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UHF Band Ground Station Antenna to track Amateur Radio Satellites

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Abstract—As the copious number of satellites in Low Earth Orbit are piled up, their short period of passes over earth station leads a way for refining the communication between ground and space segments. Accordingly this paper presents the paramount features associated with the implementation of Ground station for tracking the LEO satellites. This paper aims in designing and fabricating a Yagi antenna which has a gain of 9db with symmetrical radiation pattern. The proposed explication is based on the concatenation of commercial low cost components available in the market. The conduct of the antenna is simulated using a MMANA-GAL software. SDR Console afford the provision for satellite tracking with default availability of TLE data for all satellites. The continuous signals from satellite are recorded in Console by manual tracking and these beacon signals are decoded using FLDIGI.

Index Terms — Antenna, Ground Station, LEO, Satellite, Tracking, UHF, Yagi-Uda

1 Introduction

The prominent mobile communication system entailed had piled up during the last decade and the market demand had persistently increased. The communication systems have aspired in terms of performance and quality of service. Moreover, new network topologies and diverse interfaces are likely to be introduced [1]. In the context of increased demand and proliferation of consumer terrestrial mobile and internet communication services, technology has unfastened new opportunities for satellite communication [2].

As the small satellites in Low Earth Orbit (LEO) for various purposes like education, weather, global navigation system and remote sensing are mounting, low cost, low risk and small lead times for assembling and testing spacecrafts are the reason for this dilation of small satellites and this makes the participation of development countries [3]. These operate on VHF/UHF band and are allocated to amateur satellite services.

The ground station is generally significant for mission success and represents the health status of satellite systems in the communication link. It is responsible for tracking and communication with the LEO satellite in order to get back telemetry and experimental data or to transmit commands. Basically, the satellite average pass over the line of sight of a ground station is 10 minutes, in order to avoid such short communication periods many ground station network projects are developed to elevate the total time of contact with the satellites. The communication link between ground station segment and satellite is obtained only using antenna, which is the most important element of ground station [2].

Selection of pre-eminent antenna for ground station involves a trade-off between the electrical parameters, mechanical characteristics and cost of the antenna. The climatic conditions also influence the choice of antenna. The proposed system employs Yagi Uda antennas which provides significant performance with a desirable gain and are often a low cost alternative to corrugated antenna designs [4]. The design of an adaptive communication system is endorsed by a pliable technology which is the Software Defined Radio (SDR). This means different communication needs can be maneuvered by generic hardware design with varying frequencies, modulation schemes and data rates [5].

The telemetry data is the information sent by the satellite and this data is important to know the status of the satellite. Satellite systems collect and transmit this data to the ground segments from which we can conclude the operating status and used for further analyses [6]. This paper describes the ground station system designed to track the LEO orbit satellites and receive telemetry downlink data using manual tracking method, which is light weight, low-cost and portable with accurate results. The data reception is done using the SDR dongle in collaboration with the software SDR Console and recorded data is decoded using the software Fldigi.

2 GROUND STATION ARCHITECTURE

2.1 EXISTING SYSTEM

A Ground Station is a radio station used for tracking, reception and/or control of communication and to provide the primary downlink facility. The Ground Station services is also furnished by SATnogs and AWS [7]. SATnogs is a satellite networked open source ground station, focused on observing and receiving the satellite signal, particularly in the LEO orbit. AWS (Amazon Web Service) ground station is a fully maneuvered service that will enable customers to easily command, control, and downlink data from the satellites. It provides pay and access service for user's actual usage time of the antenna. IDSN (The Indian Deep Space Network) is a ground station built in Banglore, India which is used to track and reinforce India's first lunar mission Chandrayaan-1, an unmanned lunar exploration mission.

2.2 PROPOSED SYSTEM

It can be seen that the number of Ground Stations in India is very less compared tom other countries in the world. Hence, it is necessary to increase the setting up of ground sta-

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tions. This project relies on designing and fabricating a Ground Station Antenna for extracting useful information from the satellites in a highly cost-effective manner. The **Figure 1** depicts the block diagram of our ground station antenna.

