University of Science & Technology

College of Postgraduate Studies

Modeling of Planetary Radar for Ranging Near-Earth Asteroids

نموذج رادار فضائي لتحديد بعد الكويكبات القريبة من كوكب الارض

A Research Submitted in Partial fulfillment for the Requirements of the Degree of M.Sc. degree in Electronics Engineering (Communication)

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MARCH 2018

بسم الله الرحمن الرحيم

قال تعالى:

﴿ وَمَا أُوتِيتُمْ مِنَ الْعِلْمِ إِلَّا قَلِيلاً ﴾

صدق الله العظيم

سورة اللإسراء الآية[1]

Dedication

أهدي هذا العمل المتواضع إلى أمي التي زودتني بالحنان والمحبة

وإلى أبي الذي لم يبخل علي يوماً بشيء

أقول لهم: أنتم وهبتموني الحياة والأمل والنشأة على شغف الاطلاع والمعرفة

وإلى إخوتي وأسرتي جميعاً

ثم إلى كل من علمني حرفاً أصبح سنا برقه يضيء الطريق أمامي

Acknowledgments

In the first and before all I thank ALLAH for every things I’m reaching and going to it in our life.

As always, the completion of any project would not be possible without the support.

I would especially like to thank Dr. Ibrahim Khider for his steadfast support during the preparation of this project that has done a great job managing in the project and keeping on track.

Also grateful to thank professor Dr.Moutaman Mirghani and all researchers in ISRA., they gave me A lot of information during the preparing the project.

Last, but not least we would like to thank all teachers at the

Sudan University and especially teachers of Faculty of

Engineering and Department of Electronic

Abstract

During the last years, hazards of asteroids and other smaller bodies belt located between Mars and Jupiter orbits have dramatically increased. That is an average range from the Sun between 2.2 and 3.2 AU, astronomical unit. By definition, a solar system body is a near Earth object if its closest approach to the Sun is less than 1.3 AU. Planetary radars have been developed since the sixties of the previous century. The purpose of them is to protect the Earth from the hazards of the celestial objects that affect the life of mankind and the performance of artificial satellites, as well as other space technology fields. Planetary radars applied full transmit and receive model that is used for the track of position and velocity of the moving asteroids. In this thesis modeling and simulation have been used for moving asteroid that fully reflects all of the incident signals off its radar cross-sectional surface. The RF signal is collected by the antenna is processed by a superheterodyne receiver, which is modeled using MATLAB and Simulink. The received signal is processed and analyzed so as to examine the simulated asteroid behavior.

المستخلص

خلال السنوات الأخيرة ، زاد بشكل كبير مخاطر الكويكبات والأجسام الصغيرة القريبة من كوكب الارض التي تأتي في الغالب من حزام الكويكبات الواقع بين مداري كوكب المريخ والمشتري. ويبلغ بعد هذا الحزام في المدى من بين 2.2 و 3.2 وحدة فلكية. ومعروف ان الجسم الفضائي يعتبر كويكب قريب من الارض اذا كان بعده عن الشمس اقل من 1.3 وحدة فلكية. وقد تم تطوير الرادارات الفضائية منذ الستينات من القرن الماضي. والغرض منها هو حماية الأرض من مخاطر الأجرام السماوية التي تؤثر على حياة البشر وأداء الأقمار الأصطناعية، وكذلك مجالات تكنولوجيا الفضاء بصفة عامة.في هذا البحث تم عمل نموزج لهذا النوع من الرادارات مكون من ارسال واستقبال كامل لتتبع موضع وسرعة الكويكب سيرس المتحرك. ، تم استخدام محاكاة لكويكب متحرك يعكس تمامًا جميع الإشارات الساقطة على سطحه. ثم بعد ذلك يتم جمع هذه الاشارات من خلال الهوائي ثم يتم بعد ذلك معالجة الاشارات عن طريق المستقبِل الخاص بالرادار، والذي تم تصميمه باستخدام السيمولنك في برنامج الماتلاب. لتتم معالجة الإشارات المستقبلة وتحليلها لفحص سلوك الكويكبات القريبة من كوكب الارض.

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LIST OF ABBREVIATIONS

AU	Astronomical Unit
RF	Radio Frequency
NEAs	Near Earth Asteroids
DSS-13	Deep Space Station-13
DSS-14	Deep Space Station-13
MBAs	Main Belt Asteroids
RADAR	Radio Detection And Ranging
NAIC	National Astronomy and Ionosphere Center
NSF	National Science Foundation
MDS	Minimum detectable signal
SNR_{min}	Minimum operational signal-to-noise ratio
FIR	Finite Impulse Response

CHAPTER ONE

INTRODUCTION

Chapter one

Introduction

1.1 Introduction

Discovering Asteroids became very important in search work, as the past decade has witnessed an increase in the number of discovered asteroids. More than 35,000 numbered asteroids were discovered during the last 200 years, of which 62% were found in the past decade. Out of the 1785 Near-Earth Asteroids (NEAs) that are now known, 89% have been discovered in the last 10 years.

In this these, author present a brief historical perspective of asteroids search and an overview of general search strategies and specific search systems in existence today. Besides that, they address the current status and issues facing the continuing search for asteroid hazards to Earth. The important factor affecting searches is the apparent visual magnitude. The visual magnitude is a function of the solar phase angle, the distance between the asteroid and Earth, and the distance between the asteroid and the Sun.

Considering the apparent magnitude of 1 km asteroid (i.e. H= 18.0) on the ecliptic plane, as its location is varied away from the opposition. It would appear that an observer's big opportunity of detecting an NEA is to search near the ecliptic at the opposition for optimal rates of motion and apparent visual magnitude. Given that all asteroids regardless of their inclination, they pass through the ecliptic twice at their nodes with each orbit, which is a reasonable approach and also is the most common practice.

A review by Marsden (1994) has shown that 86% of all the numbered asteroids at that time were discovered within 30° opposition, and 96% were discovered within 20° of the ecliptic[2]. Asteroids have strong relation with meteoroids and meteors so that we have to define them. A meteor is the flash of light that we see in the night sky when a small chunk of interplanetary debris burns up as it passes through Earth atmosphere.

Meteor regards to flash of light caused by the debris, not the debris itself, and the debris is called a meteoroid. A meteor can be a meteoroid, an asteroid or another object that burns and vaporizes upon entry into the Earth's atmosphere; meteors are commonly known as shooting stars. If a meteor survives the plunge through the atmosphere and lands on the surface, it's known as a meteorite. Meteorites are usually categorized as iron or stony. As the name implies, iron meteorites are composed of about 90% iron; stony meteorites are made up of oxygen, iron, silicon, magnesium and other elements [1, 3].

