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SDR-based portable satellite tracking device

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ABSTRACT

SDR (Software Defined Radio) Based Portable Satellite Tracking Device (PSTD). It is a research-based project based on satellite tracking and thereby creating a network of satellite ground stations which is purely focused on observing and tracking of satellite signals. The deployed ground stations can either create a global network and can automatically schedule and accomplish a target satellite. The obtained data is hosted on a web server. When completed it becomes India's first active SDR Based Portable Satellite Tracking Device which provide the data to SATNOG community. The SDR Based Portable Satellite Tracking Device client area (which has a raspberry pi or Linux pc) and signal reception region which consist of commercial rotator or satellite DIY rotator which is used for controlling antennae rotation. The signal reception region consists of SDR region and signal amplification unit. The antennae may be stationary/omnidirectional and directional. The main advantages are it focuses on receiving LEO satellite signals, US's NOAA, the hardware, and software are open sources, SDR enabled RF front end for maximum flexibility, data from the deploying ground station are uploaded on cloud for easy access, web support for observation scheduling on ground station with LOS with the target.

Keywords: *SDR, SDR console, Satellite Tracking, Base station, Satellite Tracking Base Station, Tracking Device, Ground Station.*

1. INTRODUCTION

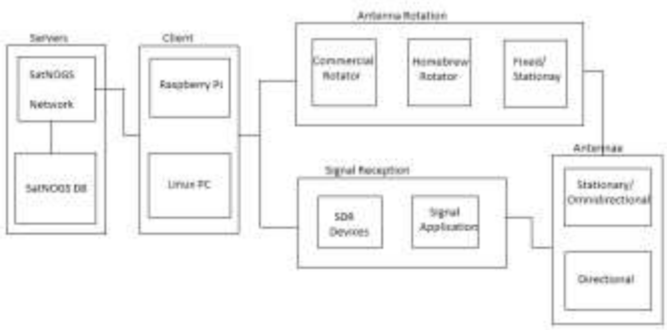
EARTH has a large number of satellites and in order to communicate with them ground stations are employed. Ground stations can communicate with the satellites directly above it. Satellite Systems can be grouped in view of their circles as low earth orbit(LEO), medium earth orbit(MEO) and geostationary earth orbit (GEO)systems. Low Earth Orbit reaches out from 200 km - 1200 km, implies that it is moderately low in elevation,. LEO satellites offer a few favorable circumstances over their geostationary earth circle (GEO).. Compared to a GEO,a LEO satellite has lower launch costs, reduced power requirements and a significantly reduced roundtrip transmission delay. The popularity of LEO satellites is increasing rapidly. Contrasted with a GEO,a LEO satellite has a lower launch costs, lessened power prerequisites and an altogether decreased roundtrip transmission delay. The ubiquity of LEO satellites is expanding quickly. The The advent of constellations, for example, Iridium (66 satellites), Teledesic (228 satellites), Skybridge (80 satellites), Globalstar (48 satellites),, National-Oceanic and Atmospheric Administration (NOAA) Satellites suggests that LEO constellations could become the basis of future two way wireless communications systems. This odds makes the tracking of LEO satellites a critical issue for the present ground stations.. As more satellites move quickly a single ground station take more time for communication. Thousands of satellites with hundreds of ground stations which are not coordinated create a complex communication issue, resulting reduced communication abilities. So the research-based project 'SDR Based Portable Satellite Tracking Device', promotes and supports free and open space applications. Here we try to solve the problem of connecting many satellite users/observers to many ground station operators in low cost manner with the help of open-sourced available data and with the help of SATNOG project Seclusion in every one of the frameworks advances the double utilization of ground stations by not meddling with neighborhood task while using the considerable measure of time a regular citizen, non-Commercial ground station would some way or another sit without moving.

The undertaking tries to construct a full pile of open advances for minimal effort satellite ground stations. Commercial satellite launches have been in a condition of progress as of late from the presentation of little space crafts which utilize institutionalized launch bearers, such as the CubeSat and PPOD (Poly-PicoSatellite Orbital Deployer) specifications.. This has lowered the bar to satellite ownership and their availability for educational and amateur projects and citizen science. Each satellite owner typically operates their own ground station for command and control. The low earth orbit of these shuttle result in brief time windows when the rocket is over the local horizon for communication. Accordingly, proprietors look to enroll the assistance of other reasonably prepared stations for accumulation of information. The FUN cube venture is a prime case of too sorted out push to get and gather information from satellite for instructive effort. Late advances in minimal effort SDR innovation and 3 dimensional printing have put ground station possession inside the span of people.