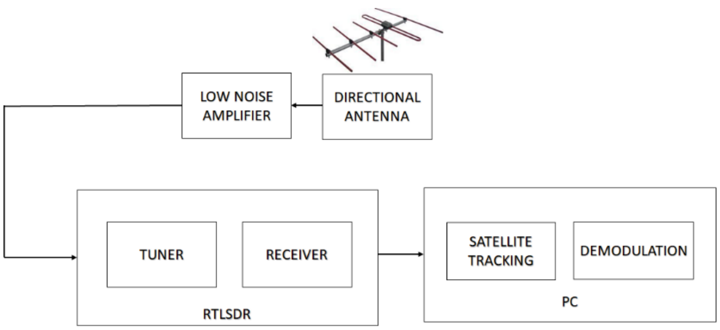

Figure 1 : Block Diagram of Designed Ground Station

Yagi-Uda antennas are conventionally harnessed at HF/VHF/UHF bands, in general elements such as active element length ranges 0.45 lambda-0.49 lambda and the reflector are mostly 5% more than active element and is located behind the active element at 0.25 lambda distance. Directors have the effectual efficiency, directivity and antenna gain. Director length differs in the range of 0.4 lambda- 0.45 lambda [8]. Increase in the number of directors raises the total gain. This antenna is used in various applications such as atmospheric radio, television broadcast and Amateur radio ground station etc.

The directional antenna we designed is shown in **Figure 2** which consists of parasitic elements and dipole arrays as shown in **Table 1**.

Reflector	1
Directors	5
Driven Element	1

Table 1: Number of Yagi elements

Fi

Boom is an unintended radiating part of the antenna, which acts as a support system for the entire antenna design. Coaxial cable is used to feed the RF power to the Yagi-Uda antenna. The driven element used in the antenna is a folded dipole antenna, which is used to provide the impedance matching and it is the only part which is directly connected to the coaxial cable [9].

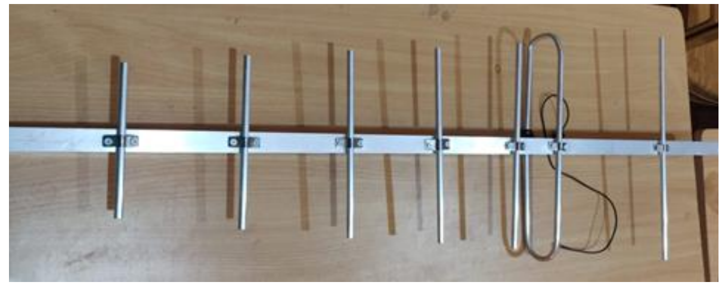

Figure 2 : Designed 7 element of Yagi Antenna

The antenna specifications are mentioned below
No. of elements - 7
Frequency range - 437MHz
Max antenna gain – 9dB
Boom length – 1m
Weight – Less than 1kg

The Register Transfer Level Software Defined Radio (RTLSDR) shown in **Figure 3** is a receiver where in the PC or embedded system components such as modulator, demodulator, mixer, filter and amplifier is implemented by means of software. The RTLSDR dongle consists of both receiver and tuner where the tuning range varies between 25MHz to 1750MHz. For receiving and decoding of the data from the satellite, software such as SD Console and Fldigi is used along with the SDR dongle. Various decoding techniques (APT, FM, CW and AFSK) have been adopted for converting the data obtained from satellites to its original form.

Figure 3 : RTLSDR

2.3 DESIGN OF 7 ELEMENT YAGI

The Yagi-Uda antenna dimensions are dependent on frequency or wavelength.

$$\lambda = c/f$$

Where λ is the wavelength, c is the velocity of light 3*10^8 m/s, f is the design frequency which is 437MHz.

$$\lambda = (3*10^8) / 437MHz.$$

The **Table 2** shows the dimensions of each element of the designed 7 element Yagi using the Yagi Calculator and then verified manually.