Radar astronomy is the observing technique nearly asteroids objects by reflecting echo signal off target objects and analyzing it[4]. These types of radars give better results of astronomy observing than an Optical telescope for the radar can calculate the distance between it and the target, determine if the asteroid approaching or moves away from it. Any change in its velocity or trajectory will cause it to collide with its closest object in space and thus turn it's to meteorites.

1.2 Literature review

The astronomy radar has been conducted for six decades there are some of the famous radars Arecibo observatory in the US, frequency 2.380 GHz, the bandwidth of 20MHZ, 1MW transmitted power, Goldstone, California DSS-14 at California frequency 8.560 GHz, the bandwidth of 50 MHZ, 0.5MW transmitted power, Goldstone, California DSS-13 at California, frequency 7.190 GHz, the bandwidth of 80 MHZ, 0.08MW transmitted power [5].

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S. Stanimirovi´c et al. (2006) reviews the history of the Arecibo Observatory. Steven J. Ostro et al. (2002) says the astronomy radar is the source to obtain the information about the physical properties and orbits of asteroids. And rhe radar measured 75 main-belt asteroids (MBAs) and 105 near-Earth asteroids (NEAs). Shantanu. P. Naidu et al. (2016) evaluated the planetary radar capabilities in severl areas around the world. M.DiMartino et al. (2003) described the first intercontinental planetary radar initiative located in Italy. They presented the results of the observations of Near-Earth Asteroid (NEA).

1.3 Problem Definition

During the last years, hazards of asteroids and other smaller bodies located between Mars and Jupiter orbits have dramatically increased. The debris of the asteroid belt falling on the ground is a risk to people, buildings and Life on Earth. That is an average range from Sun between 2.2 and 3.2 AU, astronomical unit. By definition, a solar system body is a near-Earth object if its closest approach to the Sun is less than 1.3 AU.

1.4 Objectives

The objectives of this thesis are:

- To model Tracking system for track the near earth asteroids to protect the Earth from the hazards of the celestial objects that affect the life of mankind and the performance of artificial satellites, as well as other space technology fields.
- Calculate and simulate the distance between the radar and the target, determine if the asteroid approaching or moves away from it. Any

change in its velocity or trajectory will cause it to collide with its closest object in space and thus turn it’s to meteorites.

- To evaluate the performance of the tracking model.

1.5 Methodology

In this thesis will design the tracking model using MATLAB and Simulink, by using mathematical model (radar range equation).

1.6 Thesis outlines

This thesis include the following chapters

Chapter 1: presents the Introduction.

Chapter 2:explain Overview of planetary radar.

Chapter 3: explain the Methodology.

Chapter 4: presents the Simulation and Results.

Chapter 5: describes Conclusion and recommendation.

CHAPTER TWO

OVERVIEW OF PLANETARY RADAR

Chapter two

Background

2.1 Introduction

Radar is an acronym for Radio Detection and Ranging. In the simplest radar system, a radio transmitter produces a pulse of radio frequency (RF) energy a few microseconds long. This pulse is fed into a highly directional antenna, where the resulting radio wave propagates away at the speed of light. Aircraft in the path of this wave will reflect a small portion of the energy back towards the receiving antenna. This antenna is mostly the same antenna used for the transmission or a separate one that is situated near the transmission site. The peak power of surveillance pulse radar might be in the order of a megawatt, which usually provides a range of hundreds of miles. The range of radar and its dependency on power and other factors will be presented in radar equation next. The range of the target is estimated by measuring the delay between the transmitted and the received pulse, see figure 2.1. [6].

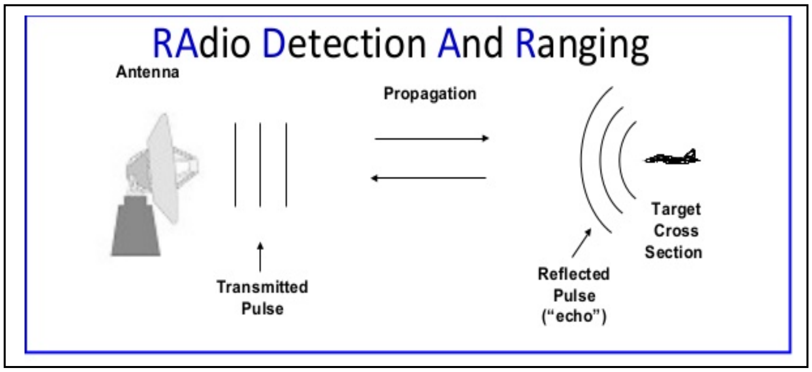


Figure 2.1: The radar

2.2 major parts of a RADAR System

We will give the six major parts of a radar system, block diagram of primary radar in figure 2.1:

2.2.1 A Transmitter

It can be a power amplifier or a power Oscillator. The signal is first generated using a waveform generator and then amplified by the power amplifier.

2.2.2 Waveguides

The waveguides are transmission lines for transmission of the radar signals. Antenna, The antenna used can be a parabolic reflector, planar arrays or electronically steered phased arrays.

2.2.3 Duplexer

A duplexer allows the antenna to be used as a transmitter or a receiver. It can be a gaseous device that would produce a short circuit at the input to the receiver when the transmitter is working.

2.2.4 Receiver

It can be a super heterodyne receiver or any other receiver which consists of a processor to process the signal and detect it.

2.2.5 Threshold Decision

The output of the receiver is compared with a threshold to detect the presence of any object. If the output is below any threshold, the presence of noise is assumed.

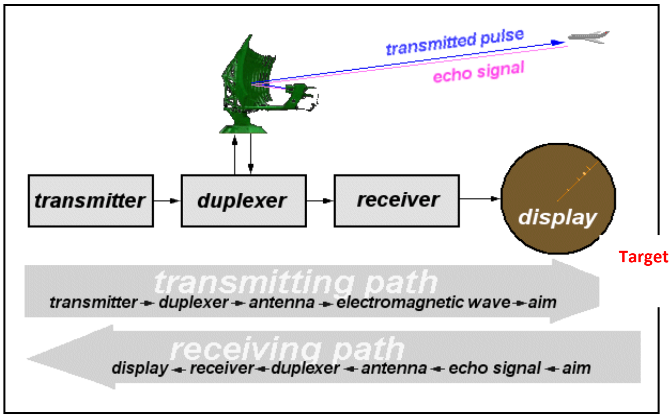


Figure2.1: primary radar system

2.3 The radar applications

The radars has very large applications we give applications in five areas:

2.3.1 Military Applications

The radar has 3 major applications in Military: In air defense, it is used for target detection, target recognition and weapon control (directing the weapon to the tracked targets).In missile system to guide the weapon. Identifying enemy locations in the map.

2.3.2 Air Traffic Control

Radar has three major applications in Air Traffic control: To control air traffic near airports.

