detector or frequency multiplier. For example, a communication receiver contains two stages in which two mixers are used. One of the mixer is used as modulator and the other mixer is used as demodulator in the receiver section. Mixer in transmitted section is used as conversion of the input signal to intermediate frequency and another mixer is used as detector for demodulation of the input signal. [16]

## 4. LOW PASS FILTER

The output of the mixer block is fed into the low pass filter to avoid the high frequency components which evolved from the mixer block. The cut-off frequency is taken into account and checks that the signal do not cross the cut-off frequency. Frequencies above the cut-off value is all minimised. After passing through the low pass filter, the output waveform is changed according to the filter. [15]

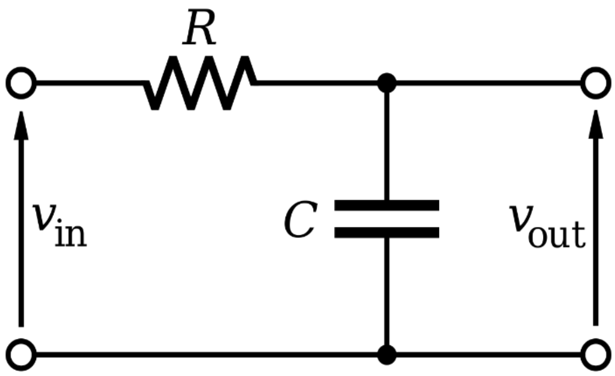



Figure 5.4. Low Pass Filter [15]

Low pass filter itself defines that it passes it allows only low frequency signals with having cutoff frequency and attenuates the frequencies which crossover the cutoff frequency. Designing of the window's specifications gives the exact frequency response. In audio applications, it is also called as high-cut filter, or treble-cut filter and it is also known as the complement of the high pass filter. [15]

Low pass filters are used in many different forms, such as, in electronic circuits as hiss filter in audio stream, acts as anti-aliasing filters which is used for conversing the data from analog to digital data, and used for smoothing the data in digital filters. The smoother form of a signal is possible only with considering the low pass filter where removing the fluctuations of the data. [15]

Low pass filters also play a major role in designing the filters as it contains the unity for bandwidth and the impedance and it is used as a prototype filter. The desired filter can be designed by using the low pass filter by increasing the bandwidth and the impedance. This lead to the evolvement of many filters such as, high pass filter, band pass filter and band stop filter.

Based on the low pass filter, it can be used in many applications and systems. It is useful in optical and in electronics field. Taking an example from electronics field, consider a low pass circuit in which it contains the resistor and the capacitor. The input voltage is given at the transmitting section and the output is calculated at the output side. When the input signal is provided in the voltage signal, the higher frequencies get attenuated and it also contains the attenuation less than the cutoff frequency which is determined by the time constant. The same operation can be operated in the current signals transmission, but the arrangement of the resistor and the capacitor should be in parallel, then observe the output through it. [15]

The usage of low pass filters has been extended to radio communications also where this filter is used for blocking the harmonic signals which interfere with the other signals in the transmission. Tone knob which present on the electric guitars is referred as low pass filter used for controlling the treble and reducing the high pitch levels in the tone.

## A. CONTINUOUS-TIME LOW PASS FILTER

There are various types of filter circuits where frequency responses changes with the change in frequency. Basically, this kind of frequency responses is plotted with the Bode plot and the filter has parameters like cutoff frequency and the rate of frequency. For each low pass filter, cutoff frequency is available and it attenuates the half power or the value of 3dB below the cutoff frequency and the order describes the additional frequencies which attenuates above the cutoff frequency. [15]

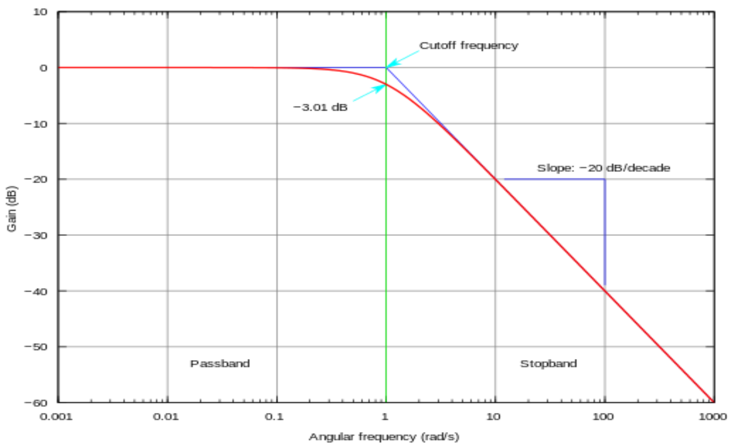


Figure 5.5. Continuous time low pass filter [15]

