DESIGNING LOG PERIODIC ANTENNA FOR THE "CALLISTO" SYSTEM BY USING "4NEC2" COMPUTER SOFTWARE

(Internship Program – Arthur C. Clarke Institute for Modern Technologies)

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DECLARATION

This dissertation describes that this industrial training report is the record of authentic work carried out by me during the period from 21st June 2021 and 21st September 2021, as an intern at Arthur C. Clarke Institute for Modern Technologies under the supervision of Industrial and Academic supervisors.

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ABSTRACT

When we consider our planetary system, there are eight main planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto which is detected as a dwarf planet. Not only them but also there are dozens of moons and millions of asteroids, comets and meteoroids are orbiting around the Sun. "Sun" is the main energy source of all the planets in our planetary system especially Earth, and it is the gravitational source that gives the energy for the planets to orbit around the sun. Hence examining the properties of the sun is important for us. Solar activities such as solar flares, solar wind, coronal mass ejections (CME) can be observed and analysed to determine the properties of the sun.

"CALLISTO" refers to "Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory" designed to collect the data of solar radio bursts. The Log-Periodic antenna system is designed to grab the radio frequencies of solar flares within the frequency range of 45 MHz to 870 MHz. The antenna system contains an 18-dipole array with the impedance of 58.3 Ω. The total height of the antenna is 5.38 m, and the longest dipole is 3.33 m. The CALLISTO system is situated at 6^{o} 47' 37'' N, 79^{o} 53' 53'' E at an altitude of 40 m and the time zone is +5.30 from UT. Its design constant is (t) 0.822 and the relative spacing factor (s) 0.149 give 7 dB theoretical gain for the log – periodic antenna. The tangent of the enclosed angle of the antenna (tan α) is 0.88625. The diameters of the dipole elements are 0.9 cm, 1.2 cm, and 1.5 cm. The boom dimensions are 37 mm × 25 mm.

In this project 4NEC2 software was used to design the LPDA antenna of CALLISTO system to analyze its theoretical and physical quantities such as SWR and radiation pattens of the designed antenna.

ACKNOWLEDGMENT

First, I would like to mention that it is a great opportunity to thank all the people who supported me and encourage me in completing my 3 months of internship period successfully in a meaningful way by sharpening my career effectively.

At first, I would like to thank the Department of Physics to offer me such a grateful opportunity to work in a place like Arthur C. Clarke Institute for Modern Technologies. I would like to thank specially Prof. A.R. Kumarasinghe the Head of the Department, Dr. S. Jayawardhana the Industrial Training Coordinator of Physics Department for guiding us throughout the program by finding good training establishment places.

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CHAPTER I

1. CHAPTER I - INTRODUCTION

1.1 INTRODUCTION OF THE INSTITUTE

(Arthur C. Clarke Institute for Modern Technologies)

1.1.1 Introduction to ACCIMT

Arthur C. Clarke Institute for modern technologies (ACCIMT) is a leading institute of technology and research education sector in Sri Lanka. It is commonly known as Arthur C. Clarke Center, which is situated in Katubedda, Moratuwa, Sri Lanka [1]. It is named after its founder patron, Srilankabhimanya Sir Arthur C. Clarke who was a famous British science fiction novel writer, inventor and a research scientist in Astronomy, Astrophysics, and telecommunication etc. [1].

The instate is mostly focused on conducting research in the fields of electronics, micro-electronics, telecommunication, information technology, space technology, embedded systems and robotics in the electronic division and astronomy, solar astronomy, observatory, astrophysics, exoplanets etc. in the astronomy division. Not only research but also ACCIMT is providing training programs for relevant industry professionals as well as university undergraduates.

Figure 1 : ACCIMT, Katubedda, Moratuwa

1.1.2 Srilankabhimanya Sir Arthur C. Clarke

Srilankabhimanya Sir Arthur C. Clarke was the first one who was able to introduce the concept of extra-terrestrial communication through geo-stationary satellites even though it was far back time which is around 1940s. Beside this, Sir Arthur C. Clarke is a successful science fiction author. Loophole, Rescue party, Against the fall of night, Childhood's end, 2001: Space Odyssey, 2010 Odyssey two, 2061 Odyssey three and 3001 the final Odyssey are some famous books that were written by him. Sir Arthur was born in the 1917 at Meinhead in the United Kingdom. He chose to live In Sri Lanka from 1956. He contributed to Sri Lankan society with his vision, writings and predictions and

[1] ACCIMT - https://goo.gl/maps/S715cavw8cehsxHQ8

brought fame to the Island for a period of over half a century until his demise on March 19, 2008, [2].

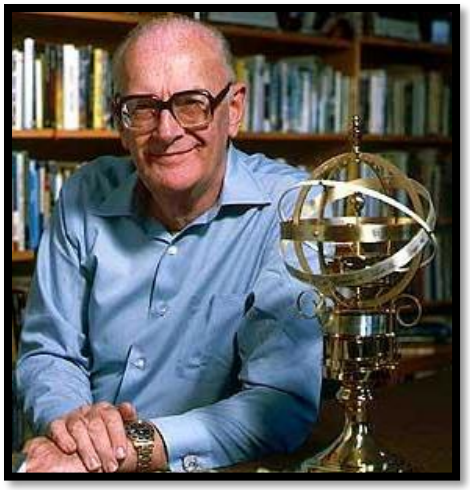


Figure 2 : Sir Arthur C. Clarke

1.1.3 History

The ACCIMT was found in 1984 by act of parliament, by the Arthur C. Clarke Centre for Modern Technologies Act, No. 30 of 1984. The institute was re-established in a corporate form in 1994 by the Science and Technology Development Act, No. 11 of 1994. ACCIMT comes under the purview of the Ministry of Science, Technology and Research, Sri Lanka. The ACCIMT was appointed as the national focal point for space technology applications, by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP).

In 1996, the institute received a 45 cm **GoTo Cassegrain reflector telescope** as a donation by the Tokyo National Observatory via the Government of Japan. It is the largest optical telescope in Sri Lanka. Relevant technical assistance was provided by Besei Astronomical Observatory, Japan and the South African Astronomical Observatory [2].

A lot of activities such as educational seminars, industrial trainings, research programs etc. are organized by ACCIMT. As a result of activities done to popularize and famous like above astronomy among the Sri Lankan community, ACCIMT received the membership of Asia Pacific Regional Space Agency Forum (APRSAF) sponsored by Japan Aerospace Exploration Agency (JAXA). ACCIMT hosted the 15th Session of the Intergovernmental Consultative Committee on the Regional Space Applications Program for Sustainable Development (RESAP) in 2011 which was conducted by UNESCAP [3].

1.1.4 Research and Facilities in ACCIMT

The ACCIMT is one of a leading research and development institute in the country which provides the experts and more experienced scientists in their fields. The process and the success of the institute

[2] Telescope - http://www.accimt.ac.lk/?page_id=670

are initiated by several pioneering projects as mentioned before. This institute consists of 6 major divisions, which are:

1) Communication and Engineering
2) Electronic and Mobile Electronic
3) Industrial Services
4) Information Technology
5) Space Applications and,
6) Astronomy

The GoTo 45cm Cassegrain telescope donated by the Japanese Government is the largest optical telescope facility available in Sri Lanka. That is used for bringing out basic research studies in astronomy as well as for teaching astronomy to school and university students. This telescope facility is equipped with a spectrograph, photometer, and Apogee ASPEN (3056×3056 pixels) and Apogee ALTA U47 (1024×1024 pixels) CCD cameras. The spectra in the wavelength region from 4000 A to 9000 A can be obtained with this system. The photometer of the telescope has RCA IP21 photomultiplier tube with pulse counting system and Johnson and Morgan UBVRI filters [3].

Figure 3 : ToGo Telescope in ACCIMT [25]

The astronomy department of ACCIMT conducts the research under four main categories.

1) Detecting Exoplanets
2) Asteroseismology
3) Solar Radio Bursts, and
4) Cataclysmic Variable Stars

Detecting Exoplanets

Detecting Exoplanets research consist of the studies about planetary systems around stars except our

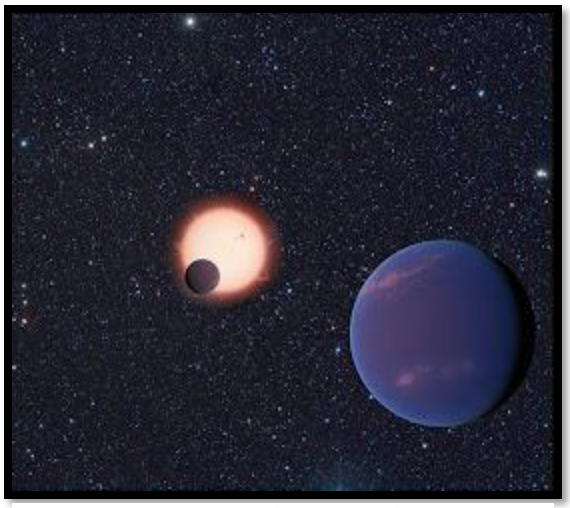


Figure 4 : Exoplanets Research [4]

sun. This kind of experiments have only been done around for about 25 years. This is mainly based on with the presence of new instruments such Kepler Space Telescope and the TESS (Transiting Exoplanets Survey Satellite) of Kepler Telescope. In ACCIMT the data collected from Kepler are analyzed [4].

Asteroseismology

In this field it has an unprecedented way of determining the internal structure of a star by studding its oscillations. Recent efforts have been performed allowing the detection of many frequencies in different kinds of pulsating stars. The pulsation is caused by stellar oscillations in three orthogonal

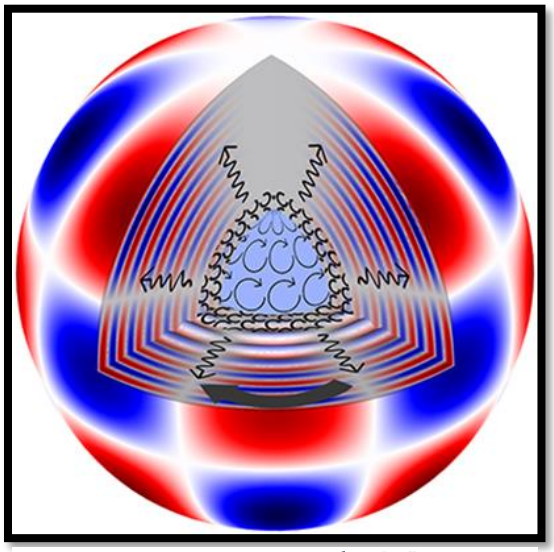


Figure 5 : Asteroseismology [26]

directions, radial distance, co-latitude, and longitude of the stellar structure [5].

Solar Radio Bursts

In ACCIMT Solar Radio Bursts are collected by using the CALLISTO antenna system. CALLISTO stands for Compound Astronomical Low-cost Low Frequency Instrument for Spectroscopy and

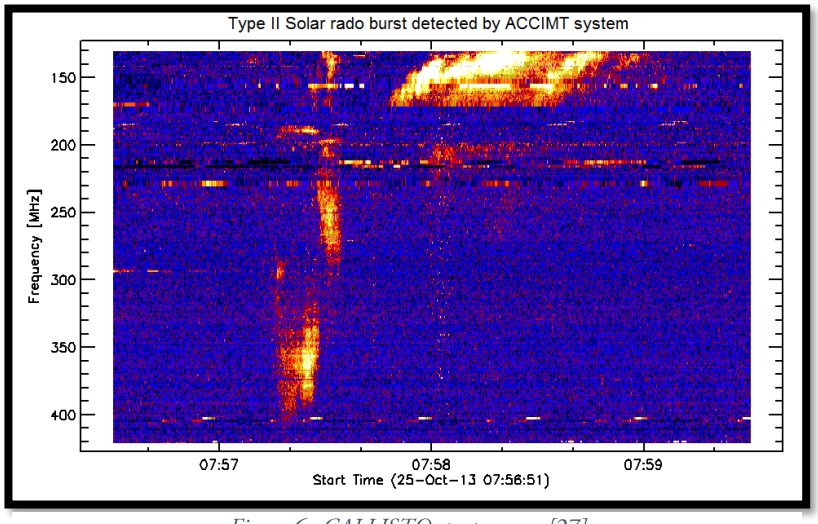


Figure 6 : CALLISTO spectrogram [27]

Transportable Observatory. It is a programmable heterodyne receiver built in the framework of IHY2007 and ISWI (International Space Weather Initiative) by former Radio and Plasma Physics Group at ETH Zurich, Switzerland. Generally, this is applicable for observation of solar radio bursts and rfi – monitoring for astronomical science, education, and outreach. The data collected in CALLISTO antenna are analyzed in ACCIMT with different approaches to identify the type of the solar radio bursts and the properties of them [4].

Cataclysmic Variable Stars

Cataclysmic variable stars research is interacting binary stars comprising a white dwarf accreting matter from a companion star. In ACCIMT, they do interesting research about these areas also. On that research there is an attempt to understand underlying scenarios and physics that reasoned to period gap of CV stars.

1.1.5 Vision and Mission of ACCIMT

Vision

To be a leading innovation center for Modern Technologies in the region

Mission

To develop, foster and facilitate the domestic base of modern technological capabilities through innovation, R & D, training, industrial services and international collaboration"

1.2 INTRODUCTION OF THE PROJECT - BACKGROUND

1.2.1 The Sun and our Solar system

"The Sun" is the main energy source to our planet Earth. Not only for us but also it is the main energy source for all the planets in our solar system. Because of that we can conclude, without sun our planet would not be exist. Therefor Analysis of its properties and its behaviors could be very helpful. There are many planetary systems that can be found in the universe like ours. It could be hundreds, thousands, millions, billions, or zillions of planetary systems in the universe. Who can count on them? But as curies humans, we can discover secrets about our planetary system which is named as "The solar system". Our planetary system is in an outer spiral arm of the Milky Way galaxy. The solar system consists of our star, "The Sun", and everything bound to it by gravity. The planets that orbit around the Sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The dwarf planets such as Pluto, dozens of moons and millions of asteroids, comets and meteoroids are moving around the Sun. The current estimate is that the solar system was created 4.6 billion years ago by a sudden expansion of space-time containing dust and gas particles. As above mentioned, our solar system has Sun as the power source and eight main planets and numerous dwarf planets as well as asteroids and meteoroids [6].

1.2.2 Solar Activities

"Sun" is the main power and energy source in our solar system as I mentioned earlier, and it is located at a gravity center point of the orbits of the planets in our solar system. The sun is gigantic star that can be categorized as a "yellow dwarf star". Sun emits different types of wave frequencies. It gives energy as Light. This light includes the full spectrum of electromagnetic frequencies; visible light, infra-red (energy of heat), ultraviolet light and radio waves. Not only that, but also sun gives off a stream of particles that reaches the earth as "Solar wind".

Sun creates its all of energy by nuclear fusion. Nuclear fusion is a reaction that take place inside stars which turns hydrogen nuclei into helium nuclei and generate huge amounts of energy during the process [7]. Because of those unpredictable nuclear reactions happen on sun, there are some solar activities that occurs on it such as Solar wind, Solar bursts, Coronal mass ejections etcetera. In this project the antenna that collects data of frequencies of solar bursts is designed by a computational method.