The air surveillance radar is used to detect and display the aircraft's position in the airport terminals.to guide the aircraft to land in bad weather using precision approach radar.to scan the airport surface for aircraft and ground vehicle positions.

2.3.3 Remote Sensing

In the remote sensing application: radar can be used for observing weather or observing planetary positions and monitoring sea ice to ensure a smooth route for ships.

2.3.4 Ground traffic control

The radar used in ground traffic control: radar can also be used by traffic police to determine the speed of the vehicle, controlling the movement of vehicles by giving warnings about the presence of other vehicles or any other obstacles behind them.

2.3.5 Space area

In the use of space area: radar has 3 major applications: To guide the space vehicle for a safe landing on the moon, to observe the planetary systems, to detect and track satellites, to monitor the meteors [7].

2.4 Planetary radar overview

In our this thesis we concern in the astronomy or planetary radar which is the Radar studies of the planets and smaller bodies in the solar system are driven by the desire to understand how our solar system formed and evolved and, in the case of near-Earth asteroids (NEAs), by the concern that some of these small objects or asteroids may pose a threat to Earth. The purpose of them is to protect the Earth from the hazards of the celestial objects that affect the life of mankind and the performance of artificial satellites, as well as other space technology fields.

The sensitivity of a planetary radar system is proportional to the average transmitter power and the effective area of the transmitting and receiving antennas, and inversely proportional to $\lambda^{3/2}$, where λ is the operating wavelength, and to the system temperature, which characterizes the noise contributions from the receiver, Earth's atmosphere, our galaxy, and the cosmic microwave background. For a particular target body, the ability to detect an echo is dependent on R^{-4}, where R is its distance from the radar, plus the size, surface electrical and physical properties, and rotation state of the body. The very large distances of solar system bodies from earth dictate the need for very high transmitter powers and large transmitting/receiving collecting areas and very low system temperatures. [7].

2.5 Planetary radar history brief

For the radar history, the rapid development of radar during World War II opened the possibility of utilizing this new technology to learn more about our solar system by detecting radar echoes from large and small solar system bodies. With today's ability to image our sister planets from orbiting spacecraft, it is hard to realize how little was known about our solar system until the early 1960s. In 1946, radar systems in Hungary and the United States first detected echoes from the Moon. However, detecting echoes from our nearest planet, Venus, required an improvement in radar sensitivity by a factor of over a million. This was achieved in the late 1950s, resulting in detections of the planet at its close approach to Earth in 1961 by five different radar systems in the United States, Great Britain, and the Soviet Union. By the mid-1960s, with the advent of the radars. The overall scale of the solar system, as represented by the astronomical unit (AU), the mean distance between Earth and the Sun, Venus was postulated to have rain forests below its clouds; science fiction had not given up on the idea that Mars had canals; and there was continuing discussion as to whether lunar craters were of impact or volcanic origin. [7].

2.6 Asteroids incidents

Chelyabinsk Meteor, On February 15, 2013, a meteor exploded in the sky over Chelyabinsk, southern Russia. Although no people or buildings were hit by the resulting meteorite, the shockwave from the exploding object injured about 1500 people and caused damage to 7200 buildings in the region.

2008 TC3 Meteor was in October 2008, Nubian Desert, Sudan, Exploded at an estimated 37 kilometers above Earth surface, Some 600 meteorites, a total of 10.5 kilograms.

Abbasia Meteorite fell into White Nile state, Sudan, June 2017, It's exploded after entered the atmosphere, many meteorite pieces were discovered.

Meteor Crater (North Arizona**)**, North Arizona desert, USA, About 1 kilometer the size of the meteor, Depth 170 meters caused in the earth, that was before 50000 years.

Chicxulub Crater fell near the town of Chicxulub, Mexico, The crater diameter is more than 180 kilometers, Before 66 million years ago.

2.7 Comets, Meteors, and Meteoroids

The solar system is littered with three kinds of space debris: asteroids, comets, and meteoroids. Although these objects represent a tiny fraction of the mass of the system, they are a rich source of information about the origin of the planets. The asteroids, sometimes called minor planets, are small rocky worlds, most of which orbit the sun in a belt between the orbits of Mars and Jupiter. More than 100,000 asteroids have orbits that are charted, of which about 2000 follow paths that bring them into the inner solar system where they can potentially collide with a planet. Earth has been struck many times in its history. Most asteroids are irregular in shape and battered by impact cratering. Many asteroids seem to be rubble piles of broken fragments. Some asteroids are double objects or have small moons in orbit around them. This is further evidence that asteroids have suffered collisions. A few asteroids show signs of geological activity that probably happened on their surfaces when those asteroids were young. It is a Common mistake that the asteroids are the remains of a planet that broke apart. In fact, planets are held together very tightly by their gravity and do not "break apart." Astronomers recognize the asteroids as debris left over from the failure of a planet to form at a distance of about 3 AU from the sun. About 200 asteroids are more than 100 km (60 mi) in diameter, and tens of thousands are estimated to be more than 10 km, Some of the meteoroids collide with Earth's atmosphere at speeds of 10 to 70 km/s. you see them vaporize as streaks across the night sky. Those streaks are called meteors ("shooting stars"). If a meteoroid is big enough and holds together well enough, it can survive its plunge through the atmosphere and reach Earth's surface. Once the object strikes Earth's surface, it is called a meteorite. The largest of those objects can blast out craters on Earth's surface, but such big impacts are extremely rare. The great majority of meteorites are too small to form craters, see figure 2.3 [8, 9].