A first order filter describes the amplitude reduces to half and the frequencies is attenuated below the cutoff frequency. The frequency response of the first order low pass filter looks like the knee shaped curve because, below the cutoff frequency, it has the straight line till the cutoff frequency and diagonal line is appeared above the cutoff frequencies. [15]

## B. IDEAL LOW PASS FILTER

The filter which eliminates the higher frequencies above the cutoff frequency is called the Ideal filter and its frequency response is rectangular window. Ideal filer can be proved by multiplying the signals with the rectangular function in the time domain. The frequencies below the cutoff frequency keeps unchanged until the cutoff frequency is kept below those frequencies. [15]

## 5. COHERENT DETECTION & A/D CONVERTER

The output of the low pass filter is fed into the coherent detection and the analog to digital converter block. The unwanted high components in the transmitted signal is removed in this coherent detection and the series of analog to digital is placed and the signal is allowed to pass into the converters. The analog signal is converted into the digital signals and the output digital waveform is obtained. Then this signal is sent to the Fast Fourier Transform (FFT). [14]

## 6. FAST FOURIER TRANSFORM (FFT)

Transmitted signal from the converters is fed into the Fast Fourier Transform abbreviated as FFT block. The input signal sent into the FFT block after sending through the low pass filter block. In this block, the peaks are arrived to the values where they are placed the targets. The logarithmic antennas send the signals, touches the target present at some distance, and reflects back to the same logarithmic antenna and the distance is shown in the peak form in the FFT waveform. The targets placed at the distance of 6m, 12m, 18m respectively, then the signals travels and touches the targets and the received signal shows the distance between the target and the SDRadar. The peaks is high at the range values of 6,12,18 respectively and FFT helps to simulate the signal processing technique. [14]

After finding out the FFT outputs, the frequency is calculated and the range resolution value to be found out. Previously, that range resolution value is up to 6meters.

## 5.2. SIGNAL PROCESSING ALGORITHM

The main steps involved in the signal processing algorithm is Parameters definition, Matrix definition and the main loop implementation and the motor controlling operations. [14]

### 5.2.1. BLOCK DIAGRAM

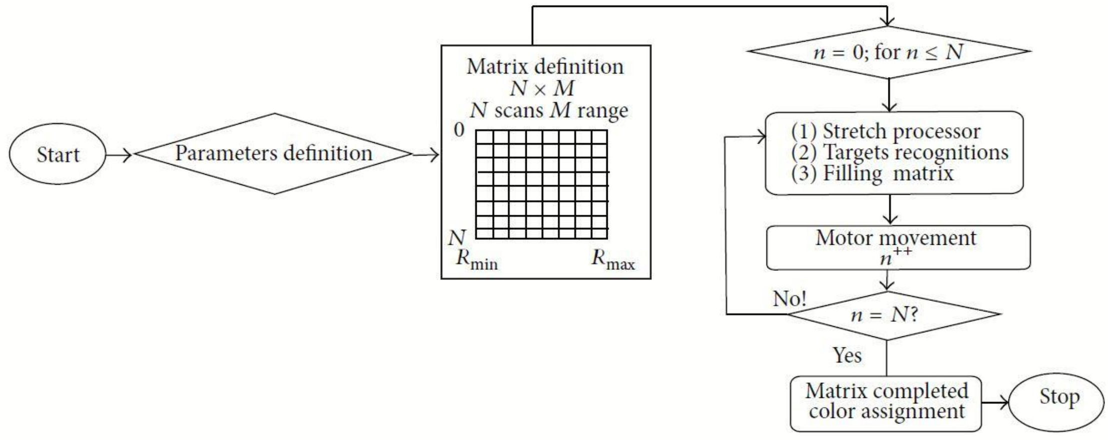



Figure 5.6. Block Diagram of Signal Processing Algorithm [14]

### A. Parameters Definition

### 1. Footprint

Antenna scans the object and the area of scan is taken into account, which is defined in terms of distance between the radar antenna and the analysing area. The other parameters are azimuth angle, elevation antenna beamwidths, grazing angle and the operating frequency. [14]

