A Review on Identification of RADAR Range for the Target by using C Band

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Abstract– *C band is a distinctive type of RADAR (RAdio Detection And Ranging) band technology in which short wavelength electromagnetic waves are being used. The electromagnetic waves are transmitted towards the object called target in order to get the reflection from it and by using that reflected signal, we can determine the range, speed of target along with its direction as well as the angular position of the target. By using C frequency band i.e. from 4 to 8 GHz and the short wavelength (3.75cm to 7.5 cm) the higher range resolution could be achieved. This band provides the benefit of decrease in the size of components like antennas and the processors that analyses the echo signals. This system combines the components such as Transmit & Receive radio frequency components, both the analog and digital (e.g. ADC i.e. Analog to Digital Converter, MCU i.e. Micro Controller Unit, DSPs i.e. Digital Signal Processors, etc.). Integrating DBF (Digital Beam Forming) and MIMO (Multiple Input Multiple Output) makes this design more advance and accurate. Power calculation based on cross-section of target and from that the range of the target can be measured. It is knotty to calculate RCS (Radar Cross Section) when it comes to smaller object like UAVs (Unmanned Aerial Vehicles) because of its size similar to that of background clutter. Power is the crucial factor in the design procedure of radar, so the power calculation become a key parameter. Based on the power, maximum range of the target that could be detected by the radar can be quantified. All these parameters has been covered in this work.*

Key Words: *C band, Radar Cross Section, UAVs, DBF (Digital Beam Forming), MIMO (Multiple Input Multiple Output), Power Calculation, RADAR Range, FMCW Radar.*

1. INTRODUCTION

Radar systems are widely used in various fields to determine range, velocity and angular position of the target. Accuracy is the main concern for the Radar system. Different targets have different cross section and according to that cross section, the reflected power of the target towards radar is different. It is important to measure that reflected power according to the transmit frequency for the estimation of the maximum detectable range of the target from the radar.

Though the application of MIMO and DBF (Digital Beam Forming) is widespread and popular in the present state-of-art technologies, its proper implementation in RADAR technology is unattended. We can achieve a very high accuracy with the wide area that could be scanned simultaneously. Radar Cross section of the smaller target like Unmanned Aerial Vehicles (UAVs) is the main concern for security. In FMCW, maximum power is restricted because of target cross-section and transmission frequency. Based on the transmission power, maximum range of the target can be defined. Only one frequency band could be transmitted at a time in the case of simple FMCW radar. Scanning with conventional method i.e. mechanically or electronically scanning is highly inefficient. Only one beam area is scanned at a time. Angular coverage area and resolution is less because of fixed or mechanically moving antenna. Less accurate with large angle of arrival (AOA).

Designing a high frequency FMCW radar that makes the use of multiple antennas at the transmitter as well as receiver side to detect the target at some particular small area. Implementation of digital beam forming to reduce the number of antennas. RCS will be calculated for the different sizes of targets (i.e. Small air crafts and small Unmanned Aerial Vehicles (UAVs)). Power will be calculated for different radar cross section and based on that power level, the maximum distance of the target could be detected. All these measurements will be calculated by using frequency in C band i.e. 4 to 8 GHz. Design will be simulated and tested on MATLAB for different RADAR parameters.

1.1 Letter – Band Nomenclature of RADAR

From whole frequency spectrum, there are some particular frequency range that can be used in RADAR technology. That band starts from 3 MHz to several tens of GHz, which contains HF, VHF, UHF, SHF and a portion of EHF frequencies. That Frequency range is divided into several bands having a letter designation for all of them according to IEEE standard. We are going to use C frequency band for this dissertation work starting from 4 GHz to 8 GHz.

Table 3.1 shows the frequencies available to detect the target known as the bands. The choice of the band is according to the application for which the RADAR is being used.