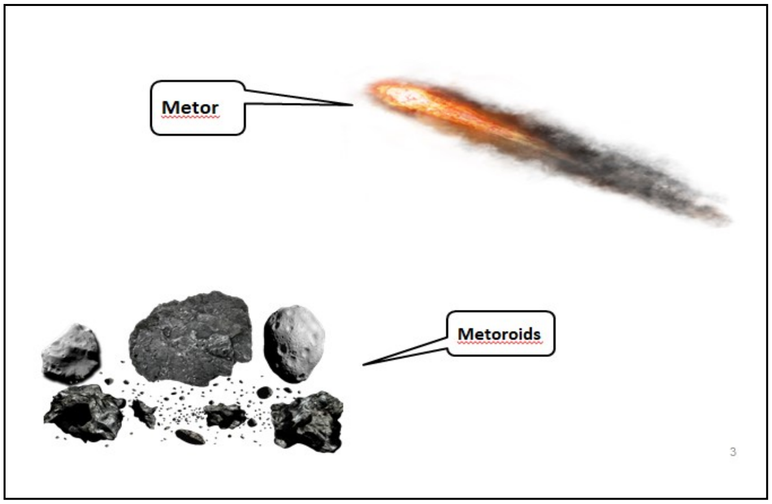


Figure 2.3: Comets, Meteors

2.8 Asteroid belt

The first asteroid was discovered on January 1, 1801 (the first night of the 19th century) by the Sicilian monk Giuseppe Piazzi. It was later named Ceres (largest body in the asteroid belt) after the Roman goddess of the harvest (and source of our word cereal). Astronomers were excited by Piazzi’s discovery because there seemed to be a pattern to the location of planet orbits, except for a wide gap between Mars and Jupiter where the pattern implied a planet “ought” to exist at an average distance from the sun of 2.8 AU. Ceres fit the pattern: Its average distance from the sun is 2.77 AU. But Ceres is much smaller than the planets, and three even smaller objects—Pallas, Juno, and Vesta—were discovered within a few years, all orbiting between Mars and Jupiter, so astronomers decided that Ceres and the other asteroids should not be considered true planets. Ceres has now been re-classified as a dwarf planet because it has enough gravitational strength to squeeze itself into a spherical shape but not enough to have absorbed or cleared away the rest of the asteroids. Today over 100,000 asteroids have well-charted orbits. Only three are larger than 400 km in diameter, and most are much smaller, see figure 2.4 [9].

Figure 2.4: asteroid belt

2.9 The dwarf planet Ceres

Ceres is the largest object in the asteroid belt and it is the only dwarf planet located in the inner solar system. It was the first object discovered within the belt when Giuseppe Piazzi spotted it in 1801. And when Dawn arrived in 2015, Ceres became the first dwarf planet, which is a diameter that is approximately 945 kilometers (587 miles), see figure 2.5, characteristic in table 1.

Authors have chosen to follow Ceres asteroid because of its large size, which makes easy to follow and monitor than other asteroids in the asteroid belt. The characteristics of the Ceres shown in the table1 [6]. Other important characteristics of Ceres are proper semi-major axis = 2.7670962 AU, eccentricity= 0.1161977, orbital periodic= 1681.601 Earth days, average orbital speed =17.905 km/s, Equatorial radius = 487.3 km, polar radius = 454.7 km [10].

Table 1: The Ceres characteristics

Characteristic	Details
Size& Distance	With a radius of 296 miles (476 kilometers), Ceres is 1/13 the radius of Earth.
Orbit & Rotation	Takes 1,682 Earth days, or 4.6 Earth years, to make one trip around the sun. As Ceres orbits the sun
Formation	Ceres formed along with the rest of the solar system about 4.5 billion years ago when gravity pulled swirling gas and dust in to become a small dwarf planet.
Structure	Ceres is more similar to the terrestrial planets (Mercury, Venus, Earth, and Mars) than its asteroid neighbors, but it is much less dense.
Atmosphere	Ceres has a very thin atmosphere, and there is evidence it contains water vapor.

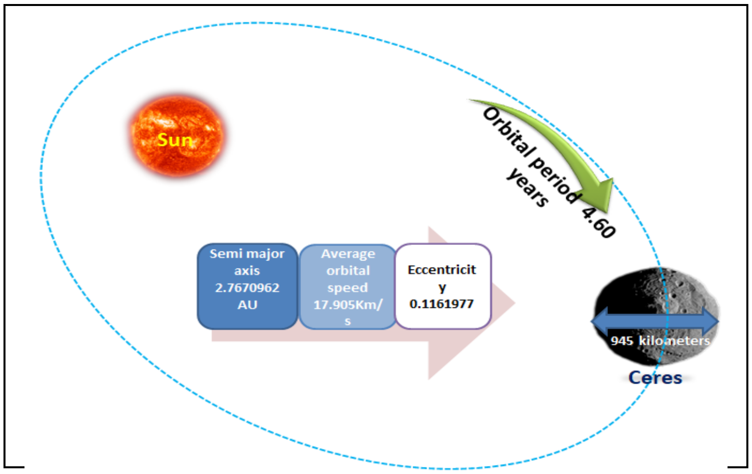


Figure 2.5: The dwarf planet ceres

2.10 Related work

The most Considerable work has been conducted in this type of radars are in the Arecibo Observatory is a radio and radar telescope in the municipality of Arecibo, Puerto Rico. In the US and Goldstone Deep Space Communications Complex is located in the Mojave Desert near Barstow in the U.S.

S. Stanimirovi´c et al. (2006) reviews the history of the Arecibo Observatory, its genesis, construction, and the two upgrades through which the remarkable 305-m telescope continues to contribute significant results in many areas of astronomy and atmospheric physics. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center (NAIC), a national research center operated by Cornell University under a cooperative agreement with the National Science Foundation (NSF).

Steven J. Ostro et al. (2002) says the astronomy radar is the source to obtain the information about the physical properties and orbits of asteroids. And them book aims to outline developments since Asteroids II (Binzel et al., 1989), radar measured 75 main-belt asteroids (MBAs) and 105 near-Earth asteroids (NEAs).Radar has finds both stony and metallic objects, principal-axis and complex rotators, smooth and very rough surfaces, objects that must be monolithic or not, spheroids and highly elongated shapes, contact-binary shapes, and binary systems. Radar also has expanded accurate orbit-prediction intervals for NEAs by as much as several centuries.

Shantanu. P. Naidu et al. (2016) evaluated the planetary radar capabilities at Arecibo, the Goldstone 70-m DSS-14 and 34-m DSS13 antennas, the 70-m DSS-43 antenna at Canberra, the Green Bank Telescope, and the Parkes Radio Telescope in terms of their relative sensitivities and the number of known near-Earth asteroids (NEAs) detectable per year in monostatic and bistatic configurations. In 2015, monostatic observations with Arecibo and DSS-14 were capable of detecting 253 and 131 NEAs respectively. The two observatories were capable of detecting 276 NEAs. Of these, Arecibo detected 77 and Goldstone detected 32, or 30% and 24% the numbers that were possible. The two observatories detected an additional 18 and 7 NEAs respectively. This indicates that a substantial number of potential targets are not being observed. The bistatic configuration with DSS-14 transmitting and the Green Bank Telescope receiving was capable of detecting about 195 NEAs, or 50% more than with monostatic observations at DSS-14.

M.DiMartino et al. (2003) described the first intercontinental planetary radar initiative located in Italy. They presented the results of the observations of Near-Earth Asteroid (NEA) 33342 (1998 WT24), performed in December 2001 using the bistatic configurations Goldstone-Medicina and Evpatoria-Medicina, The experiment goal was to characterize the system for radar follow-up observations of NEA and artificial orbiting debris.

CHAPTER THREE

METHODOLOGY

Chapter Three

Methodology

We will give a brief explanation of the equations used in the calculation of the received power in the radar receiver.