### 2. Receiving Window

This parameter ensures that the analysis area is under the topology of recognition area relative to the surface. These values can be given by Rmax and the Rmin values i.e., maximum and the minimum required target range. [14]

### 3. Total Area Size

The size of the total area is also taken into account and checks whether how many scanning’s are required to cover the total object. The total number of scanning’s are also required to fill the matrix definition. [14]

## B. Matrix Definition

In this matrix definition, it contains the total N rows which is corresponding to the N value of scanning's taken for the object, and M columns, depending on the receiving angular windows. [14]

## C. MOTOR CONTROLS

In this loop of operations, Signal Processing algorithm is implemented by the system and the scanning's is covered by the motor controls. This motor is controlled by the specific application called as LabVIEW. A single board computer is required to monitor the total operations which is happening in the Signal Processing Algorithm. [14]

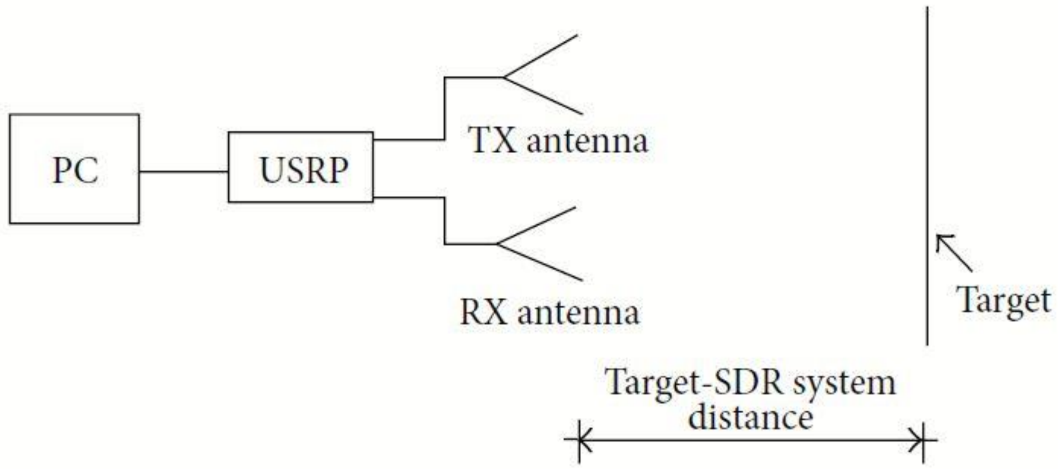



Figure 5.7. Outdoor setup [14]

Figure 5.8. Outdoor Setup Practically [14]

## 5.3. DOPPLER SHIFT ALGORITHM

SDRadar uses not only signal processing algorithm, but also doppler shift algorithm. If the object is stationary, then the signal processing algorithm is used and the results are obtained, but, if the object is in motion, it is difficult to calculate the values of the range resolution and hard to catch the targets in the motion. So, to avoid that, it has a solution of adapting another algorithm namely, doppler shift algorithm. In this algorithm, the values are added when the object is coming near to the target and the values are subtracted as the object moves away from the target. [14]

This algorithm is helpful when it is implemented over ground surfaces but not on airborne navigation. The source and the destination points are separated and the transmission of signals are allowed to pass. The logarithmic antennas are sending and receiving signals, that is carried over the airborne navigation. [14]

The targets can’t be on plane surfaces for everytime. They can be placed anywhere on the surfaces whether it may be rock surfaces, hill stations, etc. In such cases, when the target is placed over the hill station, then the antennas takes up the signal processing algorithm and calculates the distance between the target and the source. The same calculations can also be performed on the doppler shift algorithm taking surface calculations and values of the both algorithms are compared. [13]

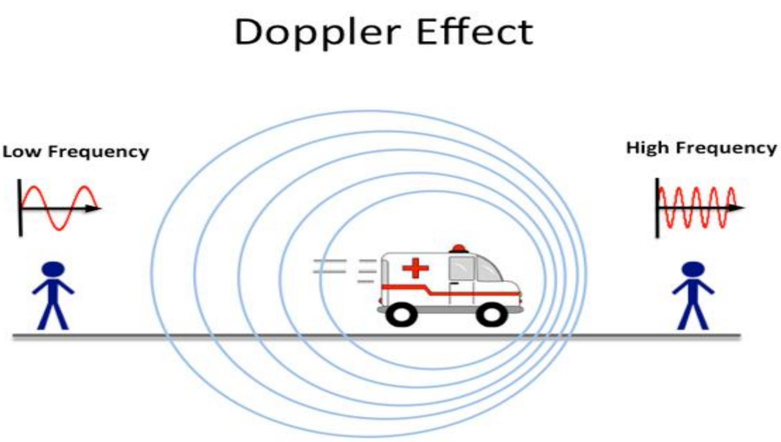



Figure 5.9. Doppler shift [13]