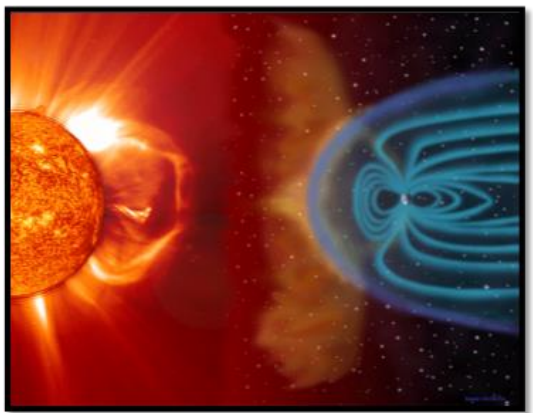


Figure 7 : Solar Flare and Solar Wind

1.2.3 Solar Flares and CALLISTO system

Solar flares are an intense burst of electromagnetic waves coming from the sun due to the release of magnetic energy associated with sunspots. Solar radio bursts are an arrangement of a frequency space that has a variation with "time". Most of the solar bursts are observed below the 200 MHz frequency level. Radio solar bursts could be categorized to five main types.

- Type I burst (Noise storm)
- Type II burst (Slow drift rate)
- Type III (Fast drift rate)
- Type IV burst
- Type V burst

CALLISTO refers to "Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory" which is created to collect the data of solar frequency bursts. CALLISTO is a programmable heterodyne receiver built in the framework of IHY2007 and ISWI (International Space Weather Initiative) by former Radio and Plasma Physics Group at ETH Zurich, Switzerland. The frequency coverage of this spectrometer is between 45 and 870 MHz with a frequency resolution of 62.5 kHz. The detector sensitivity is about 25 mV/dB, which covers the dynamic range of 50 dB. The maximum sampling rate with an internal clock of 800 S/s over 200 channels, while the integration time is about 1 ms [8]. Those instruments which are situated around the world interconnected each other and made into a network system called e-CALLISTO. All the observations of all the stations are uploaded to the e CALISTO network system every 15 minutes.

1.2.4 Solar bursts observation center at Arthur C. Clarke Institute for Modern technologies

Figure 8 : CALLISTO antenna setup at ACCIMT [27]

In ACCIMT, the CALLISTO is established as an observatory center in Sri Lanka. The location of the CALLISTO system is $6^{o}\ 47'\ 37''$ N, $79^{o}\ 53'\ 53''$ E at an altitude of 40 m and the time zone is +5.30 from UT. The type of the antenna is LPDA which refers to Log Periodic Dipole Array antenna. It is completely designed and constructed by the ACCIMT locally. Its design constant is (t) 0.822 and the relative spacing (s) 0.149 give 7 dB theoretical gain for the log – periodic antenna and it covers the frequency range of 45 – 870 MHz with 18 dipoles. Theoretically the impedance would be 58.3 Ω in the antenna which is agreed with the impedance measured in the entire frequency range. The total

height of the antenna is 5.38 m, and the longest dipole is 3.33 m. The linear polarized antenna is pointing to zenith and the dipoles directed to north-south direction. This is applicable for observation of solar radio bursts and Radio Frequency Interface (RFI) – monitoring for astronomical science, education, and outreach [9]

1.2.5 Designing of the CALLISTO antenna

As mentioned earlier the antenna design of the CALLISTO is LPDA, Log Periodic Dipole Array. In this project the main target is to create a three-dimensional design of the antenna and calculate its physical and theoretical parameters and analyze them. The software, 4NEC2 is specially designed to create and design different types of antenna designs with their actual parameters and analyze them.

1.2.6 Log Periodic Dipole Array

This LPDA is mostly known as log periodic diploe array or log periodic aerial, is a multi-element, directional antenna which is designed to operate over a wide range of or a wide band of frequencies. It was invented by "John Dunlavy" in 1952. LPDA is a one category of LP arrays (Log Periodic). This is the most common form of LP arrays. This LPDA consists of number of half wave dipole driven elements of gradually increasing length, each consisting of pair of metal rods. Depending upon its design parameters LPDA could be operated over a range of frequencies which are having ratio of 2:1 or higher [10]. The dipoles are mounted close together in a line, connected in parallel to the feedline with alternating phase electrically, it simulates a series of two or three-element Yagi antennas connected together, each set tuned to a different frequency. These LPDA antennas are very similar to Yagi UDA antennas. Because both are having sort of dipole elements mounted in a line along a support boom. But the difference is LPDA deals with frequency band width. This LPDA antenna all elements in the system are not active on a single frequency of operation.

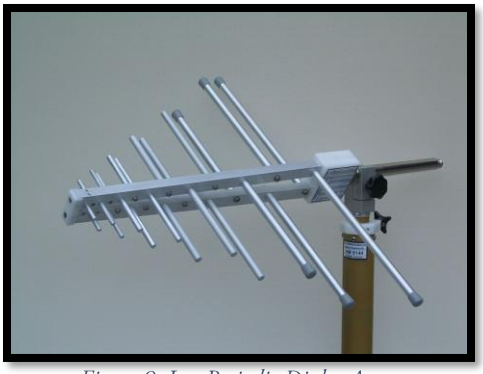


Figure 9: Log Periodic Diploe Array

1.2.7 4NEC2 Designing Software

4NEC2 is completely free open-source windows software or tool which is followed by Nec2 and Nec4 software used for creating, viewing, optimizing, and checking 2D and 3D styles of antenna geometry structures and generate, display, and compare near or far field radiation patterns for both of starting and experienced antenna modeler. It provides us a ton of valuable information as well as suggestions to improve our antenna design. Inside of the software we can call frequency sweeps, linear or logarithmic styles of V_{SWR}, gain, F/B ratio and impedance line charts with maximum user-friendly graphic interface. With the included Optimizer and Sweeper, one can optimize antenna- and/or other

environment-variables for Gain, resonance, SWR, efficiency and F/B, F/R-ratio. With the sweeper one can graphically display the effect of changing one or more of these variables for a specified range of values or frequencies. For the starting modeler a graphically based 3D geometry-editor is included which requires no additional NEC knowledge while still enabling you to create and visualize and compare current-distribution, far or near-field patterns and Gain and V_{SWR} charts. More experienced

modelers can use the gradient style and the genetic algorithm-based optimizers to improve their designs. [11]

Figure 10: 4NEC2 Software

1.3 INTRODUCTION TO THE PROJECT – TASK

As mentioned earlier the main task is designing the 3D model design to the CALLISTO antenna array for virtual simulations and further computational calculations. In the beginning the literature documents were there to be referred. As well as that the software manuals also had to be referred. After that some sample design should had been proposed before the actual design begins. The full tasks of the project can be narrowed down to following steps.

I) Literature and manual reference.
II) Sample design proposal.
III) Corrections for the sample design.
IV) Antenna design with actual dimensions.
V) Corrections for the design.
VI) Computer calculations and simulations.

CHAPTER II

2. CHAPTER II – LITRETURE REVIEW

2.1 SOLAR PHYSICS

As we all know "Physics" is behind all the events which are happening every single moment where we live. As well as events, the basic of all the things such as materials, energies etcetera could be taken as physics. When we simplify it, we can argue that all the subjects could be explained by physics theories or physics base ideas. Because of that physics plays a major role in all scientific world as well as our lives. The key point is all the things that happens every day could be explained by physics. Starting with that point, the introduction to "Solar Physics" can be started.

As mentioned earlier, Physics has a vastly speeded area in modern science. Because of that the subject could also be categorized into many fields. Classical physics, Modern physics, nuclear physics, atomic physics, Geophysics, Biophysics, Mechanics, Acoustics, Optics, Thermodynamics and Astrophysics are some branches of physics. In this report, Astrophysics is mainly being considered. If we consider a one branch of physics, there can be more and more interconnected properties inside those areas. As an example, if we consider Astrophysics; optics, computational physics, acoustics, etcetera are influenced in there. Because of that we cannot describe any of these area without help of another area.

"Solar Physics" is a branch of Astrophysics that mainly specialized in the study of the physics behind the SUN. It deals with detailed measurements that consist with sensitive information about our closest star. Solar physics is not only a simple part of astrophysics but also a complex combination of the areas of physics such as pure physics, computational physics, fluid dynamics, plasma physics, magneto hydrodynamics, seismology, partial physics, atomic physics, nuclear physics, stellar evolution, space physics, spectroscopy, radioactive transfer, applied optics, signal processing, image processing and solar astronomy as well.

When we consider solar activities, the climate and the periods of the activities could not be predictable at all. But those solar activities are the most significant events that take place in solar physics observations. Solar flares, Coronal mass ejections, High-speed solar wind and solar energetic particles are some of the solar activities that could be observed in solar physics. All solar activities are driven by the changes that occur in the solar magnetic field [7].

2.2 SOLAR FLARES

Solar flare is an observable activity in the atmosphere of the sun which was firstly and independently observed by R.C. Carrington and R. Hodgman in September 1859 in optical light. Solar flares are clearly associated with solar spots which have very high magnetic fields around 3000 Gauss [12]. Solar cycles could vary according to the number of sunspots along an 11-year cycle and sometimes according to the intensity of CMEs (Coronal Mass Ejections) which is the plasma particle propagation along with the magnetic field lines. As mentioned above a solar flare is an intensive variation of energy into the solar corona. The radiation energy of the sun is continuously being emitted with a huge band of wavelengths from radio to gamma rays. During a flare, an intense increase in the radiation level of the sun can be observed. It could happen around the sunspots and the radiation, and a huge amount of plasma particles accelerate in space along with the magnetic field lines like CME and solar wind etc. [13]

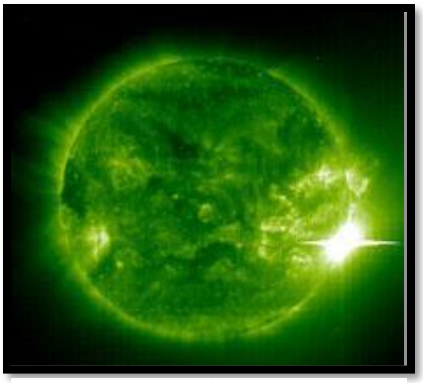


Figure 11 : Power full solar flare (4th of November 2003) by NASA

2.3 LOG PERIODIC DIPOLE ANTENNA ARRAYS

2.3.1 Broad Band Antenna

A broadband antenna can be identified as: "If the impendence and pattern of an antenna do not change significantly over about an octave or more, it will be classified as a broadband antenna". There are some types and examples for broad band antennas [14].

- Bow-tie antenna
- Spiral antenna: circularly polarized
- Log-periodic antenna: linearly polarized, but the direction of polarization depends on frequency
- Parabolic reflectors, its useful bandwidth restricted by bandwidth of its feed
- Helical antenna
- Fractal antennas

In this project log periodic dipole antenna will be examined.

2.3.2 LPDA antenna (Log-Periodic Dipole Array Antenna)

Log periodic is a broadband multi element, directional, narrow beam antenna that has impedance and radiation characteristics which are regularly repetitive as a logarithmic function of the excitation frequency. Furthermore, impedance and radiation characteristics are repeated periodically. Normally in practice, the variations over the frequency band of operation are minor, and log-periodic antennas are usually considered to be frequency-independent antennas [14].

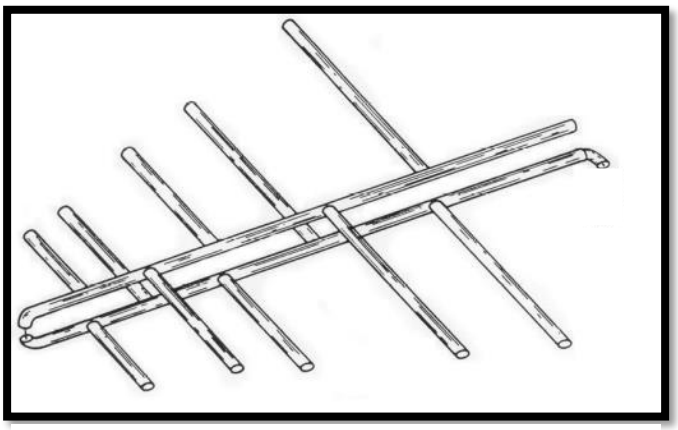


Figure 12 : LPDA Antenna

Log-periodic antennas are mainly used for detecting the high frequency band (HF 3-30MHz) of the spectrum. They are also used at very high frequency band (VHF 30-300MHz) and some of ultra-high frequency bands (UHF 300MHz-3GHz). Angle α is const. and the length and spacing of elements in a log-periodic antenna increase logarithmically from one end of the dipole to the other

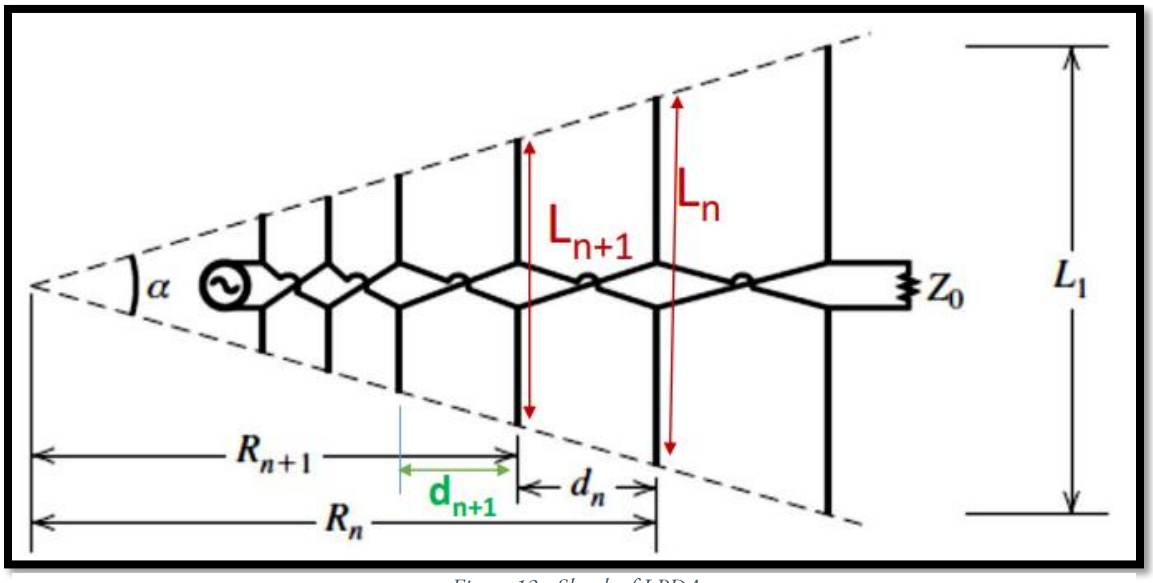


Figure 13 : Sketch of LPDA

A wedge of enclosed angle – α

Location from apex – R_n

The lengths – L_n

Space between two elements – d_n

The scale factor – τ

The spacing factor – σ

$$\tau = \frac{R_{n+1}}{R_n} = \frac{L_{n+1}}{L_n} = \frac{d_{n+1}}{d_n} < 1 \quad \text{..... (1)}$$

$$\tan\left(\frac{\alpha}{2}\right) = \frac{L_n/2}{R_n} = \frac{L_{n+1}/2}{R_{n+1}} \quad \text{..... (2)}$$

$$\sigma = \frac{d_n}{2L_n} \quad \text{..... (3)}$$

$$d_n = R_n - R_{n+1} \quad \text{..... (4)}$$

$$R_{n+1} = \tau R_n \quad \text{..... (5)}$$

From above equations, (1), (2), (3), (4), (5),

$$\sigma = \frac{d_n}{2L_n} = \frac{1-\tau}{4\tan(\alpha/2)}$$

or

$$\alpha = 2\tan^{-1}\left(\frac{1-\tau}{4\sigma}\right)$$

Above are some parametric calculations of LPDA antennas [14].