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Element	Values(mm)
Length of Driven Element	0.5(686.49)
Length of Reflector	0.58(686.49)
Length of director 1	0.45(686.49)
Length of director 2	0.40(686.49)
Length of director 3	0.35(686.49)
Spacing between directors	0.20(686.49)
Reflector to dipole Spacing	0.35(686.49)
Dipole to director Spacing	0.125(686.49)

Table 2: Dimensions of 7 element Yagi

2.4 YAGI CALCULATOR

Long Yagi antenna are used in the Amateur band range 144MHz-2.4GHz. Yagi Calculator is a program mainly used for the design of a long Yagi due antennas in VHF and UHF range. Yagi calculator is a free analysis and design software depicted in **Figure 4**. Among various software such as antenna maker, antenna design calculator, the Yagi Calculator software provides a detailed result compared to other software [10]. This is also used to find the antenna parameters such as gain, spacing, length, beam width, stacking distance, staking SWR.

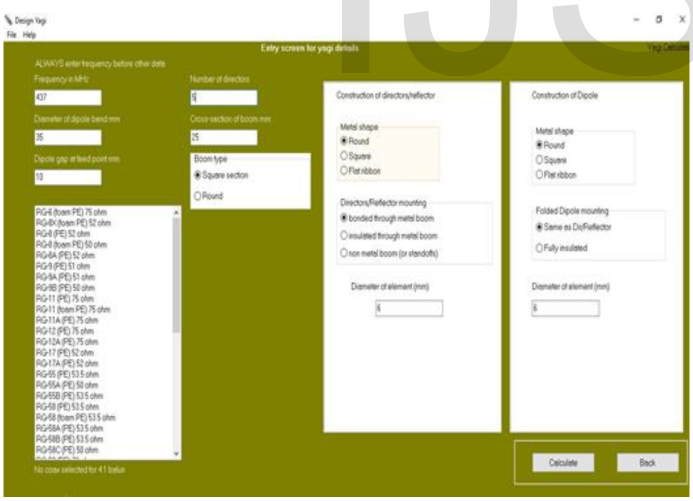

Figure 4: Yagi Calculator software

3 SIMULATION SOFTWARE

3.1 MMANA-GAL

There are many simulation software's that are in easy reach to obtain the antenna parameters such as Radiation Pattern, Impedance, Gain, SWR. One such antenna analyzing software which is the updated version of 4NEC2 is the MMNA-GAL. It is introduced in MININEC (Mini Numerical Electromagnetic Code) version 3 based on the method of moments [1]. Simulation of Yagi antenna using this software involves creating a geometrical structure and by means of excitation the Impedance, Gain, SWR and F/B ratio are obtained. The far field plots can also be obtained by optimizing SWR value. The main goals of the optimization is to serve the better efficiency in the output, minimize SWR, maximize Gain and F/B ratio. The **Figure 5** shows the construction of an antenna model by inserting the coordinate values in the form of the table.