Table -1: Radar Band Designation

Band	Frequency (GHz)	Wavelength (cm)
VHF	0.03 – 0.3	1000 – 100
UHF, P	0.3 – 1	100 – 30
L	1 -2	30 – 15
S	2 – 4	15 – 7.5
C	4 – 8	7.5 – 3.75
X	8 – 12.5	3.75 – 2.4
Ku	12.5 – 18	2.4 – 1.7
Ka	18 – 40	1.7 – 0.75
V	50 – 75	0.60 – 0.40
W	75 - 111	0.40 – 0.27

2. METHODOLOGY & PROCEDURE

The methodology that we had followed to identify the RADAR Range for the Target by using C Band:

1. Frequency effect on power calculation
2. Various RCS calculation based on the target
3. Based on target RCS, power calculation
4. Target Range detection based on power level
5. MATLAB code design
6. Simulation Results

2.1 FMCW Radar:

RADAR technology is broadly classified into two categories: Primary and Secondary. In that primary category RADAR transmit Pulses or continuous waves (CW). Both of the primary RADARs are further classified into two types. Pulse radar could be Moving Target Indicator (MTI) or Pulse Doppler RADAR. Continuous Wave RADARs are whether modulated i.e. Frequency Modulated Continuous Wave RADAR (FMCW) or Unmodulated CW RADAR.

Pulse RADAR transmits the discrete pulse train which increases the power consumption and that will lead to higher cost. Also, the design is challenging because of complexity and high frequency. Unmodulated continuous wave RADAR can only measure the speed at which target moves accurately. So that, we chose Frequency Modulated Continuous Wave RADAR (FMCW) for our research work to identify the range of the target.

2.2 MIMO & DBF:

In general, MIMO (Multiple Input Multiple Output) increases the data rate as multiple antennas transmit and receive simultaneously which decreases the number of antennas required to establish the channels. In our design, we used the same Multiple Input Multiple Output concept to increase the data rate and achieve high performance by using less number of components.

Beam forming is the technique in which transmitted or received signals are arranged in such a way that create a single beam to focus in a particular direction. When it comes to continuous shifting in scanning applications, steering the beam mechanically or electrically makes the process very much difficult and impracticable. So, the Digital Beam Forming (DBF) is very much convenient. We will be using the DBF technique along with the MIMO in order to increase the spectrum efficiency and system coverage along with low interference.

2.3 RCS:

RADAR Cross Section is not the physical area but the area of the target that could be seen by the Radar and is vary with the change in aspect angle of the target. The RCS value of the same target can be different depending on various factors. The parameters that decides the RCS are:

- Target's structural material
- Actual size of the target
- Incident angle, which is the angle at which the electromagnetic radio wave hits on the surface of the target, as well as the reflection angle (Angle of Arrival)
- Observation angle from the RADAR
- Shape of the target
- Operating frequency band
- Transmitter and receiver polarization

RCS values can be as small as 0.00001 square meter for insects to 10,000 square meter for ships and big fighter aircrafts.

Table -2: RCS measurement comparison of hypothetical missile and section of missile[2]

Frequency (GHz)	RCS of Hypothetical Missile	RCS of Section of Missile
5.9	09.2	07.3
6.0	11.5	07.9
6.2	11.9	10.2
6.4	13.0	10.5

2.4 UAVs

An **unmanned aerial vehicle** (**UAV**) also known as a **drone** is an object flying in air at shorter distance compared to any other aircrafts without any human pilot, crew, or passengers. UAVs have the attributes like low cost and very small in size as well as operates at a low altitude makes it suitable for military, civil and industrial applications. The main domain of the use of UAVs are in collection of environmental data, flying base stations, in disaster relief missions and crime scene, etc.

UAVs are annoying when they flaunt their restricted routes and fly without permission with the malicious intention. These days, the number of threatening incidence of undetectable flying UAVs increases because of illicitly monitoring private areas, transportation of the dangerous materials and smuggling.

UAVs detection and tracking by the use of RADAR remote sensing technique is needed for the security and regulation purpose and are the burning research problems. RADAR technology was designed to track and detect larger flying objects but its capabilities becomes inferior when it comes to track the target having small RADAR Cross Section (RCS). As we know that UAVs have such a small Radar Cross Section area with the very low altitude that it is very hard to distinguish it from the background clutters such as birds that decreases signal to noise ratio (SNR) and that results in the probability of missed detection. Therefore, the measurement of the RADAR Cross Section of Unmanned Aerial Vehicles are important and must be accurately calculated before identifying the range.