2.3.3 Gain(G), Directivity(D) and Total radiation power(P)

The **Directivity** of an antenna is a measurement of its ability to channel energy in a particular angular direction. When the directivity increases the ability increases. The directivity is defined using the concept of **radiation intensity** [15] [16].

$$D(\theta, \psi) = 4\pi\, U(\theta, \psi) / P_r \quad \text{..... (6)}$$

Where, D (θ, ψ) – Directivity

U (θ, ψ) – Radiation Intensity

$$G(\theta, \psi) = 4\pi\, U(\theta, \psi) / P_{in} \quad \text{..... (7)}$$

$$G = 4\pi\, \eta\, A/\lambda^2 \quad \text{..... (8)}$$

Where, G (θ, ψ) – Gain

η – Aperture Efficiency

A – Physical Aperture Area

λ – Wavelength [17]

$$\boldsymbol{P = \int_{\theta=0}^{\pi}\int_{\psi=0}^{2\pi} P_0(r,\theta,\psi) r^2 \sin\theta\, d\psi\, d\theta} \quad \text{..... (9)}$$

Where, P – Total Radiation power

2.4 DESIGNING ANTENNA WITH "4NEC2"

In this software the following can be taken as the main features that can be used for designing antennas.

- Graphical 2D and 3D visualization of Far- and Near-field data and Geometry structures (including circular polarization view).

- Line-chart visualization for frequency-sweep Gain, F/B, F/R, SWR and impedance data.
- Drag and drop style Geometry Editor to assist the starting antenna modeller.
- Full Nec2 and Nec4 command support, including GX, GM, GR, GA, GH and surface patches.
- Capable of running up to 11000 wires and/or segments (limited by the max of 2Gb of windows on-board memory)
- Support for inclusion of surface-wave component in far-field data.
- 3D geometry display for surface patches included.
- Variable substitution included for complete Nec2/4 command set enabling you to model by equation.
- Sophisticated real-time 3D geometry and pattern viewer showing real wire-radius.
- AO-style gradient/hill-climbing optimizer included.
- Genetic Algorithms based optimizer included.
- Automatic variable sweeper with line-chart output.
- Automatic convergence tester with line-chart output.
- Interactive Smith chart visualization for frequency-sweeps.
- Integrated Sommerfeld ground calculations with frequency-sweep.
- Automatic generation of VOACAP propagation prediction type 13 and –14 antenna files.
- Automatic conversion of AO (*.ant) and EZnec (*. ez) input files.
- 'Insulated-Wire' and 'LC-trap' loading-types included.
- Automatic conversion for feet, inch, #awg to meters and elevation/azimuth to phi/theta and reverse.
- Batch processing for automatic testing, calculation and/or conversion of multiple Nec, AO and/or EZnec input-files.
- Extensive segment- en geometry validation, such as: Intersecting volumes, Short/thick wires at sharp angle, Unequal segmentation for parallel wires, too low hight, large radius or length changes at junctions, etc.
- Screen grabber for easy cut/paste, print or save parts of the screen, window or form.
- Geometry builder to create cylindric, patch, plane, box, helix and parabola shaped structures using auto-segmentation and/or equal-area rules.
- Automatic generation of Stub-, L-, Pi- and Tee-matching-networks (low- and high-pass)
- Visualization of circular polarization components E(left) and E(right) for far-field.
- EZnec style MiniNec ground included.
- Capable of running the default Lawrence Livermore National Laboratories Nec4 engine.
- Running on all systems from early Windows-95 to latest Windows-Vista

Above information are taken from the official website[3].

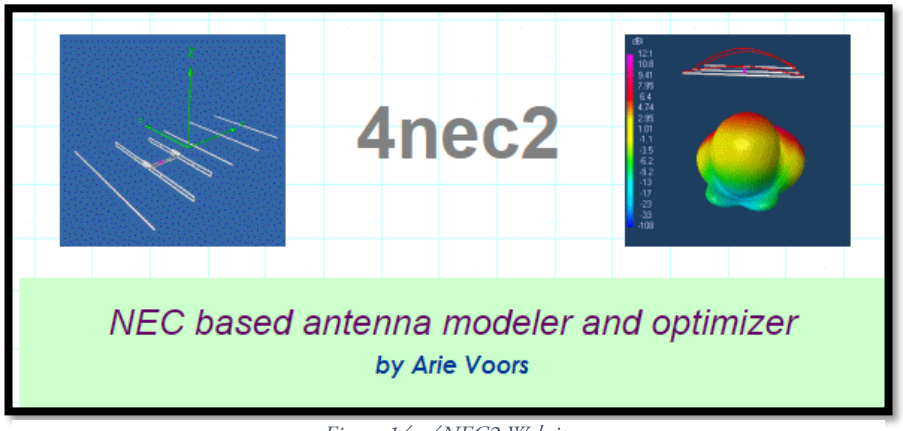


Figure 14 : 4NEC2 Website

[3] The 4NEC2 software details - https://www.qsl.net/4nec2/#:~:text=4nec2%20is%20a%20completely%20free,starting%20and%20experienced%20antenna%20modeler.

CHAPTER III

3. CHAPTER III – OBJECTIVES AND METHODOLOGY

3.1 OBJECTIVES

3.1.1 Main Objectives

- Identify the environment of the software, 4NEC2
- Design a sample for a log periodic dipole array antenna and run calculations
- Design the antenna with actual dimensions of the CALLISTO antenna and do the simulation calculations on that design with minimizing errors of the design

3.1.2 Secondary Objectives

- Study about solar observations
- Study about designing antenna arrays
- Study about fixing errors such as geometry and segment errors using 4NEC2 software
- Run frequency sweep tests
- Study about the SWR plots, gain plots etc. using the software

3.1.3 Academic Outcomes

- Gain knowledge about designing antennas and virtual simulations
- Improve communication skills and computer programming skills

3.2 METHODOLOGY

3.2.1 Software installation

4NEC2 is the main software that I used in this project as my designing tool. The installation of the software is not that much hard. In the beginning the official web page of 4NEC2 was loaded and familiar with the environment of the web page. On the web page except the "Home" option there are some other options available. 4NEC2 tutorials, Released notes and Known bugs were so much useful to study the environment of the software.

URL

https://www.qsl.net/4nec2/#:~:text=4nec2%20is%20a%20completely%20free,starting%20and%20experienced%20antenna%20modeler.

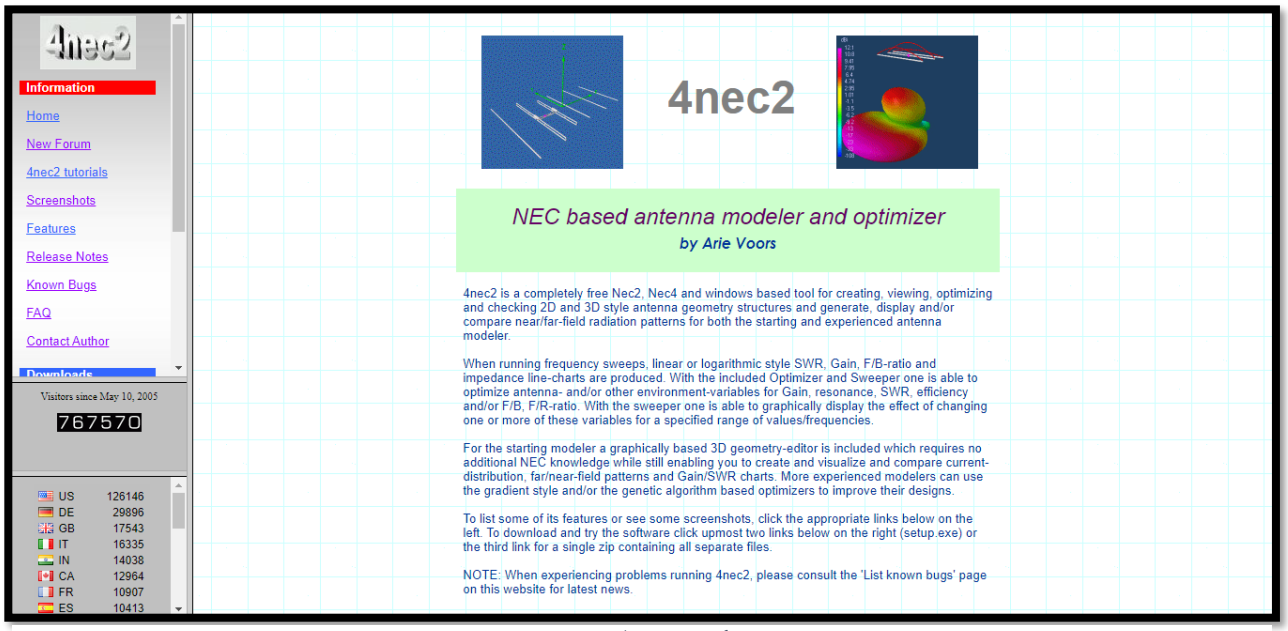


Figure 15 : 4NEC2 Web Page

This software is free of perches, and it is opensource software. The software was downloaded by clicking the download button in the page. The user manuals of the 4NEC2 were also downloaded from that page.

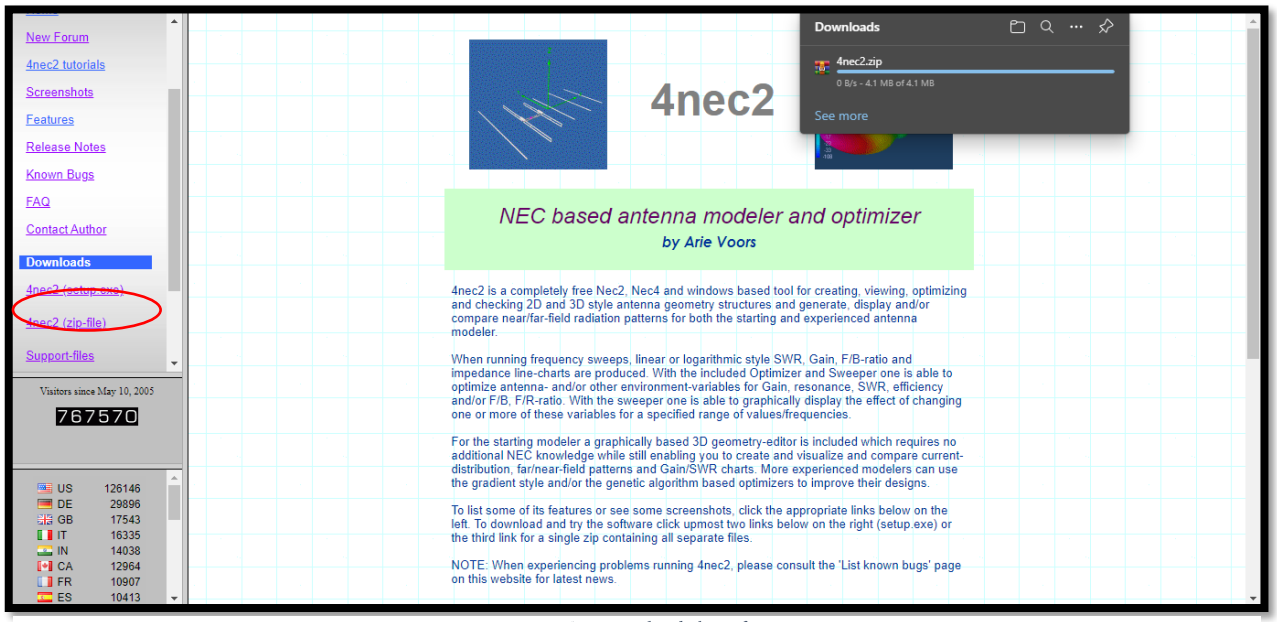


Figure 16 : Download the software

3.2.2 Environment Identification of 4NEC2

After the installation of the software, it was opened, and the GUI was simple to understand but the tools and functions were not familiar. After referring the user guide and some videos, the environment was got more familiar.