To a great extent made out of Amateur Radio administrators, these individuals get telemetry and information from numerous satellites and give the data to the proprietors and the overall population. Once an individual or association construct a ground station, particularly if not a business wander, the equipment winds up sitting inactive for an extraordinary greater part of the time. This ability, when not being effectively utilized by the nearby proprietor, could be used for the gathering of different satellites.

The SETI@home venture is one of the most punctual and surely understood activities to make utilization of sit still assets, figure cycles all things considered

2. THE SYSTEM



SDR Based Portable Satellite Tracking Device is a system of satellite ground stations concentrated on watching and getting satellite signs, especially low earth orbits (LEO) cubesats. The ground stations make a worldwide system that can consequently plan and achieve an objective satellite perception. The previously mentioned usefulness is accomplished through a group of very much characterized, totally open source applications. SatNOGS Database monitors all openly accessible cubesat-related data including RF correspondence frequencies, NORAD IDs and more. This data is used by SatNOGS Network, which enables online clients to schedule satellite pre-receptions utilizing the broadened system of ground stations far and wide. A commonplace ground station is contained three unmistakable segments: an agile rotator able to follow the requested satellite trajectory, the RF frontend which is an SDR device programmable through GNU Radio, and the SDR Based Portable Satellite Tracking Device Client. The latter is a web application capable of dictating the operation of the rotator as well as the GNU Radio module of the RF.

A. Helical Antenna

Characteristics

The parameters pertaining to the Helical Antenna used for the SDR based Portable Satellite Tracking Device are,

Frequency	435 MHz
Turns	8
Wavelength (Λ)	689 mm
Winding Diameter	219 mm
Winding Circumference	689 mm
Winding Spacing	172,3 mm
Winding Length	5683 mm
Reflector Diameter	689 mm
Boom Length	1.378 m
Gain	12 dBi

Materials

These are the materials used for the construction of the Axial mode Helical Antenna.

1 Pcs Aluminium (Square tubes profile 20x20mm)	1600mm
2 Pcs Aluminium (Symmetrical L profiles 15x15mm or 20x20mm)	680mm
2 Pcs Aluminium (Symmetrical L profiles 15x15mm or 20x20mm)	420mm
11 pcs Acrylic rods 8mm wide	140mm

1 pc at least of 70X70cm good quality grid mesh of 2mm with at 1in (25,4 mm) spaces.
22 Nylon nuts M8
1 N-Type connector
Copper wire 3mm approx. 6 m
Copper sheet 0.3 mm thick approx 20X10cm

Construction

The Aluminium pipe of square tube profile is the central boom. On it, holes were drilled as per shown Fig 4.2 on sides marked as A and B. The holes drilled on to it should need to be precise. Two Aluminium pipe of L profile is also drilled to place horizontally to the boom. One piece of a good quality mesh of circular shape is cut and made from the square-shaped material which is available in the market. It is done so with the help of a scissor-shaped large cutting tool. The other two L profile Aluminium is placed as a supporting beam for the mesh as seen in Fig 1

Figure 1 The circular mesh

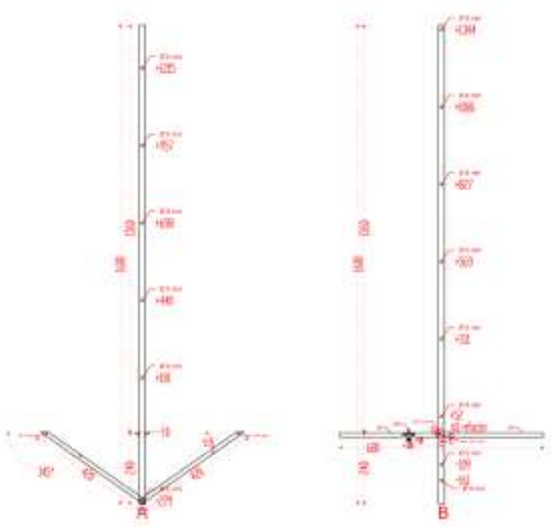


Figure 2 Drilling and cutting pattern for both side A and B

Regarding the copper wire which is to be twisted along the boom needs the winding diameter of 219 mm and 8 turns. For achieving this, assist of the wooden log is employed. It is of approximately 22mm in diameter and of considerable thickness for the winding of copper wire of length of 5683 mm into eight turns. It is tightly wound over it. The three-dimensional view of the Helical Antenna is shown below.