3.1 Radar range equation

The radar range equation, or simply the radar equation, is an equation that relates the maximum range of detection of a specific target with relevant parameters of the radar. A simple form of the range equation for monostatic radar.

$$R_{max} = \sqrt[4]{\frac{P_t\ G^2\ \lambda^2\ \sigma}{(4\pi)^3\ S_{min}}}$$ .... eq (3.1).

The received signal amplitude in dB is given as:

$P_r = 10\log10\ (P_t\sigma\lambda^2G^2/\ (4\pi)3) - 10\log_{10}\ (R4)$ ………………….eq(3.2)

Which relates the maximum range R_{max} to the peak power P_t of the transmitted signal, the common antenna gain G, the wavelength λ of the radar, the receiver sensitivity S_{min} and σ is the radar cross section of the target. Sensitivity is given here in terms of the minimum detectable signal (MDS) that the receiver can sense. There are two important parameters of the radar systems that are not shown in the range equation above and need to be emphasized. The first parameter is the noise average power at the input of the receiver. It is usual to use the minimum operational signal-to-noise ratio SNR_{min} at the input of the receiver, rather than to use its sensitivity. If we assumed only thermal noise with an average power of

kT_oB, where k is the Boltzman constant, t_o is the absolute temperature and B is the bandwidth of the receiver, we get another form of the radar equation as:

$$R_{max} = \sqrt[4]{\frac{E_t \, G^2 \lambda^2 \, \sigma}{(4\pi)^3 \, kT_o \, SNR_{min}}}$$

……………………………..… eq (3.3).

The last form of the equation emphasizes the effect of increasing the energy of the pulse so as to increase the range of detection in a noisy environment.[11] The asteroid target must be in the range of R_{max} for the success of tracking the target and received the accepted amount of power.

3.2 Calculation The distance between Ceres and Earth

We chose to follow Ceres asteroid because of its large size, which makes easy to follow and monitor than other asteroids in the asteroid belt. The characteristics of the ceres shown in the table1 [6]. Other important characteristics of ceres are proper semi-major axis = 2.7670962 AU, eccentricity= 0.1161977, orbital periodic= 1681.601 Earth days, average orbital speed =17.905 km/s, Equatorial radius = 487.3 km, polar radius = 454.7 km [7] [8]. As in figure4 Ceres distance from Earth is:

$R = (R_e^2 + R_c^2 - 2 R_e R_c \cos \theta)^{1/2}$ …………………....…… eq (3.4).

Where: R_e is the Earth semi-major axis = 149,598,023 km [8], R_c is the Ceres semi-major axis = 413,951,699.542 km. The distance between Earth and Ceres is variable. E.g., suppose the distance when the angle between them is 90 degrees,see figure 3.1.

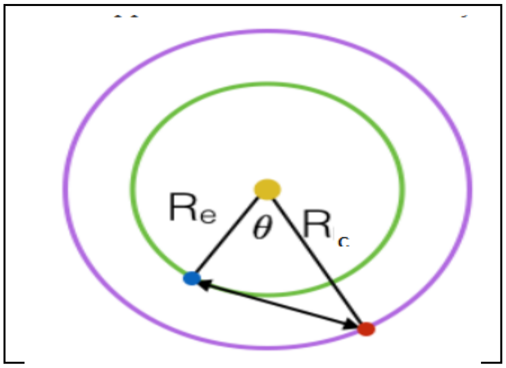


Figure.3.1. Distance between earth and ceres

3.3 The radar pulse compression

Planetary radar commonly uses pulse compression in order to enhance the range resolution without shortening the RF pulse sent from the transmitter and hence not forced to reduce its energy. Furthermore, pulse compression raises the SNR of the received signal by the amount of pulse compression ratio, which is the ratio between the long transmitted RF pulse and the compressed pulse that is produced at the output of the matched filter in the receiver. If the radar sends an RF pulse of width = 100 µsec and the compressed pulse width is 0.1 µsec, then the pulse compression ratio equals

PCR= $T/\tau = 100/0.1 = 1000 = 30$ dBW ……………………… eq (3.5)

3.4 system models

3.4.1 General model

Make use of planetary radar simulation for tracking a moving asteroid that fully reflects all of the incident signals off its radar cross-sectional surface, at the receiver simulation analyzing the received signal from the target to follow and monitor it.

The model of the planetary radar includes a transmitter, receiver, common antenna, and simulation of the target, collect The RF signal received by the antenna, and processes it by a super heterodyne receiver, The received signal will process and analyze to examine the simulated asteroid behavior, and then the received signal passed to FIR filter used to enhance the received signal as in show in figure1.1.

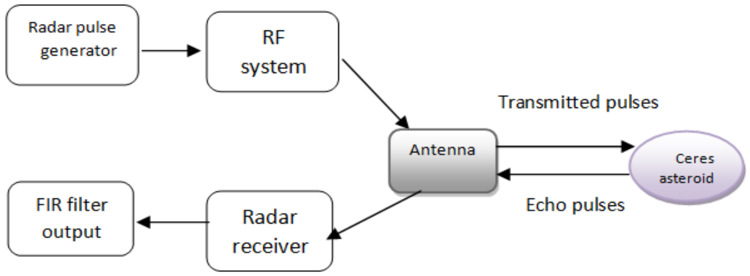


Fig. 3.2 the model block diagram.

3.4.2 The modeling block diagram using Matlab Simulink

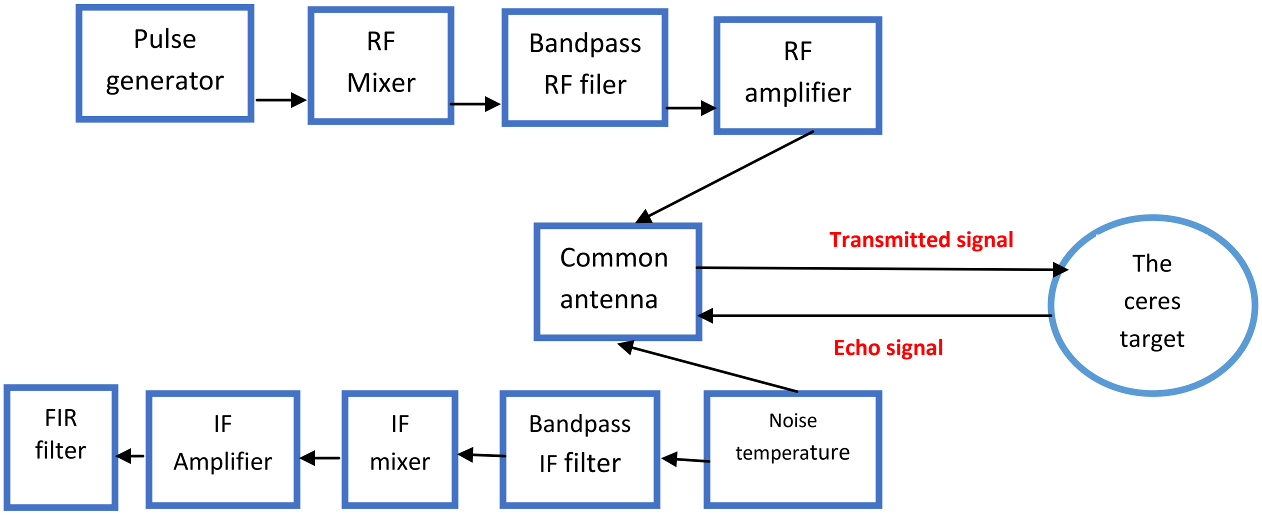


Fig. 3.3 the model block diagram in details

3.4.2.1 The pulse generator

The pulse generator generates the pulses using A MATLAB simulink block used for generating pulses of various kind of pulses at regular intervals, The block waveform parameters, Amplitude, Pulse Width, Period, and Phase delay, determine the shape of the output waveform.