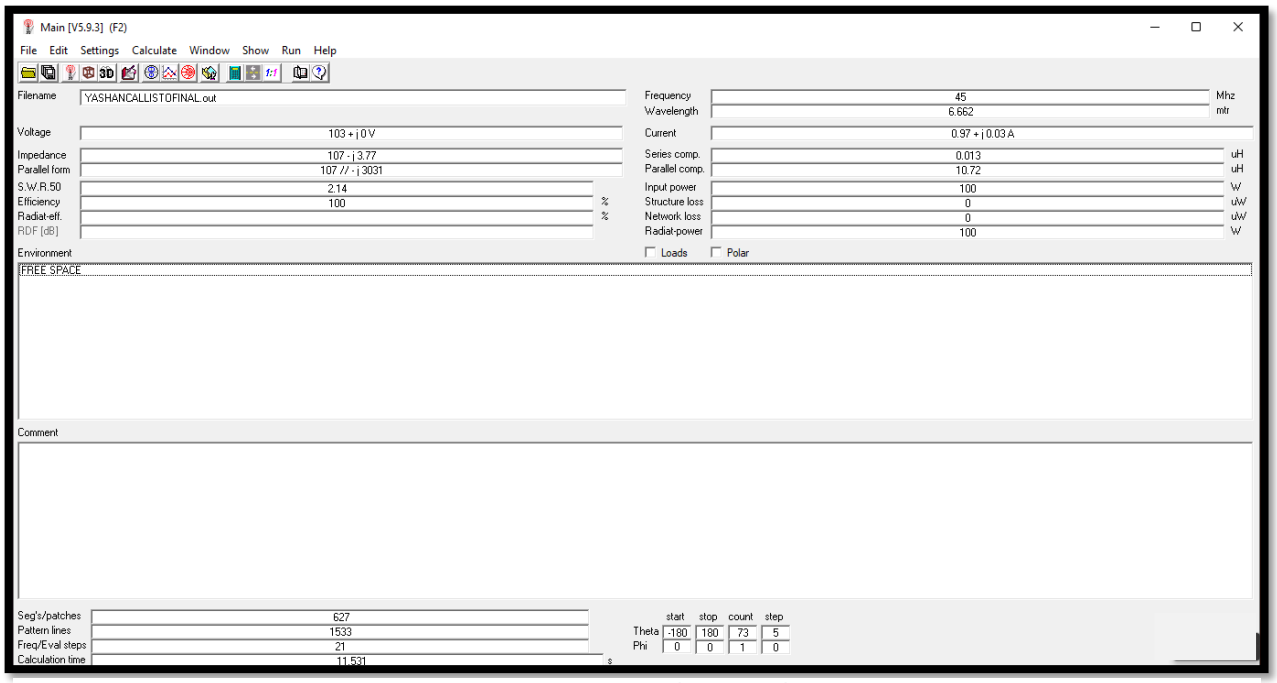


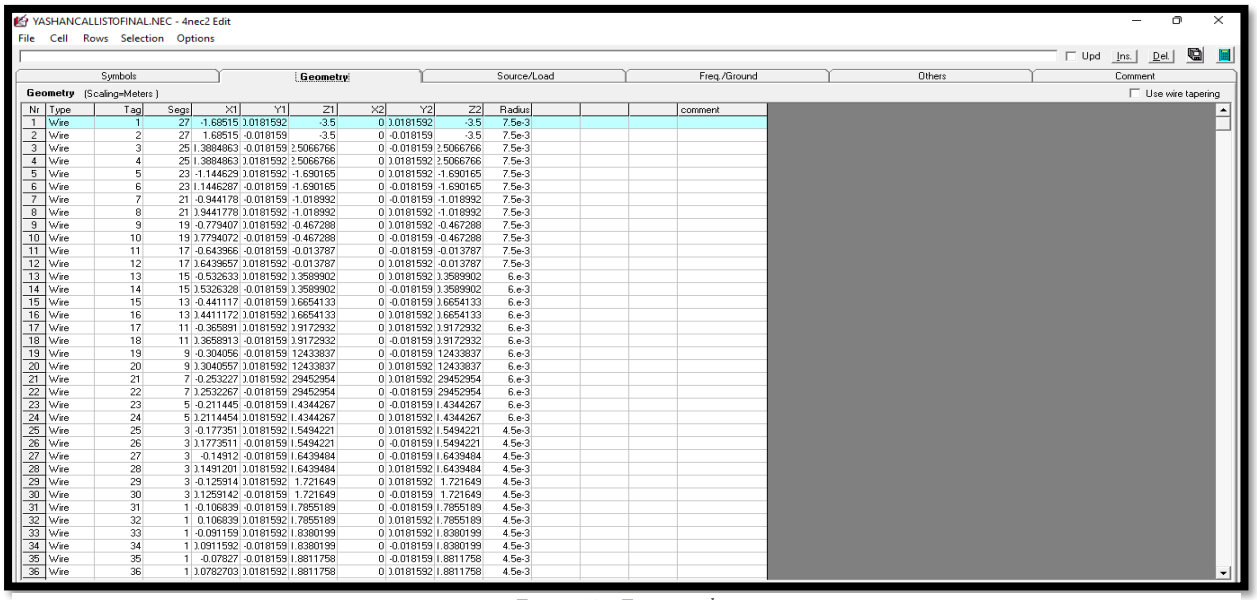
Figure 17 : 4NEC2 Software Interface

3.2.3 Entering data to the software

In the "Edit" bar on the top of the software, there is "input (.nec) file" option. From that we can define our material type, shape etc. before entering the dimensions of the antenna. In the "geometry" tab, those variables and parameters can be edited separately. Opening data editing mode can be done in follow steps.

"Settings → nec editor (new) and then edit → input (.nec) file"

In the beginning a simple dipole array was designed and plotted in the software. Then after the actual design was created with the real dimensions of the antenna.



Nr	Type	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius	comment
1	Wire	1	27	-1.68515	0.0181592	-3.5	0	0.0181592	-3.5	7.5e-3	
2	Wire	2	27	1.68515	-0.018159	-3.5	0	-0.018159	-3.5	7.5e-3	
3	Wire	3	25	1.3884863	-0.018159	2.5066766	0	-0.018159	2.5066766	7.5e-3	
4	Wire	4	25	1.3884863	0.0181592	2.5066766	0	0.0181592	2.5066766	7.5e-3	
5	Wire	5	23	-1.144629	0.0181592	-1.690165	0	0.0181592	-1.690165	7.5e-3	
6	Wire	6	23	1.1446287	-0.018159	-1.690165	0	-0.018159	-1.690165	7.5e-3	
7	Wire	7	21	-0.944178	-0.018159	-1.018992	0	-0.018159	-1.018992	7.5e-3	
8	Wire	8	21	0.9441778	0.0181592	-1.018992	0	0.0181592	-1.018992	7.5e-3	
9	Wire	9	19	-0.779407	0.0181592	-0.467288	0	0.0181592	-0.467288	7.5e-3	
10	Wire	10	19	0.7794072	-0.018159	-0.467288	0	-0.018159	-0.467288	7.5e-3	
11	Wire	11	17	-0.643966	-0.018159	-0.013787	0	-0.018159	-0.013787	7.5e-3	
12	Wire	12	17	0.6439657	0.0181592	-0.013787	0	0.0181592	-0.013787	7.5e-3	
13	Wire	13	15	-0.532633	0.0181592	0.3589902	0	0.0181592	0.3589902	6.e-3	
14	Wire	14	15	0.5326328	-0.018159	0.3589902	0	-0.018159	0.3589902	6.e-3	
15	Wire	15	13	-0.441117	-0.018159	0.6654133	0	-0.018159	0.6654133	6.e-3	
16	Wire	16	13	0.4411172	0.0181592	0.6654133	0	0.0181592	0.6654133	6.e-3	
17	Wire	17	11	-0.365891	0.0181592	0.9172932	0	0.0181592	0.9172932	6.e-3	
18	Wire	18	11	0.3658913	-0.018159	0.9172932	0	-0.018159	0.9172932	6.e-3	
19	Wire	19	9	-0.304056	-0.018159	1.2433837	0	-0.018159	1.2433837	6.e-3	
20	Wire	20	9	0.3040557	0.0181592	1.2433837	0	0.0181592	1.2433837	6.e-3	
21	Wire	21	7	-0.253227	0.0181592	1.5452954	0	0.0181592	1.5452954	6.e-3	
22	Wire	22	7	0.2532267	-0.018159	1.5452954	0	-0.018159	1.5452954	6.e-3	
23	Wire	23	5	-0.211445	-0.018159	1.4344267	0	-0.018159	1.4344267	6.e-3	
24	Wire	24	5	0.2114454	0.0181592	1.4344267	0	0.0181592	1.4344267	6.e-3	
25	Wire	25	3	-0.177351	0.0181592	1.5494221	0	0.0181592	1.5494221	4.5e-3	
26	Wire	26	3	0.1773511	-0.018159	1.5494221	0	-0.018159	1.5494221	4.5e-3	
27	Wire	27	3	-0.14912	-0.018159	1.6439484	0	-0.018159	1.6439484	4.5e-3	
28	Wire	28	3	0.1491201	0.0181592	1.6439484	0	0.0181592	1.6439484	4.5e-3	
29	Wire	29	3	-0.125914	0.0181592	1.721649	0	0.0181592	1.721649	4.5e-3	
30	Wire	30	3	0.1259142	-0.018159	1.721649	0	-0.018159	1.721649	4.5e-3	
31	Wire	31	1	-0.106839	-0.018159	1.7855189	0	-0.018159	1.7855189	4.5e-3	
32	Wire	32	1	0.106839	0.0181592	1.7855189	0	0.0181592	1.7855189	4.5e-3	
33	Wire	33	1	-0.091159	0.0181592	1.8380199	0	0.0181592	1.8380199	4.5e-3	
34	Wire	34	1	0.0911592	-0.018159	1.8380199	0	-0.018159	1.8380199	4.5e-3	
35	Wire	35	1	-0.07827	-0.018159	1.8811758	0	-0.018159	1.8811758	4.5e-3	
36	Wire	36	1	0.0782703	0.0181592	1.8811758	0	0.0181592	1.8811758	4.5e-3	

Figure 18 : Entering data

When entering the data as mentioned in the figure 19, there was a special way to enter them. The data sheet was written for three-dimensional design. Because of that the starting and ending points of the "X, Y and Z" coordinates should be given in the data sheet.

Ex: - If we enter the first element which is a cylindrical waveguide and it is situated in X and Y plane only, we can enter the data as follows.

Type – Wire , Tag – 1 , Seg (Segments; this is not very much important parameter in the moment and a length of a segment of the element should be higher than the radius of the element) – 27 , X1 (starting point in the X axis) – (+12.5) , Y1 (starting point in the Y axis) – (+2.0) , Z1 (starting point in the Z axis) – (0) , X2 (end point in the X axis) – (0), Y2 (end point in the Y axis) – (+2.0), Z2 (end point in the Z axis) – (0), Radius (radius of the element in millimetres) – (10)

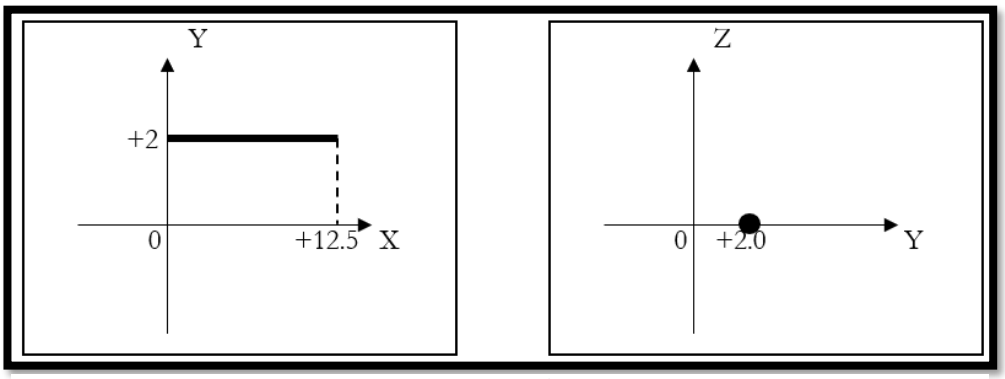


Figure 19 : Data coordinate System

In the software it has some other methods as well to design the antenna in 3D live editing mode in 3D array. In this project both methods were used because there were some elements which cannot be designed only by entering coordinates. They should be checked with the 3D mode. To switch from data coordinates mode to geometry editing mode follow steps were used.

"Settings → geometry edit" and then "edit → input (.nec) file"

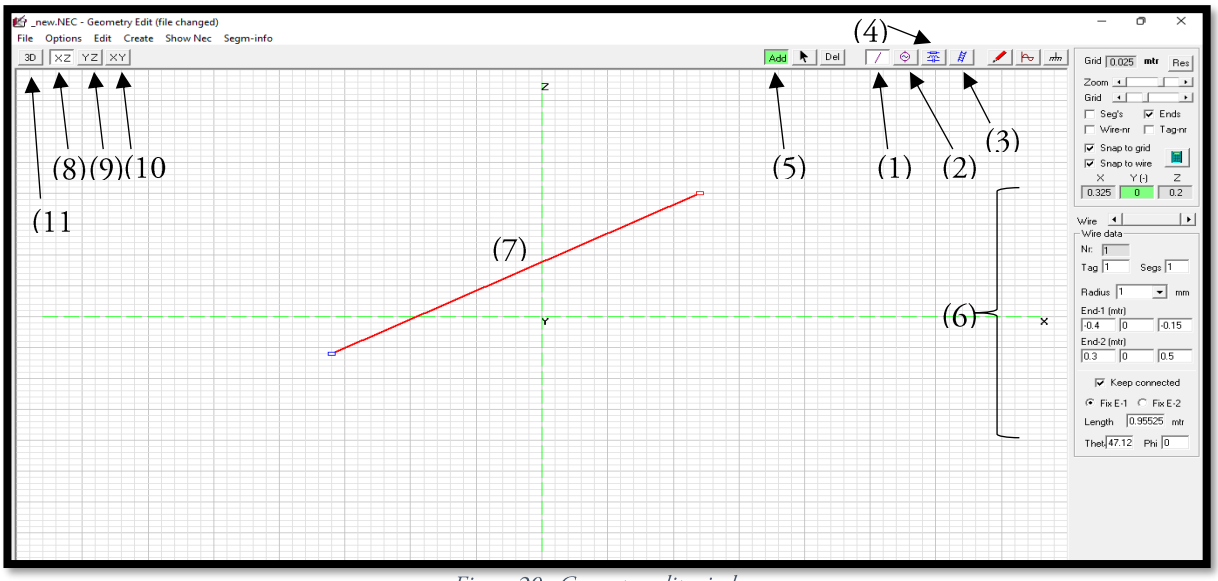


Figure 20 : Geometry edit window

Above figure shows how to use geometry edit window.

(1) The wire geometry – Select wire or element to draw. This tool is used to select the wire and after that we can draw that in the working space after select the add button.
(2) The V/I source – Select the voltage or Current source. When the antenna design needs a voltage or current input source this tool is used to create that.
(3) Transmission Line – Draw transmission lines. By using this tool, the transmission lines can be drawn in the design.
(4) LRC loads – By using this tool we can add resistive components, capacitive components, and inductive components in the forms of active and passive if necessary.
(5) Add – When clicking the "ADD" button simply we can add above element details into the working space.
(6) Minor correction panel – In this panel it has all the tools to correct minor errors that can be happen while drawing the design. X, Y and Z corrections, radius corrections, segment selections, wavelength selections etc. are there.
(7) Workspace – This is the space where we can draw the design. Above figure shows only the XZ plane. But we could switch that into XY, YZ planes or 3D mode.
(8) X-Z plane – By selecting this we can switch the plane to XZ plane.
(9) Y-Z plane – By selecting this we can switch the plane to YZ plane.
(10) X-Y plane – By selecting this we can switch the plane to XY plane.
(11) 3D plane mode – By selecting this tool we can switch 2D planes into 3D plane. After switching to this mode, the whole 3D design, or the model can be seen in the workspace.

After pressing F3 key, the geometry sample mode will be activated.