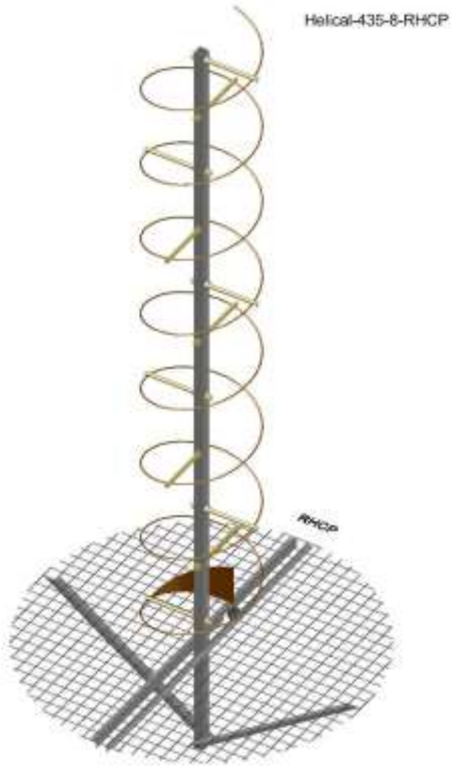


Figure 3 Three Dimensional views of the Helical Antenna

B. Yagi Antenna

The construction of the Yagi Antenna is simple and need not need any specialist tool or skill. For the SDR based Portable Satellite Tracking Device Yagi Antenna of 145MHz is built. The materials fetched for the Yagi Antenna are 2m Aluminium pipe of the square profile. Aluminum rods for Yagi antenna are placed accordingly as shown in the Fig

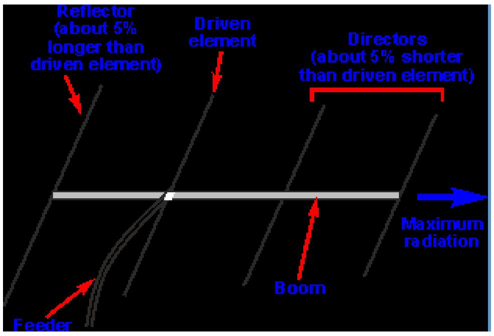


Figure 4 A model of Yagi Antenna

The main part of the Yagi Antenna design is a main radiating or driven element**.** Further 'parasitic' elements are added which are not directly connected to the driven element. Parasitic elements get control from the dipole and re-transmit it. The stage is in such a way, to the point that it influences the properties of the RF reception apparatus as a whole, making power be engaged one specific way and expelled from others. Along these lines, the flag is fortified in a few headings and offset in others. It is discovered that the sufficiency and period of the present that is prompted in the parasitic element is needy upon their length and the separating amongst them and the dipole or driven component. The components inside Yagi are, Driven element: The determined component is the Yagi receiving wire component to which control is connected.

The structure of Yagi explained,

- Driven element: It is a part of Yagi antenna element to which power is applied. It is normally a half wave dipole or a folded dipole.
- Reflector: The Yagi antenna will generally have one reflector. This is behind the main driven element, i.e. the side away from the direction of maximum sensitivity.

Further reflectors behind the first one add little to the performance. However many designs use reflectors consisting of a reflecting plate or a series of parallel metallic roads simulating a reflecting plate. This gives a good improvement in performance, by reducing the level of radiation or pick-up from behind the antenna, i.e. in the backward direction. Commonly a reflector will add up around 4 or 5 dB of gain the forward direction.

- Director: There might be none, one of more reflectors in the Yagi antenna. The directors are set before the driven component, that is in toward greatest affability or for maximum sensitivity. Normally every director will include around 1 dB of gain in the forward path, in spite of the fact that this level decreases as the quantity of directors increments

The antenna displays a directional example comprising a primary forward lobe and various misleading side projections called side lobes. The main one of these is the reverse lobe caused by radiation in the direction of the reflector. The antenna can be optimized to either reduce this or produce the maximum level of forwarding gain. Unfortunately, the two do not coincide exactly and a compromise on the performance has to be made depending upon the application.