The frequency components can be subtracted which leads to the low frequency when the object/target is moving away and the frequencies are added when the object/target is appearing near, then it leads to have the high frequency. [13]

# CHAPTER - 6

## SIMULATED RESULTS AND DISCUSSION

The signals transmitted through the antennas and it reaches back to the antenna. The whole setup is controlled by the specific application called LabVIEW. The signal processing algorithm is used and the final signal outputs is observed after the FFT block. In this FFT block, the peaks are raised at the values of the targets placed in meters. This can be graphically represented for the modulated signals. The bandwidth has limitations and the slant range resolution.

Input signal waveform is shown in Figure 6.1, is a linear modulated waveform which contains the cosine components in the signal. Input signal is of sinusoidal signal having phase of 90 degrees, which is cosine signal having frequency 2 MHz.

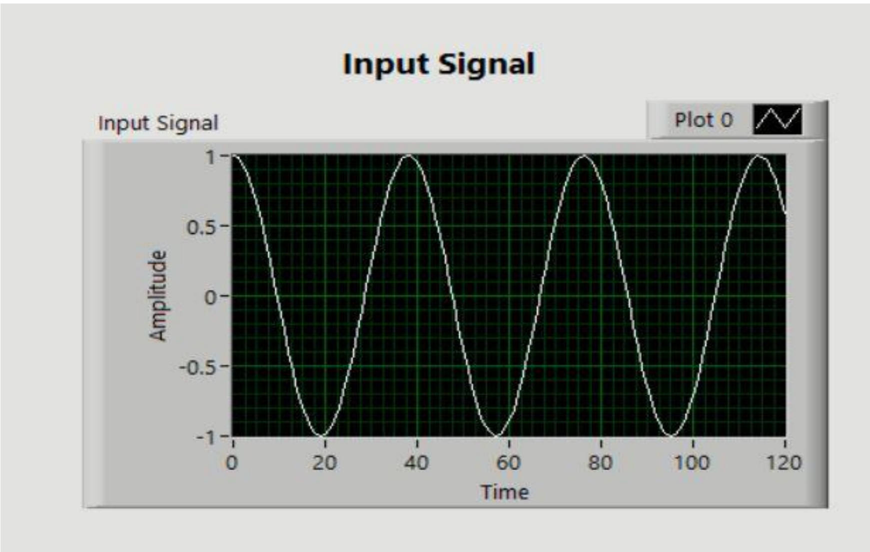



Figure 6.1. Input signal waveform

Input signal equation [14] is applied into the input signal block [14], parameter values are provided and the analog waveform signal is shown above with respect to the amplitude and time. The input signal is allowed to mix the signal with the local oscillator signal shown in [14] comes from the local oscillator block having very high frequencies greater than the input signal frequency where cosine components is present in signal. The waveform of local oscillator is shown in Figure 6.2.

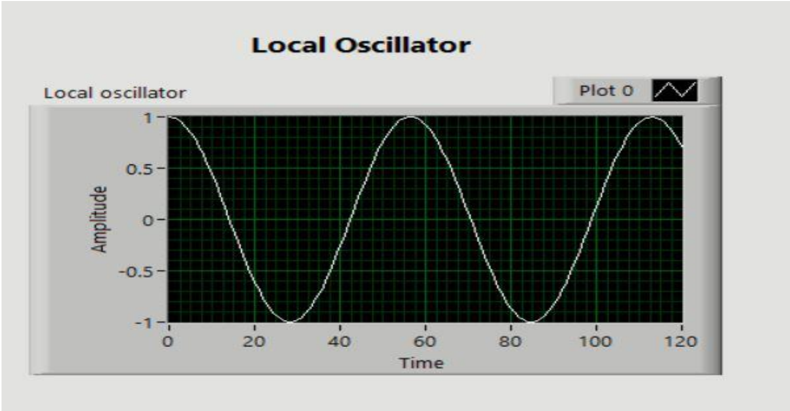



Figure 6.2. Local Oscillator Waveform

The above two signals shown in Figure 6.1 and Figure 6.2 is allowed to mix in the mixer block [14] which produces the outputs of both the frequencies added and the frequencies subtracted. The waveforms of both addition and subtraction shown in Figure 6.3 and Figure 6.4 respectively.