3.4.2.2 The RF Mixer

The mixer includes local oscillator using S-parameters, its frequency-dependent S-parameters, the frequencies and reference impedance of the S-parameters, noise data (including phase noise data), and nonlinearity data, it can be up converter or down converter, If you choose Downconverter, the output frequency, F_{out} from the mixer input frequency, F_{in}, and the local oscillator frequency, F_{lo}, as $F_{out} = F_{in} - F_{lo}$. If you choose Up converter, $F_{out} = F_{in} + F_{lo}$. For a down converting mixer, the local oscillator frequency must satisfy the condition $F_{in} - F_{lo} \geq 1/(2ts)$, where ts is the sample time specified in the Input Port block. Otherwise, an error appears.

3.4.2.3 The bandpass RF filter

The Bandpass RF Filter block of Simulink MATLAB lets you design standard analog bandpass filters, first we must select the filter design method options: Butterworth, Chebyshev I, Chebyshev II, Elliptic or Bessel. We can change The parameters displayed in the block: filter order, Lower passband edge frequency, VUpper passband edge frequency.

3.4.2.4 The RF amplifier

We use the S-Parameter Amplifier block model in Simulink MATLAB, its depend on the frequencies dependent parameters, reference impedance of the S-parameters, noise data, and nonlinearity data. On the block of amplifier we must chose the suitable gain.

3.4.2.5 The common antenna

We have the simulation of antenna to give the suitable gain for transmit and received signal.

3.4.2.6 The asteroid target (ceres dwarf planet)

The simulation of the fully reflects target for all of the incident signals off its radar cross-sectional surface, it has Doppler shift zero for it’s very slow speed compared to speed of the earth.

3.4.2.7 The Noise Temperature

The Receiver Thermal Noise block simulates the effects of thermal noise on a radar receiver, baseband signal. You can specify the amount of thermal noise in three ways, according to which Specification method you select: Noise temperature, Noise factor, Noise figure.

3.4.2.8 The bandpass filter

The Bandpass IF Filter block of Simulink MATLAB lets you design standard analog bandpass filters, first we must select the filter design method options: Butterworth, Chebyshev I, Chebyshev II, Elliptic or Bessel. We can change the parameters displayed in the block: filter order, Lower passband edge frequency, and Upper passband edge frequency.

3.4.2.9 The General Mixer

The parameter values refer to the mixer input frequency. If the parameter data and corresponding frequencies exist as S-parameters, the General Mixer block interpolates the S-parameters to determine their values at the modeling frequencies. Here in the receiver we select the down converting to be in the IF range.

3.4.2.10 the Amplifier

We use the S-Parameter Amplifier block model in Simulink MATLAB Same as the amplifier in the Rf radar system but different in the gain.

3.4.2.11 the FIR Filter

The Discrete FIR Filter block independently filters each channel of the input over time using an FIR filter. You can specify filter coefficients using either tunable dialog parameters or separate input ports, which are useful for time-varying coefficients. In This block filters each channel of the input signal independently over time. The Input processing parameter allows you to specify whether the block treats each element of the input as an independent channel (sample-based processing), or each column of the input as an independent channel (frame-based processing).

CHAPTER FOUR

RESULTS AND DISCUSSION

Chapter four

Simulation and Results

4.1 The distance between Ceres and Earth calculation

We use the equation eq (3.4) for calculate the distance between Ceres and Earth:
$R = (R_e^2 + R_c^2 - 2 R_e R_c \cos\theta)^{1/2}$

Where: Re is the Earth semi-major axis = 149,598,023 km [8], Rc is the Ceres semi-major axis = 413,951,699.542 km. The distance between Earth and Ceres is variable. E.g., suppose the distance when the angle between them is 90 degrees, then according to Equation above R will be 440154038.990009 km.

4.2 Radar link budget calculations

4.2.1 Radar Doppler Frequency Shift Considerations

Doppler frequency shift is caused by motion that changes the number of wavelengths between the moving target and the radar, which at certain radial velocities it degrades performance. In this paper, the model is assumed not effected by Doppler shift, which is ignored supposing that Ceres asteroid has a fixed distance from the radar during the hour of the tracking process that results in a zero relative velocity of an asteroid with Earth.

4.2.2 Calculation of Received Power

Assuming the parameters and values needed to calculate the received power at the receiver (Rx) of the radar are according to the specifications of the goldstone california dss-14 radar X band, as follows[5] [6, 12]:

The received power at RX radar:
The power of received by Radar = Tx Amplitude - Path Loss - Target Return

Then the power of received by Radar = TX Amplitude - 10*log10 (Target Range^4)

- 10*log$_{10}$10 (Target Cross Section*(λ^2)/ (4*pi)^3) eq(4.1)

Target cross section= 2π AB = 1.4x1012 m^2

The radar path loss=10*log10 (Target Range^4)

= 10*log10 (440154038.990009 Km)^4

= -474.67 dB.

The Target Return= 10*log$_{10}$10 (Target Cross Section*(λ^2)/ (4*pi)^3)

=10*log$_{10}$10 (1.4x1012 m^2*(0.035 m^2)/ (4*pi)^3)

= -416.87 dB.

Table: 4.1 the radar and target parameters

	The parameter	**The value**
	Frequency	8.56GHZ
1	Wavelength	0.035 m
2	Tx power	500kW
3	Bandwidth	50MHZ
4	Receiver amplifier	50dBW
5	Common antenna gain	71.6dBi
6	Receiver LNA	38dBi
	Path Loss	-474.67 dB.
	Target Return	-416.87 dB.
	Frequency	8.56GHZ.
7	**Target specifications**	
8	R	2.7670962 AU=440154038.990009 Km
9	Target cross section	1.4x1012 m^2

Where A= Ceres polar radius, B= Ceres equatorial radius.

According to Equation (4.1) above, the power received at radar station Rx is found as -116.198.