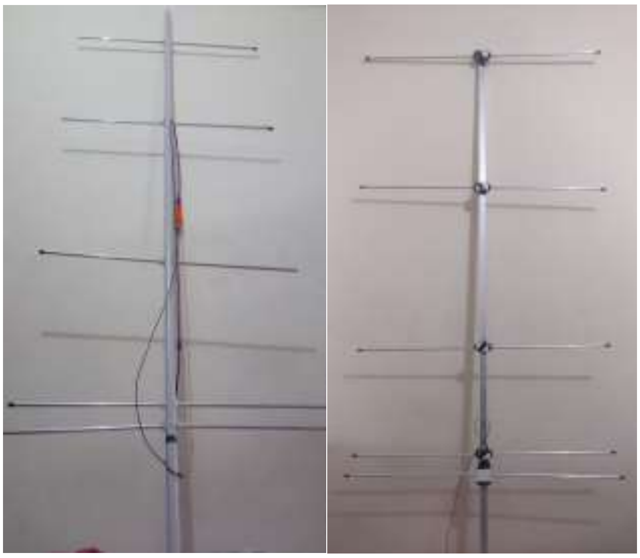


Figure 5 Yagi Antenna with PVC pipe as the boom and aluminum pipe of the square profile as boom respectively

C. 3D Printing

Figure 6 3D Printer

3D printing is also known as additive manufacturing. It was developed in the 1980's as a process used to make three-dimensional objects. The additive manufacturing creates parts from the ground up by fusing together layers of materials. For the project, PLA is used for the 3d printing of shown material in Fig 4.5 and Fig 4.6. PLA or Polylactic acid is a thermoplastic polyester. It is commonly derived from renewable resources, such as corn starch, tapioca roots or sugarcane. One of the most attractive things about PLA plastic is that it naturally degrades when exposed to the environment. For example, an item made of PLA plastic in the ocean has a degradation time on the order of six months to two years. Compare this to conventional plastics, which take from 500 to 1,000 years to degrade. It is important to point out that although PLA will degrade in an exposed natural environment it is very robust when used in any normal application such as a printed toy or a critical piece of a printer. In that respect, you can think of it as being similar to iron. If we were to expose it to continuous moisture or leave it outside, it would "rust" and become unusable in short order.

D. Rotor Assembly

The 3d printed elements are joined along with the ball bearing and screws of appropriate size and fit for the construction. The rotor is placed in a box made of an acrylic material of considerable dimension. The acrylic material is chosen so that the inside view of the arrangement and fitting can be visible clearly from outside.

Figure 7 The 3d printed materials

Figure 8 3D printed material side view

The Acrylic box is made out of a sheet of acrylic 6mm thickness using laser printing. After the components are arranged as given the rotor part is made to rotate with help of stepper motor. The stepper motor is made to rotate step by step with the simple program loaded to it via Arduino board

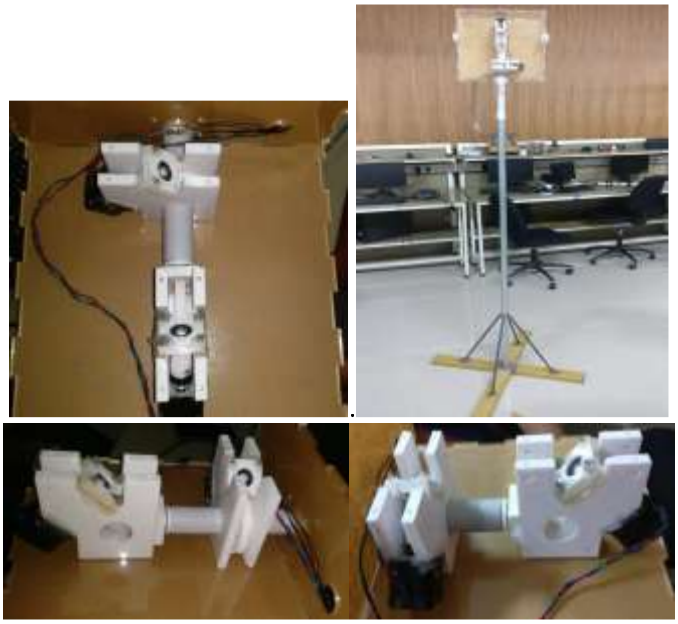


Figure 9 Rotor Setup in the Acrylic box

E. SDR Console

In order to receive a signal from the satellites, we need to track revolving satellite around the planet. So we used the SDR Console for satellite tracking and reception of the signal. The satellite tracking provides a simple yet powerful support for all satellites. A minimum knowledge of satellite theory and operation is required to use this software. The tracking feature of the software gives us a list of satellite passes around that time as the shown in Figure 9. It also set the frequency of the respective satellite which is selected. The satellite list is a convenient way of quickly accessing your most frequency used satellites.