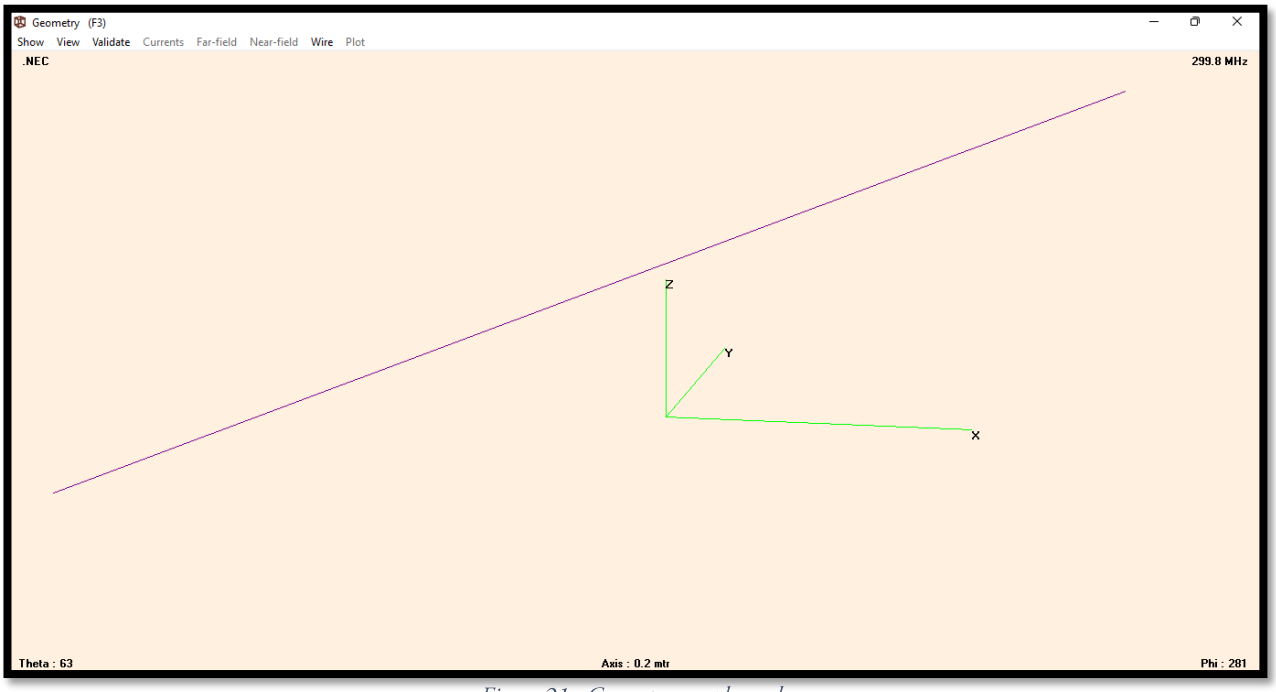


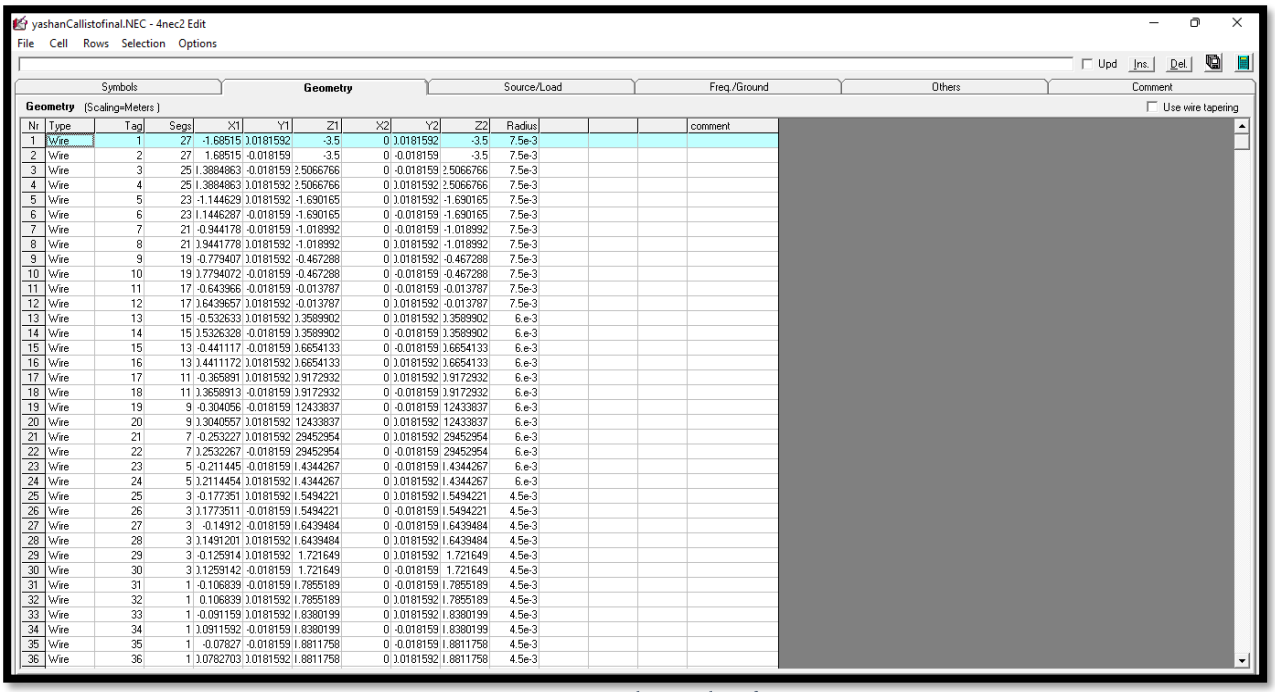
Figure 21 : Geometry sample mode

3.2.4 Designing the LPDA antenna design for CALLISTO antenna

According to above figure, described steps the LPDA antenna design was created. In the beginning the 18 elements were designed. When doing that, at first the longest elements were created. Then after the upper boom and the lower boom elements were separated after switching to the 3D mode. Then the radiuses of the elements were adjusted by referring the real dimension data sheet.

The data sheet: - The data sheet collected from the ACCIMT was customized according to the data that needed in the software. The customized data sheet will be appeared in the appendix section.

As mentioned in the bellow figure the CALLISTO antenna data were added to the data sheet of the software. When adding data to the sheet there were some errors in the data. They were also fixed by considering the segment error check.



Nr	Type	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius	comment
1	Wire	1	27	-1.68515	0.0181592	-3.5	0	0.0181592	-3.5	7.5e-3	
2	Wire	2	27	1.68515	-0.018159	-3.5	0	-0.018159	-3.5	7.5e-3	
3	Wire	3	25	1.3884863	-0.018159	2.5066766	0	-0.018159	2.5066766	7.5e-3	
4	Wire	4	25	1.3884863	0.0181592	2.5066766	0	0.0181592	2.5066766	7.5e-3	
5	Wire	5	23	-1.144629	0.0181592	-1.690165	0	0.0181592	-1.690165	7.5e-3	
6	Wire	6	23	1.1446287	-0.018159	-1.690165	0	-0.018159	-1.690165	7.5e-3	
7	Wire	7	21	-0.944178	-0.018159	-1.018992	0	-0.018159	-1.018992	7.5e-3	
8	Wire	8	21	0.9441778	0.0181592	-1.018992	0	0.0181592	-1.018992	7.5e-3	
9	Wire	9	19	-0.779407	0.0181592	-0.467288	0	0.0181592	-0.467288	7.5e-3	
10	Wire	10	19	0.7794072	-0.018159	-0.467288	0	-0.018159	-0.467288	7.5e-3	
11	Wire	11	17	-0.643966	-0.018159	-0.013787	0	-0.018159	-0.013787	7.5e-3	
12	Wire	12	17	0.6439657	0.0181592	-0.013787	0	0.0181592	-0.013787	7.5e-3	
13	Wire	13	15	-0.532633	0.0181592	0.3589902	0	0.0181592	0.3589902	6.e-3	
14	Wire	14	15	0.5326328	-0.018159	0.3589902	0	-0.018159	0.3589902	6.e-3	
15	Wire	15	13	-0.441117	-0.018159	0.6654133	0	-0.018159	0.6654133	6.e-3	
16	Wire	16	13	0.4411172	0.0181592	0.6654133	0	0.0181592	0.6654133	6.e-3	
17	Wire	17	11	-0.365891	0.0181592	0.9172932	0	0.0181592	0.9172932	6.e-3	
18	Wire	18	11	0.3658913	-0.018159	0.9172932	0	-0.018159	0.9172932	6.e-3	
19	Wire	19	9	-0.304056	-0.018159	1.2433837	0	-0.018159	1.2433837	6.e-3	
20	Wire	20	9	0.3040557	0.0181592	1.2433837	0	0.0181592	1.2433837	6.e-3	
21	Wire	21	7	-0.253227	0.0181592	1.5452954	0	0.0181592	1.5452954	6.e-3	
22	Wire	22	7	0.2532267	-0.018159	1.5452954	0	-0.018159	1.5452954	6.e-3	
23	Wire	23	5	-0.211445	-0.018159	1.4344267	0	-0.018159	1.4344267	6.e-3	
24	Wire	24	5	0.2114454	0.0181592	1.4344267	0	0.0181592	1.4344267	6.e-3	
25	Wire	25	3	-0.177351	0.0181592	1.5494221	0	0.0181592	1.5494221	4.5e-3	
26	Wire	26	3	0.1773511	-0.018159	1.5494221	0	-0.018159	1.5494221	4.5e-3	
27	Wire	27	3	-0.14912	-0.018159	1.6439484	0	-0.018159	1.6439484	4.5e-3	
28	Wire	28	3	0.1491201	0.0181592	1.6439484	0	0.0181592	1.6439484	4.5e-3	
29	Wire	29	3	-0.125914	0.0181592	1.721649	0	0.0181592	1.721649	4.5e-3	
30	Wire	30	3	0.1259142	-0.018159	1.721649	0	-0.018159	1.721649	4.5e-3	
31	Wire	31	1	-0.106839	-0.018159	1.7855189	0	-0.018159	1.7855189	4.5e-3	
32	Wire	32	1	0.106839	0.0181592	1.7855189	0	0.0181592	1.7855189	4.5e-3	
33	Wire	33	1	-0.091159	0.0181592	1.8380199	0	0.0181592	1.8380199	4.5e-3	
34	Wire	34	1	0.0911592	-0.018159	1.8380199	0	-0.018159	1.8380199	4.5e-3	
35	Wire	35	1	-0.07827	-0.018159	1.8811758	0	-0.018159	1.8811758	4.5e-3	
36	Wire	36	1	0.0782703	0.0181592	1.8811758	0	0.0181592	1.8811758	4.5e-3	

Figure 22 : Data sheet in the software

Design in XZ plane

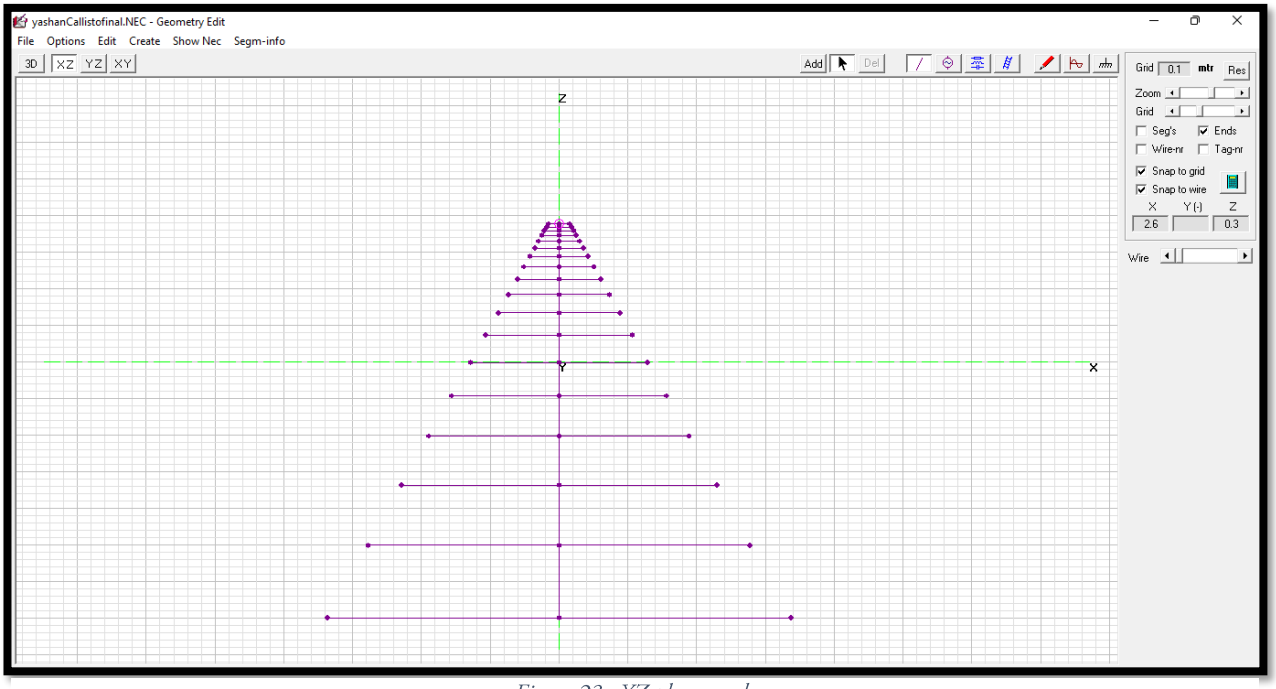


Figure 23 : XZ plane mode

Design in YZ plane

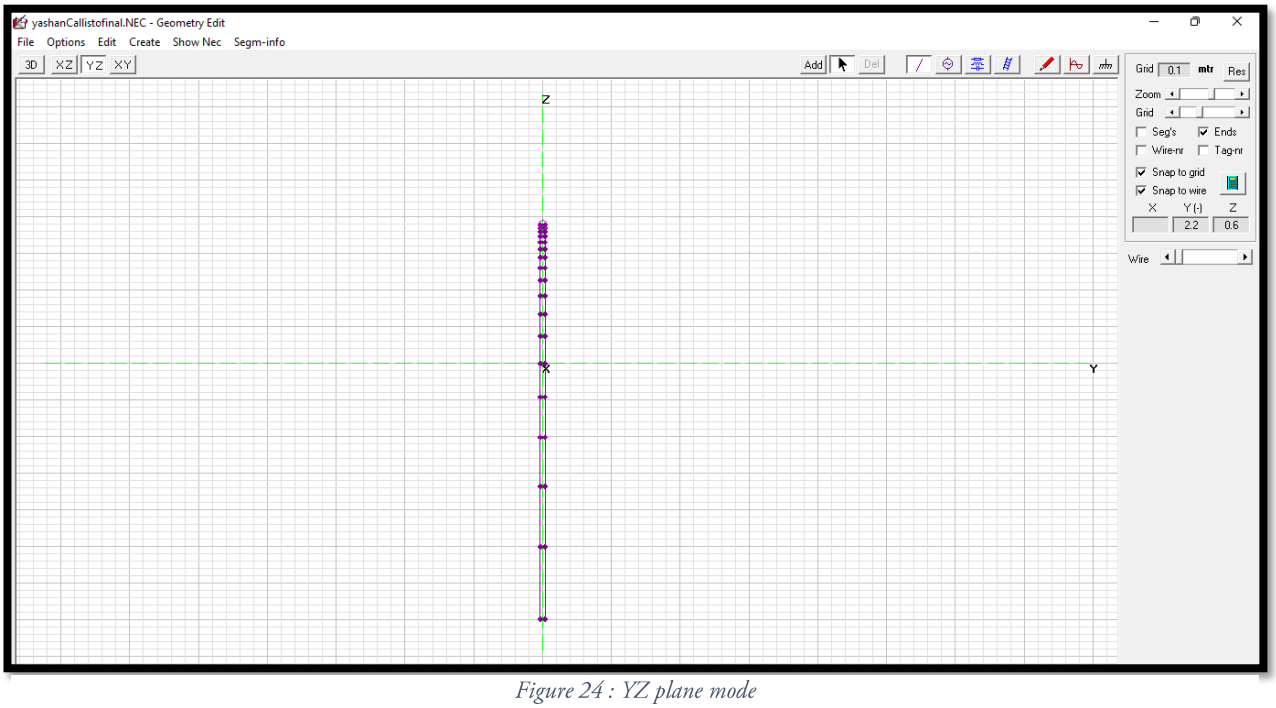


Figure 24 : YZ plane mode

Design in XY plane

Figure 25 : XY plane mode

Design in 3D mode

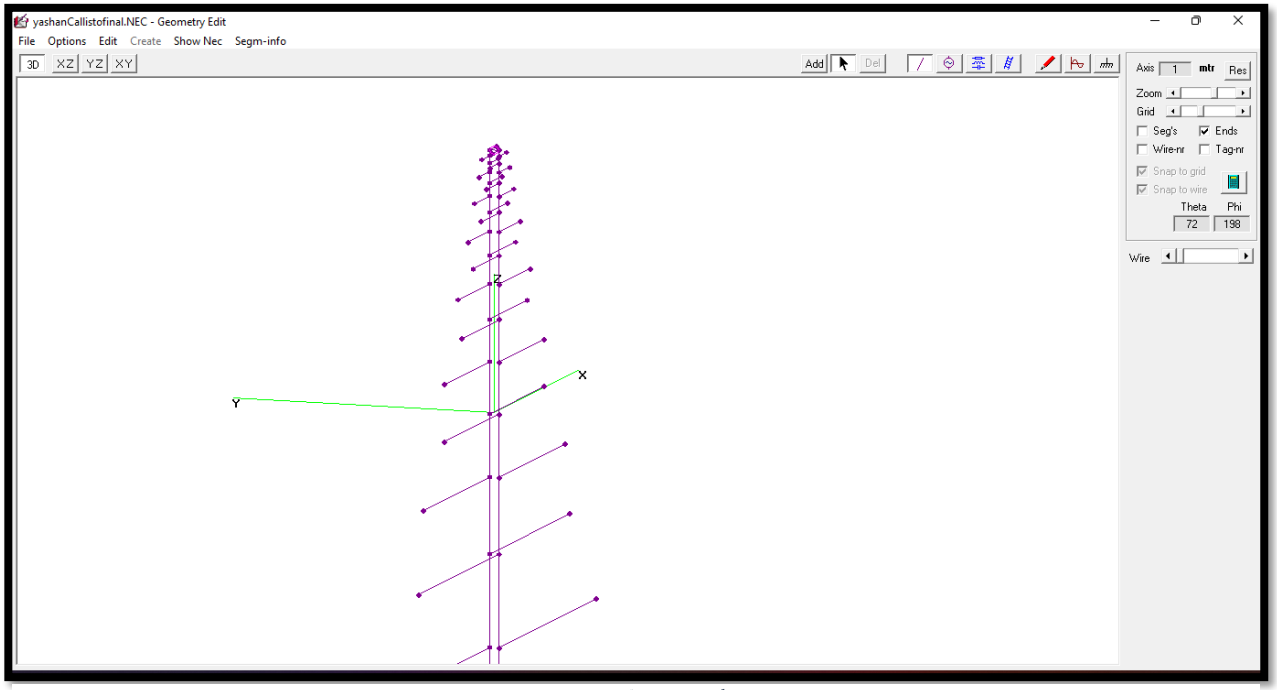


Figure 26 : 3D mode

After designing the LPDA array, some errors were checked by the tools of the software. And then they were fixed with the 3D design mode and minor adjusting panel of the workspace.