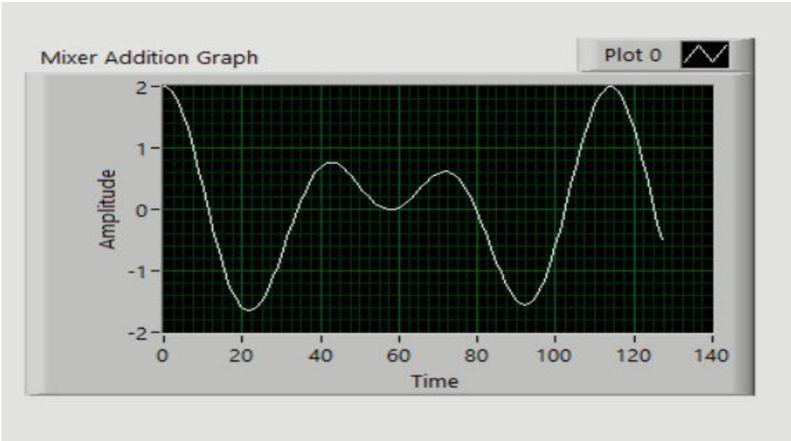



Figure 6.3. Mixer addition graph

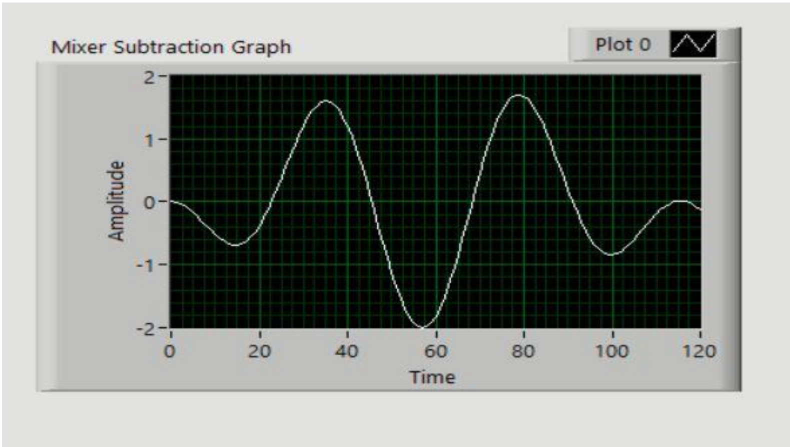



Figure 6.4. Mixer subtraction graph

Outputs of the mixer block shown in Figure 6.3 is given into the low pass filter block [14] and the cut-off frequency is provided, which is used to stop the frequencies above the cut-off *fc* frequency. The low pass filter output is shown in Figure 6.5 for smaller frequencies which is in Hertz.