Figure 10 Showing list of satellite passes

Using the Passes window we could see the live route of satellites. The satellite pass window consists of the list of satellites, time left for AOS (acquisition of signal) and LOS (line of sight) as shown below.

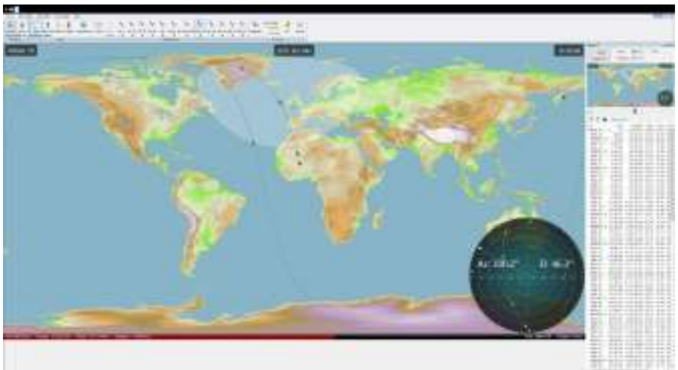


Figure 11 Satellite Passes Window

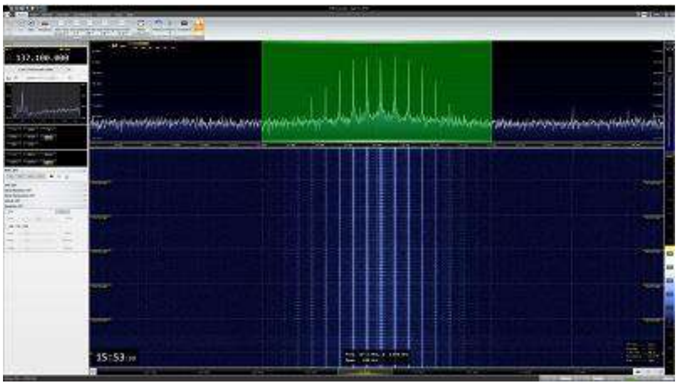


Figure 12 The signal received

The signal is ready to be received when the satellite enters the LOS regions. When the antenna picks up the corresponding signal the SDR console simulate the signal as shown in Figure 11.

F. SatNOG SERVER

For the public to access the decoded information that we captured via our ground station module we host the data to the domain https://network-dev.satnogs.org/. It is a SatNOG (Satellite Network Open Ground Station) commenced Network domain as a part of an open-source platform for collecting and hosting the useful information like weather images and other cubesate data from around the globe. It has a collection of such open source hosting services around the world one of which is us in Kerala, India. We also host the data privately on the website of URL www.mbcetgroundstation.atspace.cc including the project details and videos of signal reception. The home page of the URL is as shown below.

Figure 13 Map showing our SDR based Portable Satellite Tracking Device

Figure 14 Home page of the URL www.mbcetgroundstation.atspace.cc

G. RASPBERRY PI AS TRANSMISSION CONTROL PROTOCOL (TCP)

MODULE

One of the abilities of the Rpi (Raspberry Pi) is that it can be used as a server. With Rpi as the server, we can control the SDR console remotely either by LAN or by using the same wireless network which enhances the ease of use and compatibility, for it a router is employed which allocate the IP address to the SDR. The condition is that both the Rpi and SDR should be connected to the accessing point using the same network.

3. RADIATION PATTERN

A. Yagi Antenna

The antenna shows a directional example comprising a fundamental forward lobe and various deceptive side lobes. The fundamental one of these is reversed caused by radiation toward the reflector. The reception apparatus can be streamlined to either decrease this or deliver the most extreme level of forwarding gain. Unfortunately, the two do not coincide exactly and a compromise on the performance has to be made depending upon the application. Shown below is radiation pattern obtained by using simulation software called the Altair FEKO. Altair FEKO consists of two components viz. CADFEKO and POSTFEKO.