2.5 Power, Range & Range Resolution

The relationship between transmitted and received Power can be written in the form of equation as:

$$P_r = \frac{P_t G}{4\pi R^2}\frac{\sigma}{4\pi R^2}A_e = \frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 R^4} \qquad [W]$$

The RADAR range equation calculates the distance of the target from Radar. This equation shows the relation of the distance with the radar cross section, transmit and receive antenna power and gain of the antenna. The equation is,

$$R_{max} = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}\right]^{\frac{1}{4}}$$

When two or more targets are so close then it is very difficult to recognize them as two different targets by Radar. This ability of the radar is called Range Resolution, the extent to which it separates target from one another.

$$\Delta d > \frac{c}{2ST_c} = \frac{c}{2B}$$

3. RESULT & ANALYSIS

3.1 Range Power Relation calculation Based on Target RCS

Transmit power = 0dBm = 1 mW
Gain = 20dB

Table -3: For RCS = 0.02 m²

Distance(Km)	Power(dBm)
0.5	-68.95
1	-74.97
2	-80.99
3	-84.51
5	-88.95
10	-94.97
50	-108.95
100	-114.97
500	-128.95
1000	-134.97

Table -4: For RCS = 0.1 m²

Distance(Km)	Power(dBm)
0.5	-61.97
1	-67.99
2	-74.01
3	-77.53
5	-81.97
10	-87.99
50	-101.97
100	-107.99
500	-121.97
1000	-127.99

Table -5: For RCS = 5 m²

Distance(Km)	Power(dBm)
0.5	-44.98
1	-51
2	-57.02
3	-60.54
5	-64.98
10	-71
50	-84.98
100	-91
500	-104.98
1000	-111

We can see from the Table 3, Table 4 and Table 5 that for smaller RCS value, the power level is small and for the bigger RCS value, the power level is higher. Also for the particular RCS, power level decreases with increase in distance between radar and target.

3.2 Range FFT Simulation Output

Table -5: Simulation Parameters

Parameters	Value
Starting Frequency (f0)	5.7 GHz
Stop Frequency (f1)	5.9 GHz
Sweep Time (T)	100 microsecond
Dead Time (Td)	10 microsecond
Sampling Frequency (fs)	0.1 GHz
Receiver Antenna Element Spacing (d_Rx)	4*lambda
Transmitter Antenna Element Spacing (d_Tx)	0.5*lambda
Signal Power	-10 dBm
Noise Power	-38 dBm
Resistance (R)	50

For this simulation, we used the parameters mentioned in Table -5. Also we used 8 antennas to apply MIMO concept along with Digital Beam Forming. Chart -1 illustrates the Power versus Range cell graph for range FFT output on MATLAB.

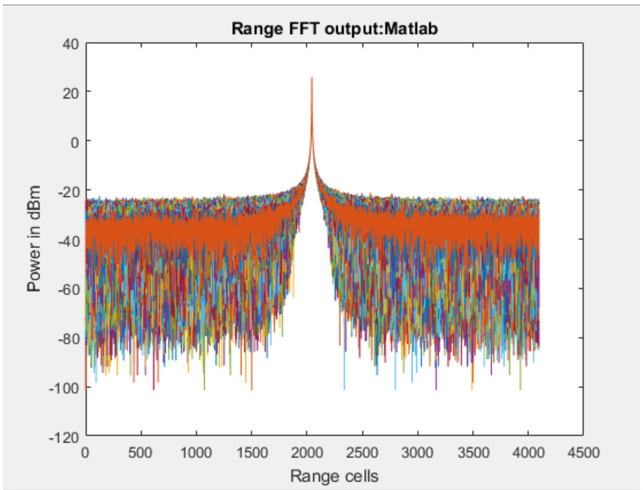

Chart -1: MATLAB Simulation Result

4. CONCLUSION

Using higher frequency band for accurate detection of the Radar cross sections.

By making the use of measured RCS of UAVs will be helpful in designing the systems which are specially developed for tracking the UAVs and identifying malicious UAVs in restricted zones.

Multiple Antenna system for both transmission and reception can increase the data rate.

Using Digital Beam Forming increases the System Coverage as well as Spectrum Efficiency and Decreases Interference.

By using FMCW radar, accurate measurement of the range of the target could be achieved.

5. Future work

Different frequency bands other than “C band” can be used to detect the target RCS. Higher frequency bands like X band, V band, millimeter Wave, etc. gives different power level and leads us to more accurate range detection. There is a scope for the combination of micro-Doppler analysis with RCS to accurately identify flying UAVs. There is a future scope for the detection of the velocity of the target along with the use Doppler FFT by using C frequency band or other higher band.

Abbreviations –

RCS: Radar Cross Section
UAV: Unmanned Aerial Vehicle
DBF: Digital Beam Forming
MIMO: Multiple Input Multiple Output

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