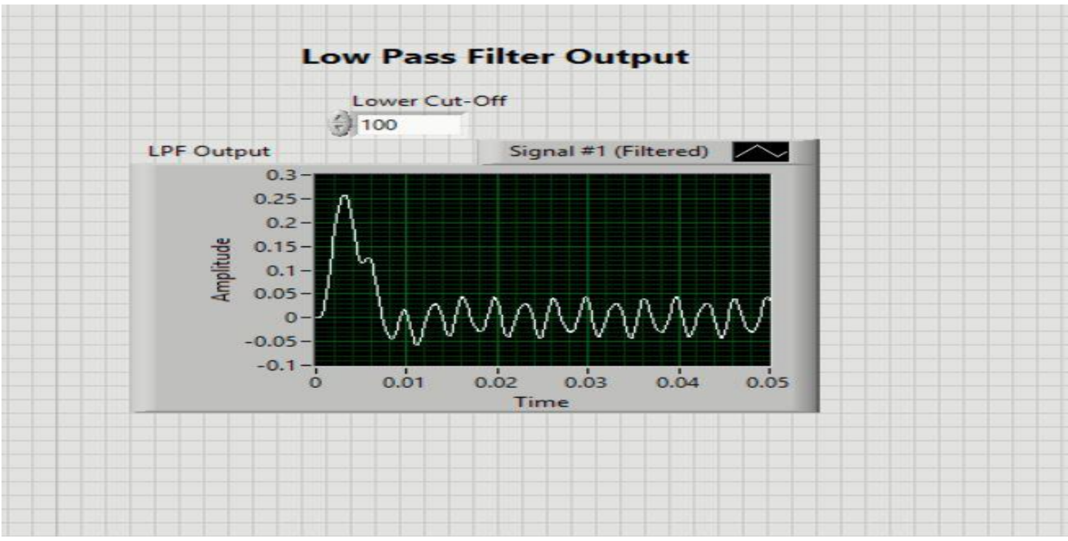



Figure 6.5. Low pass filter output

After receiving the output of low pass filter shown in Figure 6.5, the transmitted signal is allowed to pass into the Fast Fourier Transform block. The output of the FFT block is shown in Figure 6.6.

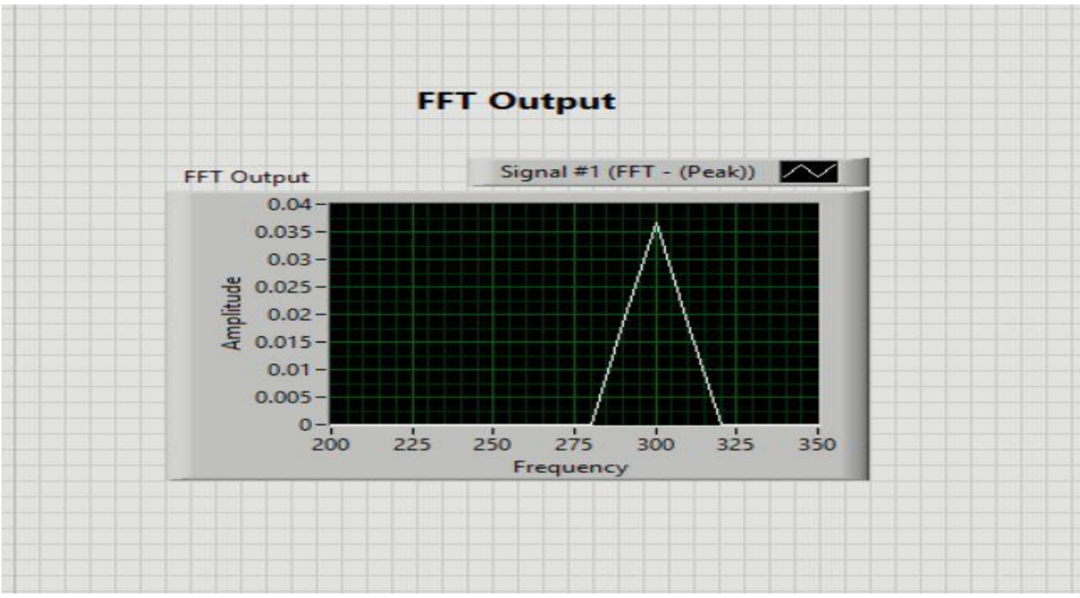



Figure 6.6. FFT output

The same procedure is repeated for higher frequencies i.e., in MHz. Input signal is given with 2MHz frequency and the waveform representation of signals till mixer block is approximately same. The output of the low pass filter for higher frequencies is shown in the Figure 6.7.