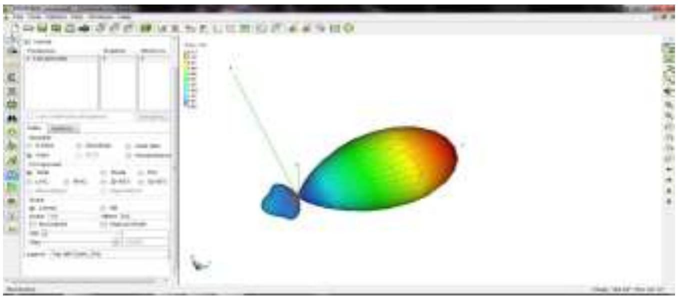


Figure 15 Radiation Pattern of Yagi Antenna

B. Helical Antenna

It is the simplest antenna, which provides circularly polarized waves. The radiation is in the end-fire direction along the helical axis and the waves are circularly or nearly circularly polarized. This is obtained using the aforementioned Altair FEKO

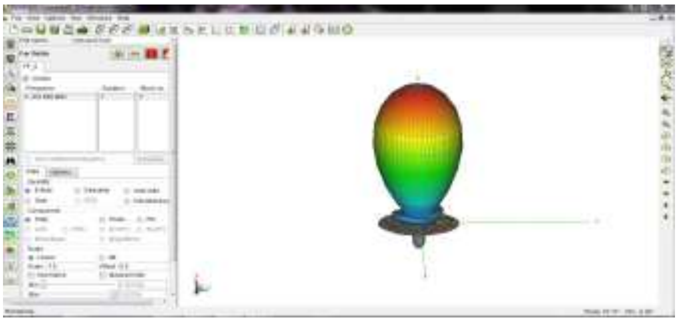


Figure 16 Radiation Pattern of Helical Antenna

C. Altair FEKO

Altair FEKO is software used for the precise simulation of the above-shown radiation pattern.

A brief to CADFEKO and POSTFEKO,

- CADFEKO is the FEKO component that facilitates the creation of CAD geometry using canonical structures and performs boolean operations. It also supports the import and modification of CAD models and meshed geometries. The setting of material properties, solution parameters and the required calculations defined by the user, are all part of the CADFEKO model. If an optimization search is required, the optimization parameters and the goal functions can be specified.
- POSTFEKO is utilized for the most part for two purposes: to approve coincided geometry and to dissect comes about. Approval of work geometry is done as such that clients can affirm that their models are right before beginning a recreation. This is especially valuable when models are made utilizing EDITFEKO, however, is similarly as pertinent for CADFEKO displaying. Examination of results is the other essential capacity of POSTFEKO. Once a model has been recreated, POSTFEKO can be utilized to show and audit the outcomes. A variety of tools are available to help visualize data in a constructive manner.

4. RESULT

Using this project, it is found that a student with intermediate computer knowledge can successfully read and take the data from the aforementioned sites, obtained from the ground station without any external physical aid. It is found that the obtained data are useful for the weather analysis, geographical study, obtain real-time geological data and data for other subsidiary fields. Additionally, the project created a complete system that can be used in helping the user in the various fields of life e.g. Conference meeting can be arranged by streaming the real-time feed from the LEO satellite obtained from the aforementioned websites, with Rpi as TCP module one can access the data from anywhere within the campus and institution. A network of such ground station quenches the thirst of the common people notion of the satellites deployed.

The fundamental idea behind LEO satellites deployment is to provide free access to the data it captured to the public. With this project, it has borne fruit to the idea with little financial outlay.

Figure 17 The final Outlook of the Ground Station

5. CONCLUSION

The SDR Based Portable Satellite Tracking Device project aims to provide and promote free and open source satellite ground stations. Modern open software and web technologies are used to coordinate these stations to more fully utilize the reception capabilities for low earth orbiting satellites by utilizing a particular way to deal with the ground station fragment, the current stations of radio armatures and other might be utilized

with the system. Staying away from custom, organize particular programming and equipment and guaranteeing all project data, code, and the information that obtained during this research is and remains openly accessible is a centre principle of the undertaking. People and associations are urged to collaborate with the undertaking to help understand these objectives. And all thanks to mr. Joji John Varghese, Ani sam Varghese, and to the satnogs team.

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