If the system uses the pulse compression technique Then accordingly, the power of the received signal out of the matched filter will be -116.198 dB + 30 dB = -86.198dBW dB.

4.3 Simulation Description and result:

The Simulink model of the planetary radar includes a transmitter, receiver, common antenna, and target as in show the block diagram in figure1. The radar pulse generator generates 10% duty cycle pulses of sample period 0.18µsec and of 1mW power sends to the RF system with common impedance of 50 ohms. The frequency of radar carrier is 8.56 GHZ, the mixer uses the carrier oscillator to up convert the signal to RF signal. A TWT amplifier amplifies the OIP3 output to 57 dB, the antenna adds 71.6 dBi, the power sent up to 500kW for propagating through more than million kilometers. The common radar antenna receives the echo signal from Ceres asteroid after delay 880.3 seconds. LNA add 38dBi The superheterodyne receiver with amplifier 50 dB, the common receiver impedance 50 ohm, supposed the thermal noise of receiver 20 Kelvin temperature, Then the received signal is passed to FIR filter used to enhance the received signal as in shown in figure 5.4, the pulse sent via a transmitter in figure 5.5, the screenshot of full system shown in figure 5.1 to 5.3.

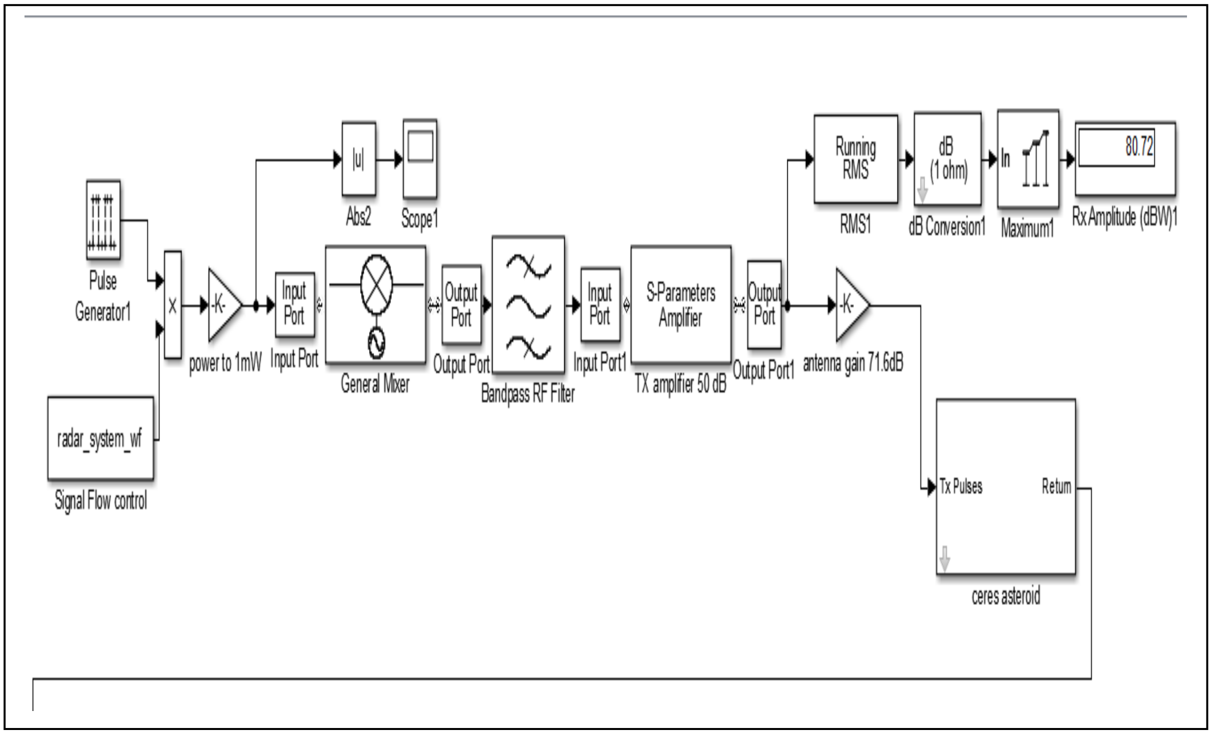
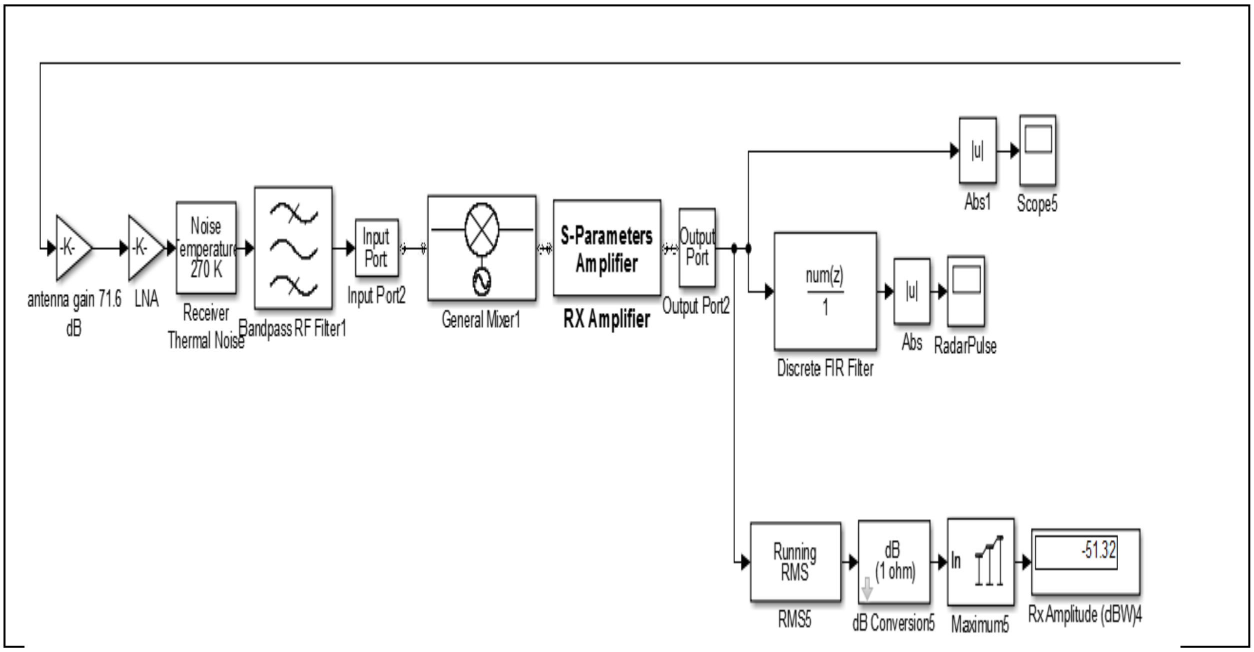