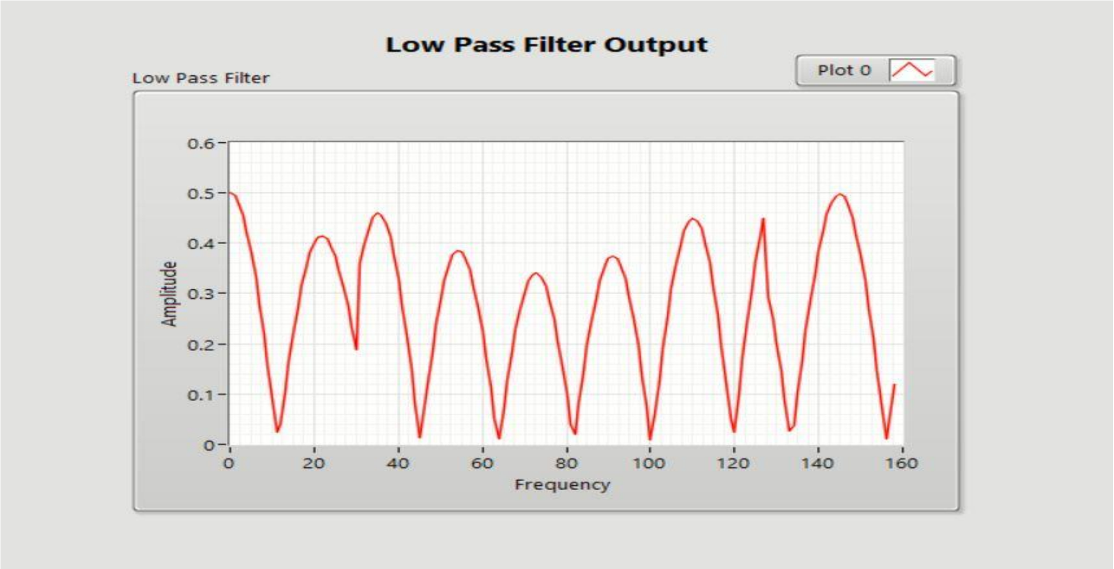



Figure 6.7. Low pass filter for Higher frequencies

Transmitted signal is allowed to pass into the transformation technique tool called Fast Fourier Transform (FFT) block [14] and the output peaks is observed in the graphical representation which is shown in the Figure 6.8.

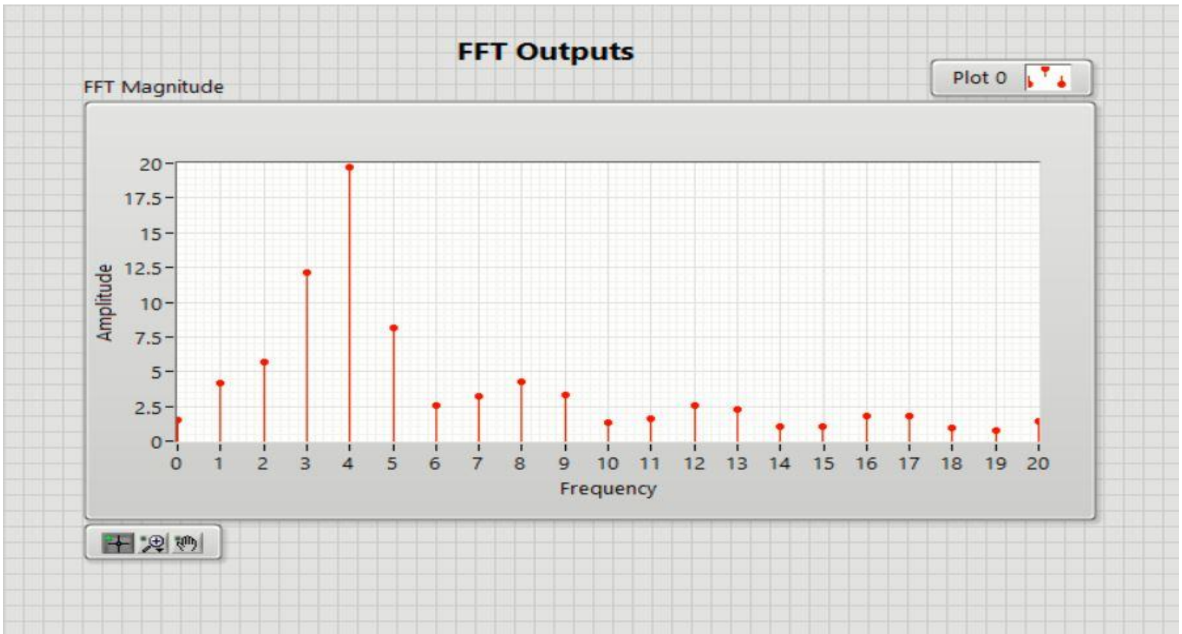



Figure 6.8. FFT Output

The above results shown in Figure 6.8 represents for the lower and the higher frequencies' and their FFT output values are calculated and shown in the above figures. The final outputs of all the FFT outputs is calculated and shown in Figure 6.9.