Figure 27 : Geometry window

There are two error checks that we must do after designing the antenna.

(1) Geometry check

Geometry Window → Validate → Run geometry check

(2) Segment check

Geometry Window → Validate → Run segment checks

After following above steps, the geometry errors and the segment errors can be found.

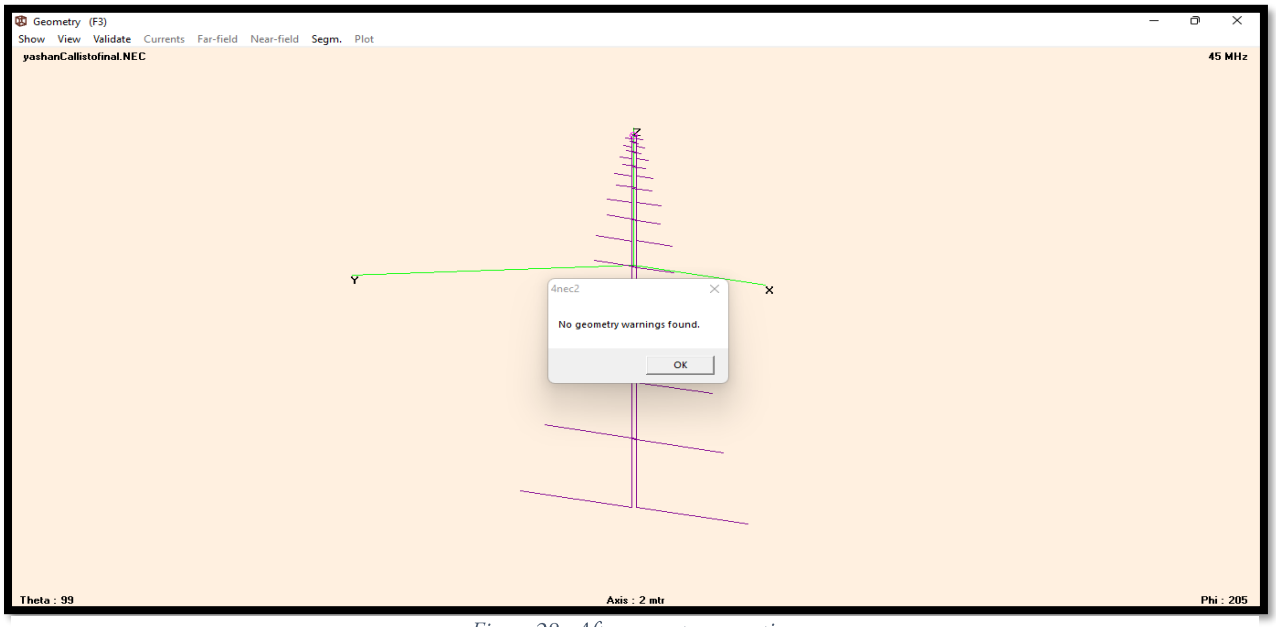


Figure 28 : After geometry corrections

Figure 29 : After segment corrections

After fixing those errors, the design is ready to the virtual calculations. In this project, frequency sweep calculations were done in 2D and 3D dimensions. To do those calculations follow steps were followed.

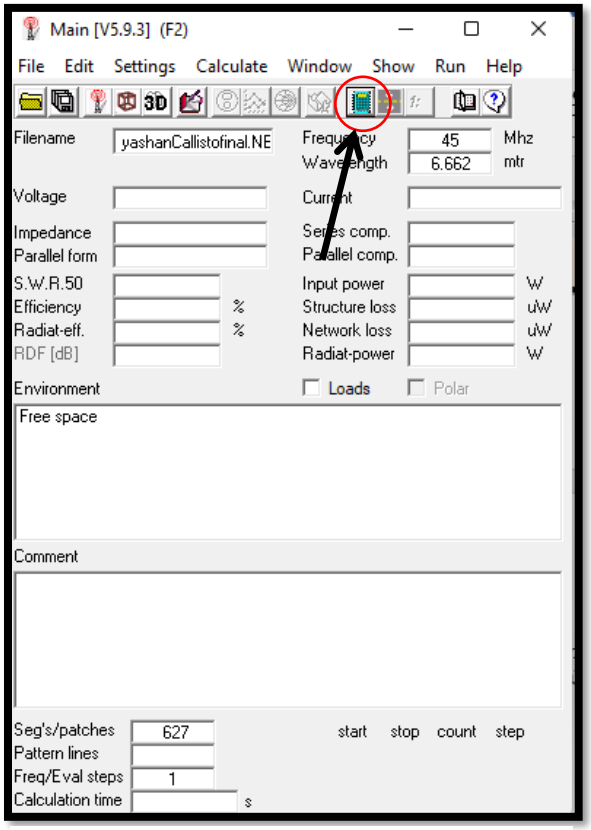


Figure 30 : Virtual Calculation

After clicking the calculator icon, follow steps were done.

Calculate new output → frequency sweep →

Figure 31 : Calculation in Frequency sweep

As above figure shows, the frequency sweep calculations were done in vertically and full/3D modes. Frequency range can be defined from 45 MHz to 1445 MHz with variable step size. After that The Generate button was clicked.

CHAPTER IV

4. CHAPTER IV – GANTT CHART

	21st June 2021 - 21st July 2021				21st July 2021 - 21st Aug 2021				21st Aug 2021 – 21st Sep 2021			
	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
T_1												
T_2												
T_3												
T_4												
T_5												
T_6												
T_7												
T_8												
T_9												
T_{10}												

T_1 – Literature study

T_2 – Software installation and study about the functions, tools and the environment of the software

T_3 – Study about 4NEC2 antenna designs

T_4 – Drawing sample designs

T_5 – Checking errors and fixing errors of the sample design

T_6 – Designing the CALLISTO antenna with actual dimensions

T_7 – Checking errors and fixing errors of the actual design

T_8 – Virtual calculations

T_9 – Results interpretation

T_{10} – Document finalization

CHAPTER V

5. CHAPTER V – RESULTS AND OBSERVATIONS

In this project, the virtual calculation was done to observe some main results as follows.

(1) To observe the design of the CALLISTO LPDA antenna
(2) Plot the SWR graph for the certain range of frequency
(3) Plot the Gain graph for the certain range of frequency
(4) Plot the Impedance graph for the certain range of frequency
(5) Plot total gain patterns:
    - Frequency wise
    - Falling angle of the EM wave to the antenna wise
(6) Plot 3D diagram of the radiation patterns with intensities of the radiation

5.1 DESIGN OF THE CALLISTO ANTENNA

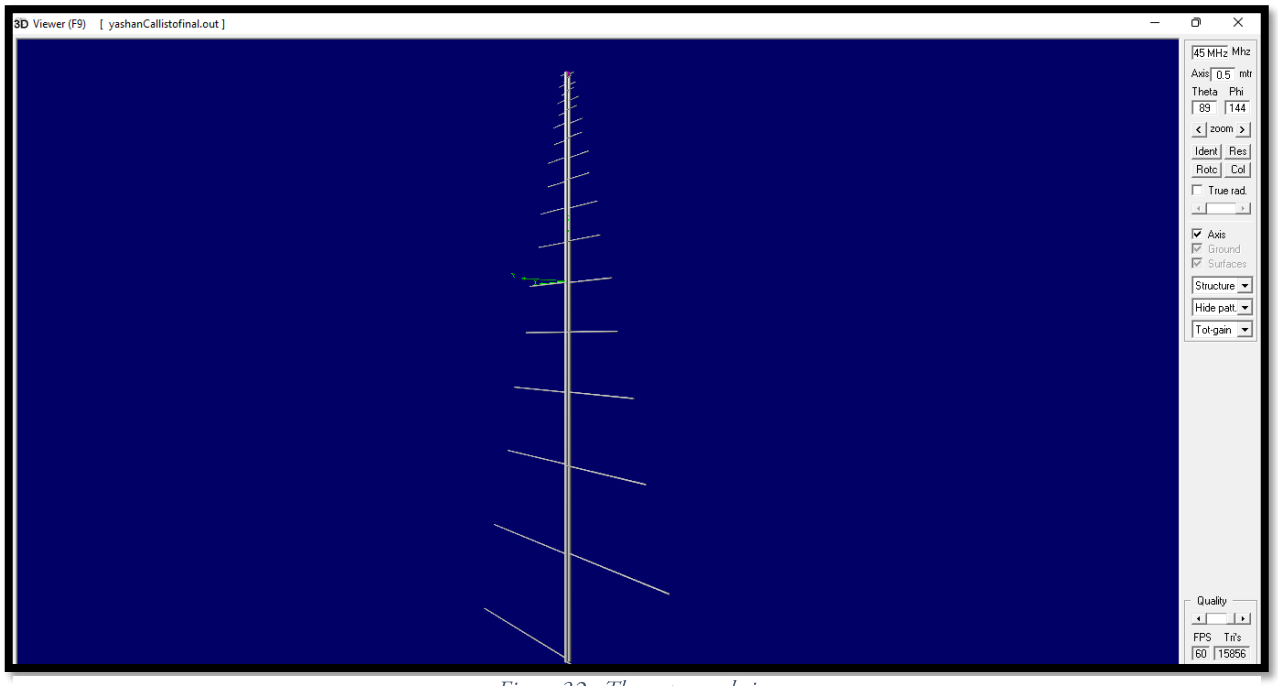


Figure 32 : The antenna design

5.2 SWR GRAPH

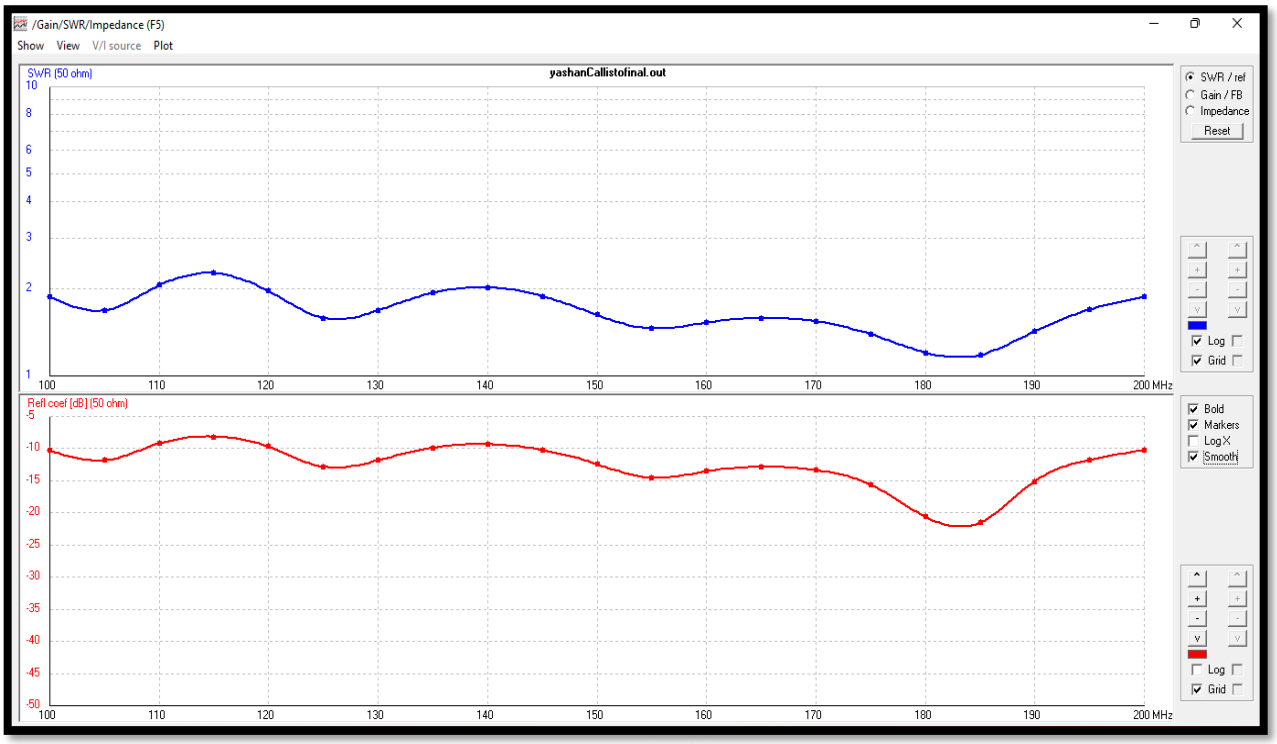


Figure 33 : SWR plot of the antenna

From considering above figure, we could state that the SWR curve is all most all below two. That means this antenna design can be acceptable for the use. As we can see in the figure there are some points that almost consider as near to lie on one even though the general consideration of the SWR curve in above figure is below two. In SWR analyzations the literature claims that a good waveguide or a transmitter must have the SWR value; 1. That is because the voltage ratio between the forward and the backward EM wave inside the waveguide should be 1 if that is a good waveguide. Standing wave ratio is a measure of impedance matching of loads to the characteristic impedance of a transmission line or waveguide. If this is a matched line the SWR plot should be almost all-around 1 [18]. If we consider the above graph, we can observe that the SWR curve almost all below two. But some points are not. In between 110 MHz and 120 MHz the SWR value is higher than 2. And, in 140 MHz the curve almost lies in 2. That means for those frequencies we cannot take the design as much good as the other frequencies. But if we consider the other frequencies in the plot, we could fair to say that the design is acceptable for use.