Figure 5.1: Simulation screen shot of the pulse generator, transmitter radar system and the simulation of Ceres target



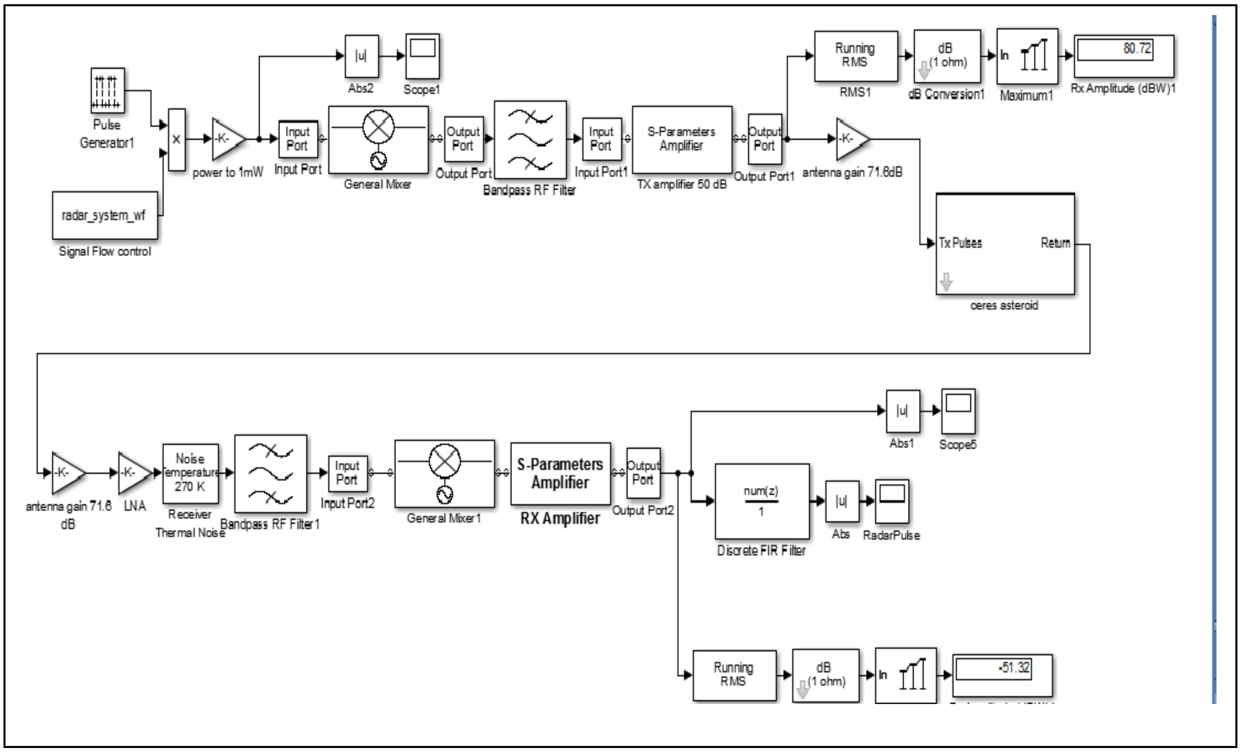


Figure 5.3: The simulation full design screen shot

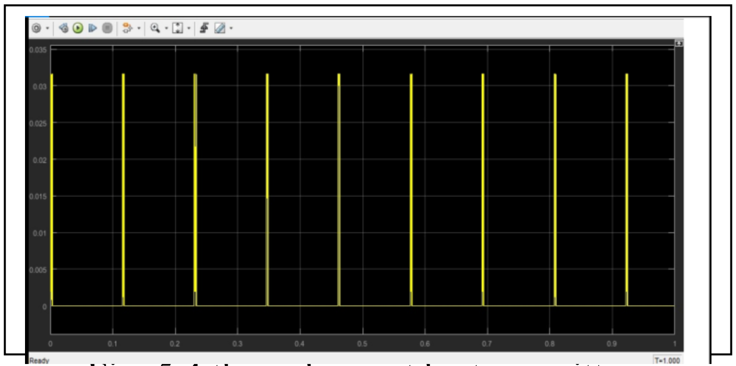


Fig. 5.4 the pulse sent by transmitter

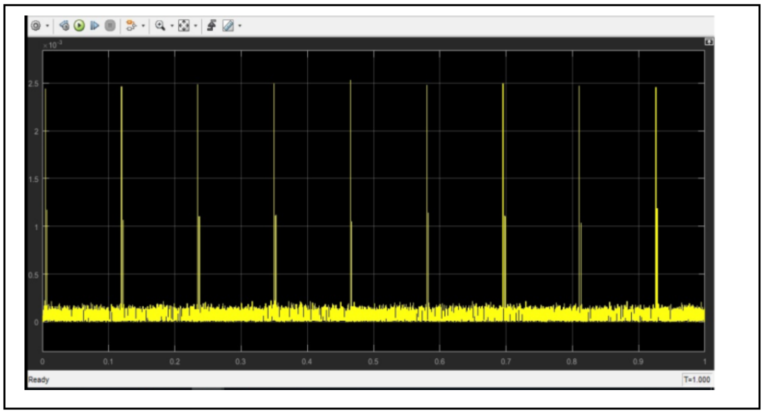


Fig. 5.5 the FIR filter result display the time domain of the filter response signal

CHAPTER FIVE

CONCLUSION AND RECOMONDATIONS

Chapter five

Conclusion and recommendations

5.1 Conclusion

Success of Applied full transmit and receive model that is used for the track of position and velocity of the moving Ceres asteroids, The modeled using MATLAB and Simulink was success to received signal to processed and analyzed for the examine the simulated asteroid behavior as you see in the FIR filter result display, Receive -116.198dB is the acceptable amount of power to process and success of tracking the Ceres asteroid if it's approaching the earth to protect the Earth from the hazards of the celestial objects that affect the life of mankind and the performance of artificial satellites, as well as other space technology fields. . The nature of the rock asteroid and the big size of the asteroid dimensions help in reflect the signal towards the receiver and receive an acceptable amount of power. Received the echo radar signal before 880.3 seconds indicates to the asteroid is approaching towards earth. The radar station system operates in the range of power with in a megawatt must be in place uninhabited that is for the amount of power directed from the radar antenna danger on people.

5.2 recommendations

We can develop our simulation by increasing the amplifier and antenna gains to achieve more transmitted power, also by helps of pulses compression for tracking farer objects. Furthermore we can directs our common antenna to tracks others objects in the space like comets and other closest planets to the earth in the solar system like Venus, Mercury, Mars and our Moon. Increasing the sensitivity of radar receiver helps our system to collects the receive power reflected from farer target

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