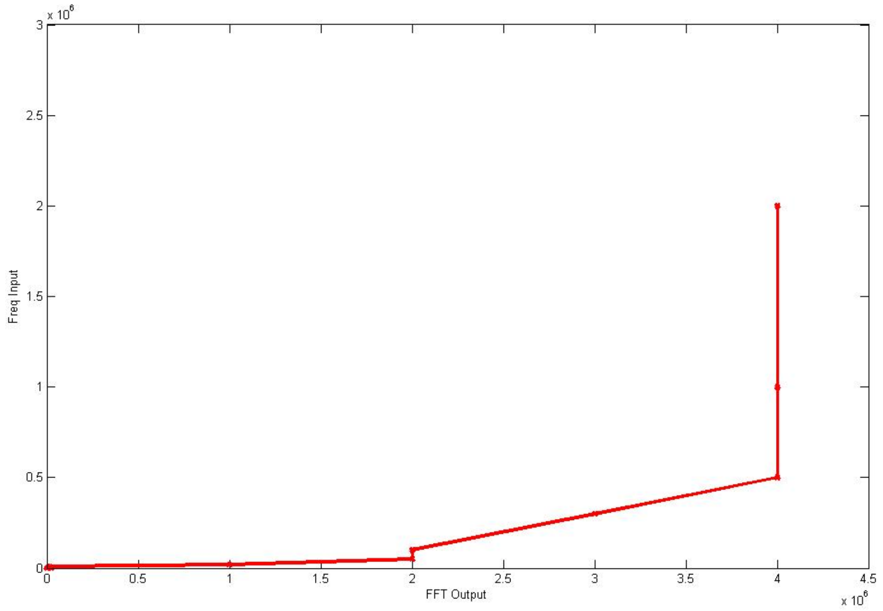



Figure 6.9: Various FFT outputs over different frequencies

In the above Figure 6.9, the frequencies from the Hertz is taken and calculated FFT outputs for each of the frequency in the intervals. This calculation has been carried out until the last frequency is provided in the modulating signal, i.e., 2MHz. The whole FFT outputs for each frequency is represented in the above Figure 6.9. The code has been written for each value and the graph is plotted. It represents that 4MHz is constant FFT value which varied over different frequency values.

## 6.1. Performance of the proposed work with the Existing Method

| Parameters | Existing Methods | | | | Proposed Work | Remarks |
|---|---|---|---|---|---|---|
| | [12] | [14] | [22] | [24] | | |
| **Range Resolution** | 4m | 6m | 15m | 8m | 3m | Range resolution value is increased |
| **Frequency Operates** | 5 GHz | 2 MHz | 2 GHz | 2.1 GHz | 2 MHz | Attempt to increase BW with same operating Freq. |
| **Techniques Used** | Fast Fourier Transform | Fast Fourier Transform | Six port, Fast Fourier Transform | Fast Fourier Transform | Fast Fourier Transform | FFT is comparatively best |
| **Algorithms Used** | Doppler Shift Algorithm | Signal Processing Algorithm | Digital Signal Processing Algorithm | Doppler Shift Algorithm | Stretch processing algorithm, Doppler shift algorithm | Algorithms developed for operating at frequencies |
| **Software** | MATLAB | LabVIEW | - | MATLAB | LabVIEW | LabVIEW is best |
| **Signal Bandwidth** | 10 MHz | 25 MHz | 10 MHz | 0.75 MHz | 50 MHz | Bandwidth is increased |

Table 3. Performance of existing to proposed system

# CHAPTER - 7

## CONCLUSIONS AND FUTURE SCOPE

Software Defined Radar is used in this application to find the slant range resolution for which stretch processing algorithm is used where 2MHz frequency is taken as the input frequency. Simulated output waveforms for each section is shown in simulation results and Fast Fourier Technique is used as the transformation technique for transforming the data into frequency domain. By considering the FFT simulation waveform, bandwidth frequency value can be obtained by considering the FFT peaks and range resolution value can be found out which is the main objective for this application. [14]

The proposed work is carried out by LabVIEW platform and SDRadar application in this uses for target detection precisely. It is used in many other applications and designing of the blocks is not required because it can use the blocks from the previous application which is useful for faster execution and reduction in cost of blocks. [1]

In this project, micro frequencies i.e., 2 MHz, is used in Software Defined Radar for getting the FFT outputs. So, this could be limitation for this project if SDRadar is designed to operate with nano frequencies. Alternatively, many other algorithms can be implemented for SDRadar whose bandwidth is in the range of nano frequencies. By implementing the Software Defined Radar (SDRadar) for micro frequencies, will be able to design other application in which design blocks can be re-used and many other algorithms can be developed for detecting the targets even present at larger distances. [2]

Future work can be carried out in this SDRadar for developing the software defined radar which operates at the frequency of nano hertz. Algorithms can also be developed for SDRadar operating at frequencies of nano hertz. This is the limitation of this project where it can’t be used for operating at nano hertz.

# CHAPTER - 8

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