5.3 GAIN GRAPH

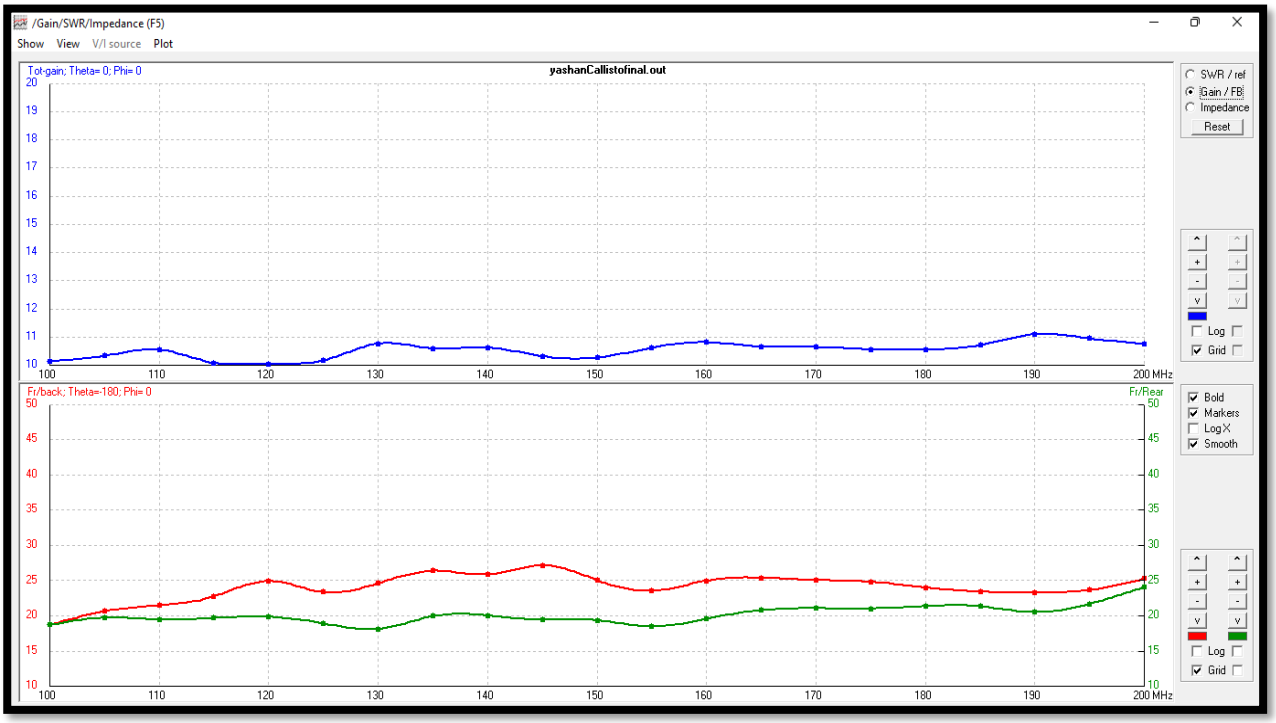


Figure 34 : Gain graph

From considering above gain graph we can state that the design has 10 dB or above total gain for almost all frequencies (100 MHz to 200 MHz). But for the frequencies between 115 MHz and 125 MHz the total gain is lie on 10 dB. As well as that region the total gain of the 150 MHz is also mostly near to 10 dB. Antenna gain indicates how strong a signal an antenna can send or receive (receive in this project) in a specified direction. Gain is calculated by comparing the measured power received by the antenna in a specific direction to the power received by a hypothetical ideal antenna in the same situation [19]. In here according to above graph we can state that the antenna design has almost 10 dB total gain which can be perfect because according to literature a real LPDA array will have total gain around 3 to 6 dB [20]. Which makes this design acceptable.

5.4 IMPEDANCE GRAPH

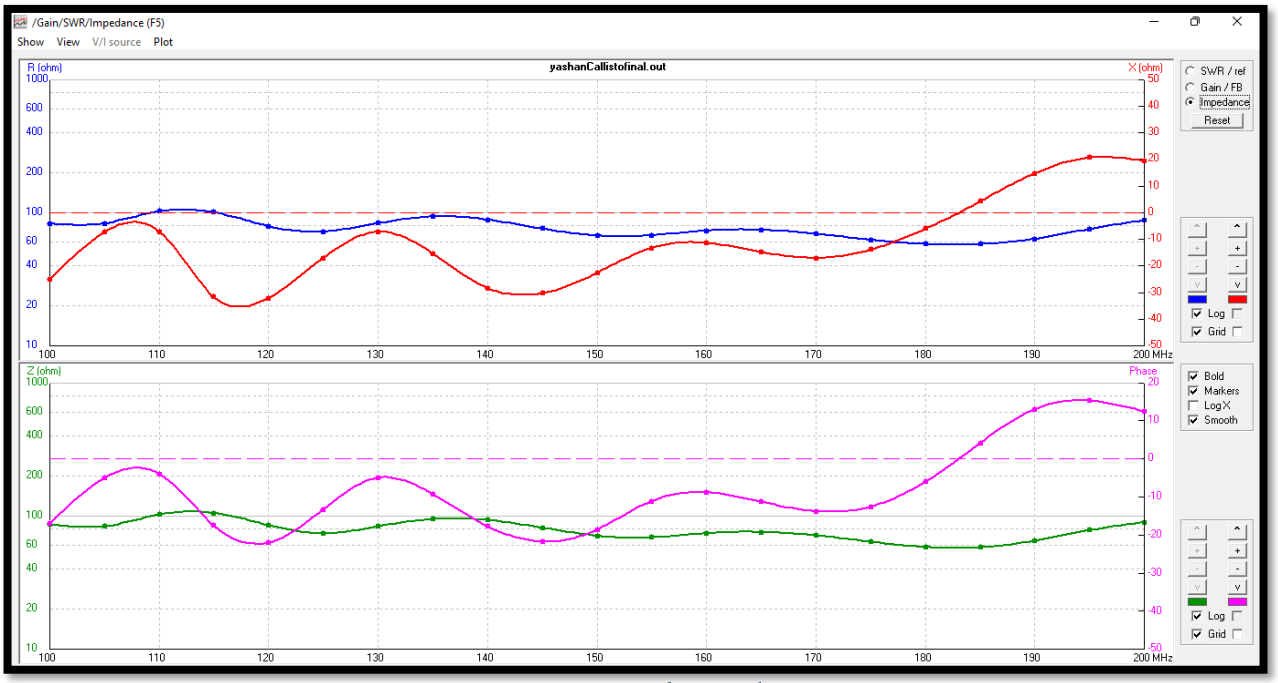


Figure 35 : Impedance graph

Impedance graph is also a valuable plot which this software provides automatically in the calculations and analyzation of the design. The literature claims that in a LPDA array when the number of dipoles increases the antenna almost provides uniform frequency range over the entire frequency range which the design is carry out [21]. This design was carried out for 18 dipole LPDA array. When we consider the above graph, the impedance can be mostly detected as uniformly distributed around 100 Ω which is the input impedance of the design. Even though for some frequency ranges like 120 MHz to 130 MHz and 170 MHz to 190 MHz, the impedance variates lower 100 Ω. But with the general consideration about the above graph leads us to state that the design is acceptable to use for the CALLISTO antenna system.

If we consider the "Red" colour curve in above graph, it shows the "Reactance" of the antenna. It is also a valuable plot which is given by the software. Literature claims that when the reactance of the antenna is below 0 or negative, the antenna is capacitive. And also log periodic antenna arrays are capacitive antennas [22]. By analyzing the reactance plot, we can state that except the reactance between 180 MHz and 200 MHz the rest is below 0 or negative. It means it is a capacitive type of antenna. And between 180 MHz and 200 MHz it is an inductive type of antenna. But generally, we can state that the design is suitable for use.

5.5 TOTAL GAIN PATTERNS

5.5.1 Frequency Wise

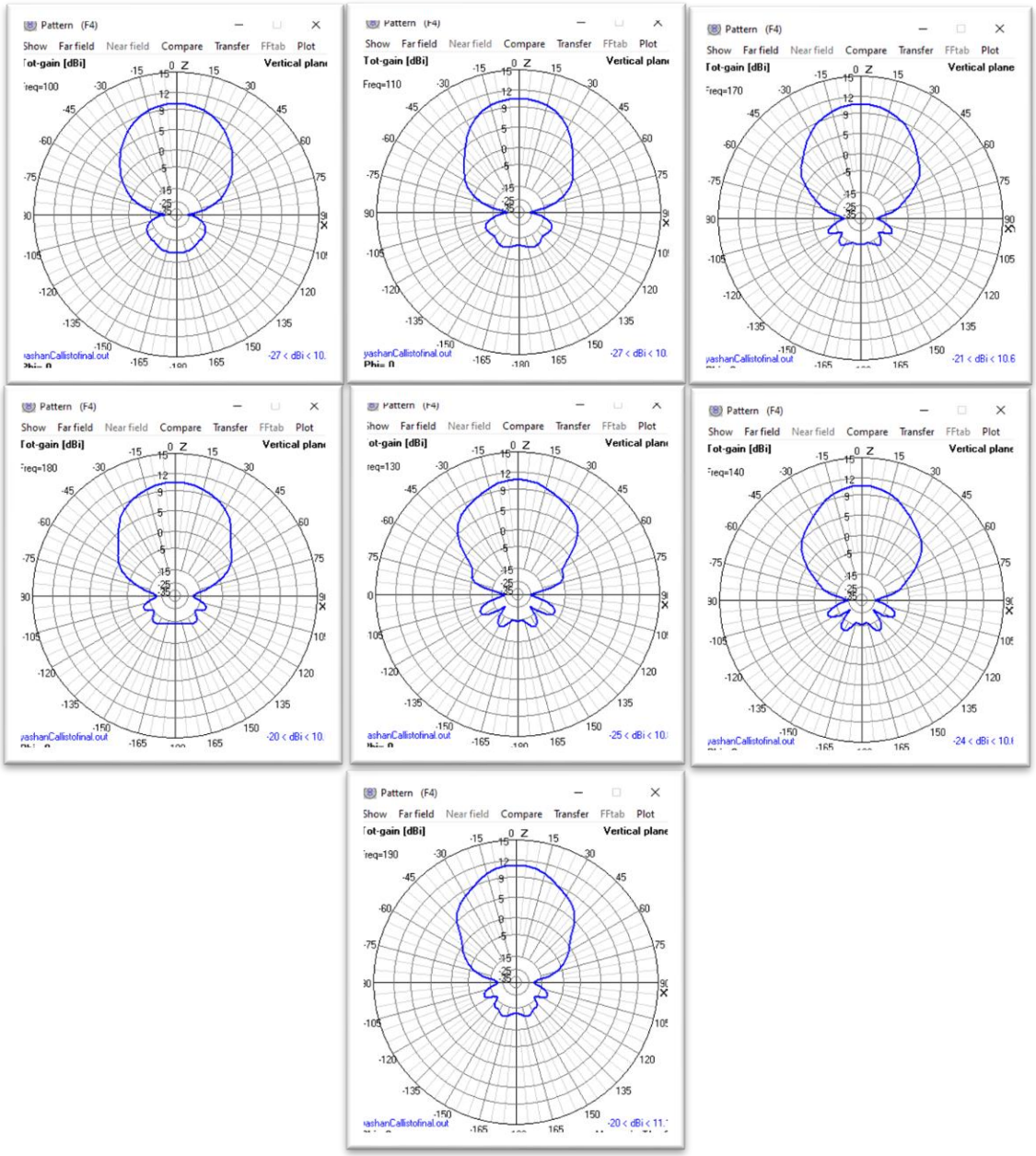


Figure 36 : Frequency wise radiation patterns

Figure 37 shows, how the total gain radiation pattern vary with the frequency. The radiation power is plotted in those figures are polar image plots. As discussed in the chapter II, 2.3.3 – equation (8) the total gain is dependent directly on the wavelength or frequency. That is why when the frequency changed the gain pattern changed. And the literature claims that the actual graphs also similar as above graphs [23].

5.5.2 Falling angle of the EM wave to the antenna wise

45 Degree

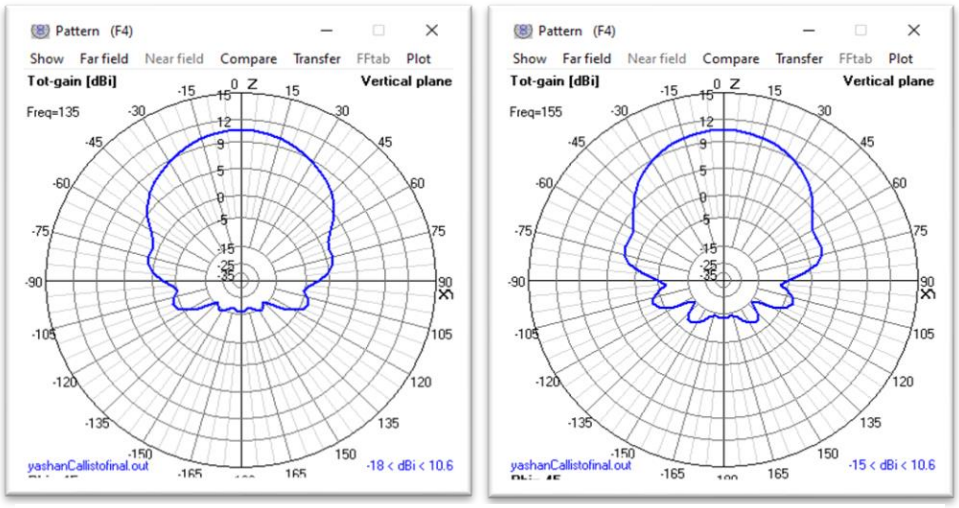


Figure 37 : Angle 45 Degree

90 Degree

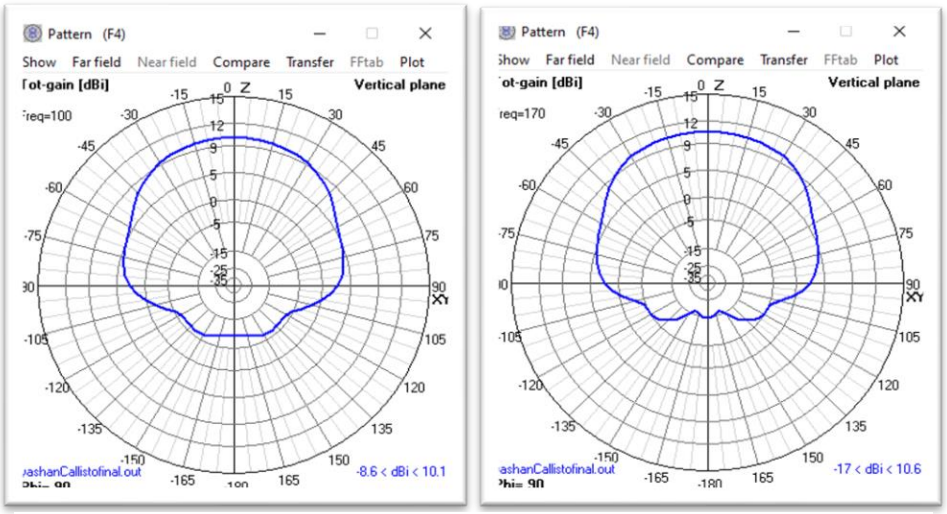


Figure 38 : Angle 90 Degree

Figures 38 and 39 show, how the total gain radiation pattern vary with the falling angle. The radiation power is plotted in those figures also are polar image plots. As discussed in the chapter II, 2.3.3 – equation (7) the total gain is dependent directly on the falling angle. That is why when the falling angle changed the gain pattern also change.

5.6 3D RADIATION PATTERN WITH INTENSITY

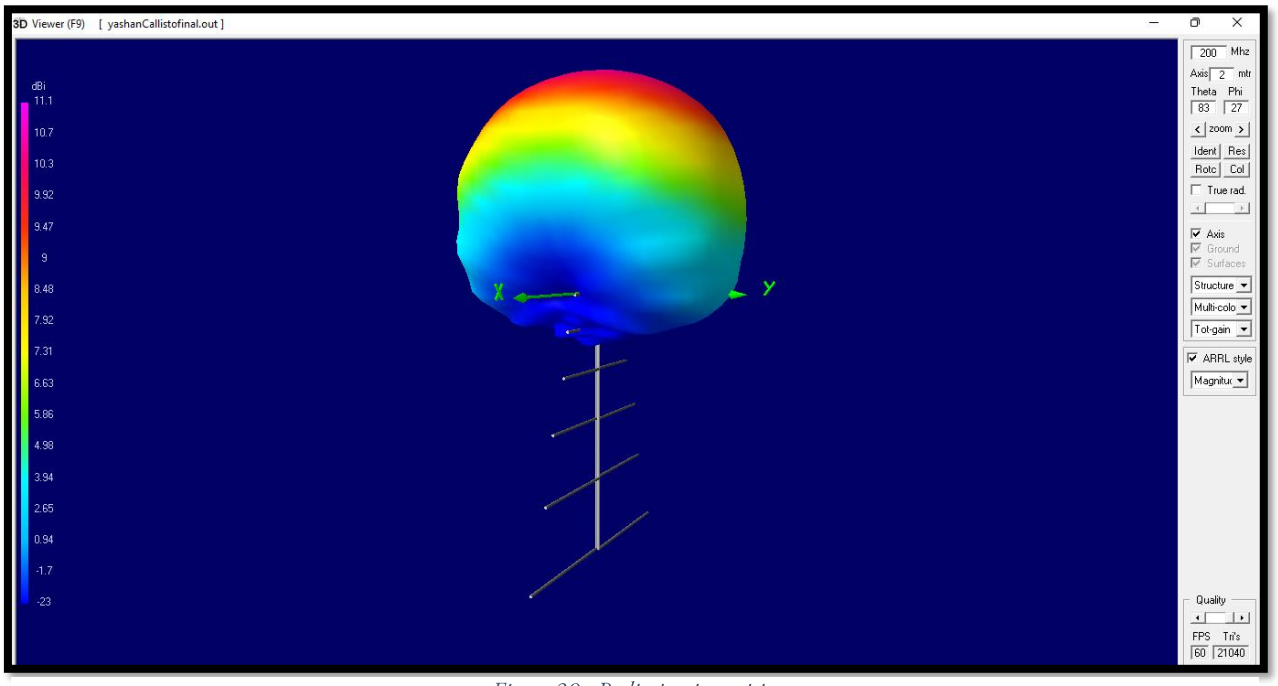


Figure 39 : Radiation intensities

CHAPTER VI

6. CHAPTER VI – DISCUSSION AND CONCLUSION

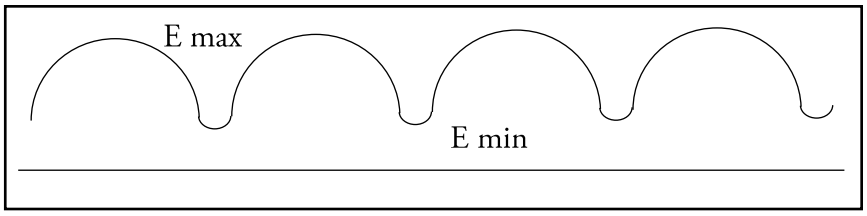
6.1 DISCUSSION

In the beginning of the project, it was too hard-to-find literature for designing with 4NEC2 software. Projects that are done with this software were rare to find. However, it was easy to download and install to my computer. When checking the requirements of the software, some positive features were found such as the software is required lower than 100 mb in the storage, it is required DirectX 9.0 or above, it can work with windows vista, XP, 7 home, 7 Ultimate, 8, 8.1, 10, 10 pro and windows 11. When examining the tools inside the software, some useful features were also found such as draw in 2D and 3D coordinate systems, automatically calculated SWR plot, gain plot and Impedance plot, display errors in the design, etc. There are very useful documentations in the official website of the software like user manual of the software and sample .nec files for practice.

After the installation process the environment of the 4NEC2 was studied. It was hard on some level because the user manual was not clear about using the software. But some useful videos were found on YouTube, and they were followed to understand the environment of the software. After the sample design was finished the geometry and segment checks were ran and there were lots of errors on that. In that time those error messages were not much clear but after referring the user manual the way of fixing them was found. After the corrections there were no error messages on either geometry or segment checks. When designing the CALLISTO antenna, entering data was not easy because the information should be inserted one by one manually from the data sheet. After entering the data to the software, the rest was easy to be done.

When consider the calculations of the design, there are very useful information that can be taken from the results of the calculations. The first one is the SWR graph. SWR refers to Standing Wave Ratio. Standing wave ratio is a measure of impedance matching of loads to the characteristic impedance of a transmission line or waveguide. In theoretically, a transmission line can be considered as good when its SWR is equal to 1 or vary around 1. But in practice if the SWR is vary below 2 in a waveguide or a transmission line can be taken as a good waveguide. Except SWR curve, the gain graph and the impedance graphs also can be obtained by the software. Considering the properties of the antenna, those graphs are very important.

Note:



When load is not equal to the characteristic impedance of the waveguide standing waves will result. E max is corresponding to the points where the incident and reflected waves add in phase and E min is corresponds to the points where the incident and reflected waves 180^0 out in phase.

$$SWR = \frac{E\ max}{E\ min} = \frac{\left(|\overrightarrow{E\ i}| + |\overrightarrow{E\ r}|\right)}{\left(|\overrightarrow{E\ i}| - |\overrightarrow{E\ r}|\right)}$$

When $\frac{|\overrightarrow{E\ r}|}{|\overrightarrow{E\ i}|} = \rho$

$$SWR = \frac{1 + \rho}{1 - \rho}$$

Not only that but also the software can generate radiation patterns in 2D as well as 3D. That graphs (figure 37 to 40) are very much important to understand the variations of the radiation pattern with the frequency. Also, the software provides the smith chart as well.

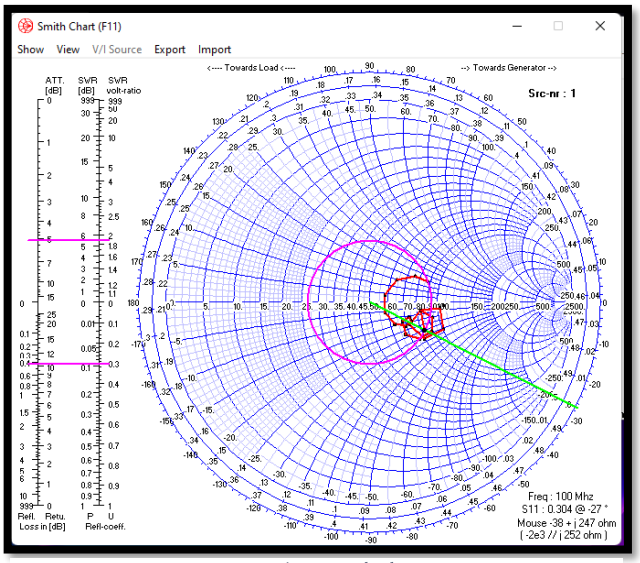


Figure 40 : Smith chart

Smith chart is also a valuable graph to collect information about the antenna design. From smith chart we can gather the SWR values as well. From the literature we can state that this smith chart is acceptable for our design [24].

6.1 CONCLUSION

4NEC2 is a very useful working environment for antenna designing purposes. Even though it is a free software, it can generate a very good virtual environment for antenna designs. The antenna design which was created in this project can be accepted because the SWR is below 2. By considering the figure 34, we can conclude that the antenna performs as very good transmission line or waveguide in the frequency range 170 MHz – 190MHz. When correcting the errors of the design, the error sheet generated by the software was very useful.

Ultimately, we can conclude that analyzing solar radio bursts are very important because they can directly cause some damages on the earth. Because of that CALLISTO antenna does major role in collecting data about solar radio bursts. Because of that it is very important to simulate the CALLISTO antenna virtually.

CHAPTER VII

7. FEED BACK AND SUMMARY

7.1 FEED BACK

The all 12 weeks that I spent as a trainee in the Arthur C. Clarke Institute for Modern Technologies (ACCIMT) I worked from home by connecting the astronomy department via internet platforms such as ZOOM and Google Meet. Even though it was a work from home internship, during the time I gained a lot of new knowledgeable facts and technologies within the 3-month period. I got some valuable experience with related to new technologies in designing and analyzing antenna virtually with some computer software. Collaborating with the astronomy department of ACCIMT was a huge and valuable opportunity to me because I was able to gain much more knowledge about theoretical and experimental information about CALLISTO antenna setup and Solar flares. The project was done with a software named as "4NEC2" and it was all strange program to me but at the end of the project I was able to collect much more knowledge about the software and how to design an antenna with it. Because of this project has less literature I was able to learn many things by myself. It helped me to improve my reading and comprehension skills as well. During this project some theories that had got learned in the university were much helpful to understand the basic phenomenon inside the project. As an example, SWR theory, Wave guide theory, Smith charts were used in this project, and they were learnt in the university courses.

During the internship period my industrial supervisor Dr. Janaka Adassuriya gave me a big support to success the project. His technical advice was very useful and valuable for my project. As well as that my internal supervisor Mr. C.H Manathunga also gave me a big support to success my project. From this project I was able to learn about interpreting the SWR values in experimental uses. During this time, I was able to improve some of my soft skills too. As an overall view I was very satisfied with my internship at ACCIMT even though it was a work from home internship. And I can recommend this institute for future undergraduates in physics specials degree course.

7.2 SUMMARY

CALLISTO is referring to "Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory" that is constructed to collect the data of solar frequency bursts or flares. The equipment that is used to collect data is a LPDA antenna. LPDA means Log Periodic Dipole Array antenna which is a category of Log Periodic Arrays. In this project 4NEC2 software was used to design the LPDA antenna of CALLISTO system to analyze its theoretical and physical quantities such as SWR and radiation pattens of the designed antenna.

In this project the design for CALLISTO antenna was created and virtually simulated and calculated the parameters of the design. SWR plots, gain plots, Impedance plots, radiation patterns over frequency etc. are generated. And they were interpreted as well. Ultimately the properties of the design were found using the 4NEC2 software.

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ANNEXES

	dipole L(i)	Length (m)	Length (cm)	half length (mm)	Half length With Boom (m)	Half length With Boom (mm)	R(i+1)-R(i) Spacing (m)	R(i+1)-R(i) Spacing (cm)	Boom Size (mm)	Accumulated (m)	A
2	L1	3.3333	333.33	1666.65	1.68515	1685.15	0.9933234	99.33234	37x25	0.9933234	
3	L2	2.7399726	273.99726	1369.9863	1.3884863	1388.4863	0.816511835	81.65118348	37x25	1.809835235	
4	L3	2.2522575	225.2257477	1126.128739	1.144628739	1144.628739	0.671172728	67.11727282	37x25	2.481007963	
5	L4	1.8513556	185.1355646	925.6778231	0.944177823	944.1778231	0.551703983	55.17039826	37x25	3.032711946	
6	L5	1.5218143	152.1814341	760.9071706	0.779407171	779.4071706	0.453500674	45.35006737	37x25	3.486212619	
7	L6	1.2509314	125.0931388	625.4656942	0.643965694	643.9656942	0.372777554	37.27775538	37x25	3.858990173	
8	L7	1.0282656	102.8265601	514.1328007	0.532632801	532.6328007	0.306423149	30.64231492	37x25	4.165413322	
9	L8	0.8452343	84.52343243	422.6171621	0.441117162	441.1171621	0.251879829	25.18798286	37x25	4.417293151	
10	L9	0.6947826	69.47826146	347.3913073	0.365891307	365.8913073	0.207045219	20.70452191	37x25	4.62433837	
11	L10	0.5711113	57.11113092	285.5556546	0.304055655	304.0556546	0.17019117	17.01911701	37x25	4.79452954	
12	L11	0.4694535	46.94534961	234.7267481	0.253226748	253.2267481	0.139897142	13.98971419	37x25	4.934426682	
13	L12	0.3858908	38.58907738	192.9453869	0.211445387	211.4453869	0.114995451	11.49954506	37x25	5.049422133	
14	L13	0.3172022	31.72022161	158.601108	0.177351108	177.351108	0.09452626	9.452626039	37x25	5.143948393	
15	L14	0.2607402	26.07402216	130.3701108	0.149120111	149.1201108	0.077700586	7.770058604	37x25	5.221648979	
16	L15	0.2143285	21.43284622	107.1642311	0.125914231	125.9142311	0.063869882	6.386988173	37x25	5.285518861	
17	L16	0.176178	17.61779959	88.08899795	0.106838998	106.838998	0.052501043	5.250104278	37x25	5.338019904	
18	L17	0.1448183	14.48183126	72.40915632	0.091159156	91.15915632	0.043155857	4.315585717	37x25	5.381175761	
19	L18	0.1190407	11.9040653	59.52032649	0.078270326	78.27032649	5.381175761	538.1175761		0	

Accumulated (cm)		Slimness Factor	Dim (m)	Dim (cm)	Frequency (MHz)
99.33234	993.3234	222.22	0.015	1.5	45.00045
180.9835235	1809.835235	182.66484	0.015	1.5	54.745073
248.1007963	2481.007963	150.1504985	0.015	1.5	66.5998455
303.2711946	3032.711946	123.4237098	0.015	1.5	81.02170985
348.6212619	3486.212619	101.4542894	0.015	1.5	98.56655699
385.8990173	3858.990173	83.3954259	0.015	1.5	119.9106533
416.5413322	4165.413322	85.68880011	0.012	1.2	145.8767072
441.7293151	4417.293151	70.43619369	0.012	1.2	177.4655805
462.433837	4624.33837	57.89855121	0.012	1.2	215.8948668
479.452954	4794.52954	47.5926091	0.012	1.2	262.6458233
493.4426682	4934.426682	39.12112468	0.012	1.2	319.5204663
504.9422133	5049.422133	32.15756449	0.012	1.2	388.7110296
514.3948393	5143.948393	35.24469068	0.009	0.9	472.8844642
522.1648979	5221.648979	28.97113574	0.009	0.9	575.2852363
528.5518861	5285.518861	23.81427358	0.009	0.9	699.8603847
533.8019904	5338.019904	19.57533288	0.009	0.9	851.4116603
538.1175761	5381.175761	16.09092363	0.009	0.9	1035.780609
		13.22673922	0.009	0.9	1260.073733
		74.06259459			