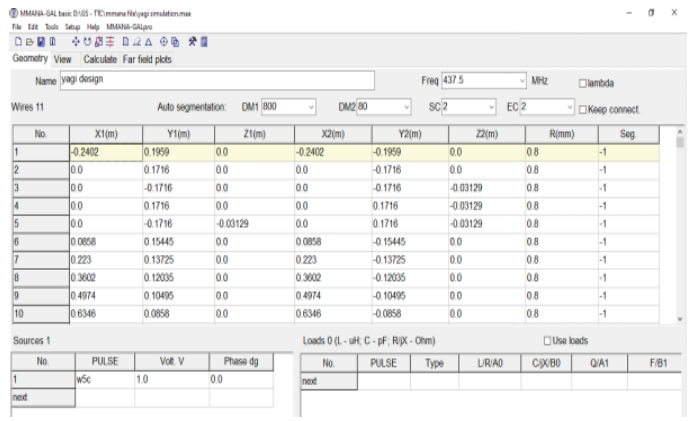

Figure 5 : Co-ordinate values of designed Yagi

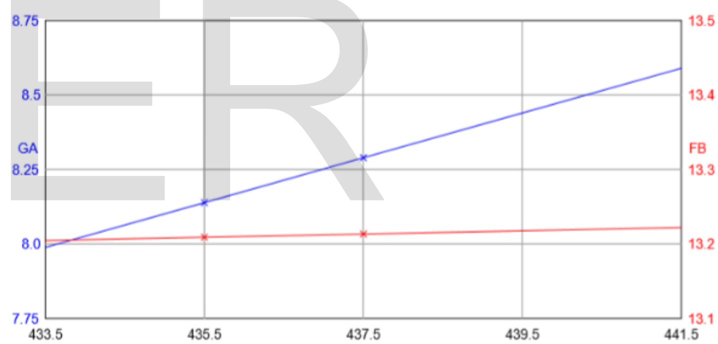

Figure 6 : Gain and F/B Ratio plot

The **Figure 6&7** shows the plots of Gain, F/B ratio and radiation pattern of the designed antenna. By applying the current pulse to the dipole, the antenna gets excited and designated plots are obtained. Initially the obtained SWR reading seems to be high (nearly 8). Hence it is optimized to 1 by adjusting other parameters to certain values. From the results obtained it can be elucidated that the designed 7 element Yagi antenna seems to be highly efficient for reception of LEO satellite signal

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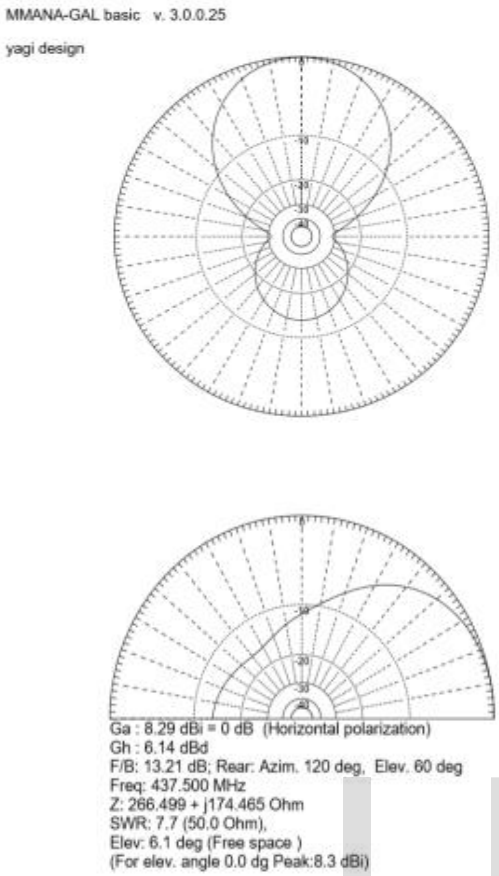

Figure 7: Radiation pattern of designed Yagi antenna

NORAD ID	:	37841
Int'l Code	:	2011-058D
Perigee	:	855.7 km
Apogee	:	872.8 km
Inclination	:	20.0 °
Period	:	102.1 minutes
Semi major axis	:	7235 km
Uplink(MHz)	:	145.900
Downlink(MHz)	:	437.500

Beacon(Mhz) : 437.425
Mode : CW

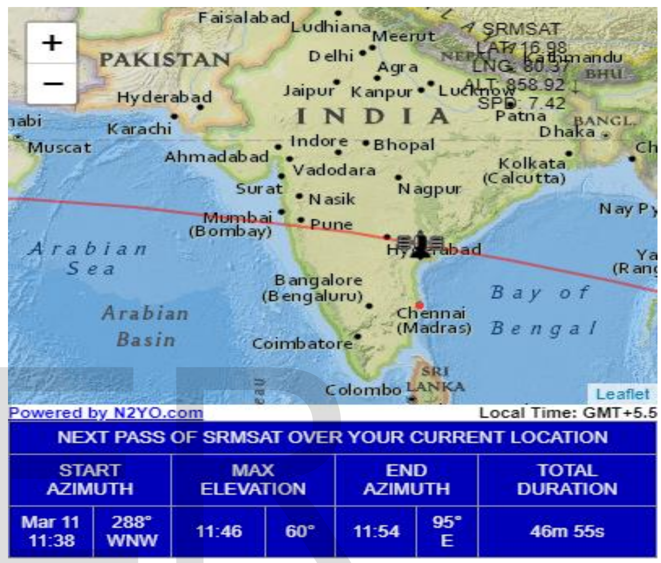

Figure 8: Pass of SRMSAT SDR CONSOLE

4 SATELLITE TRACKING & RECEPTION

4.1 N2YO

The N2YO site is basically a tool to predict the pass of orbiting satellites over a location. It is a real time tracking site and provides facilities such as alerting system which gives the information about satellite and International space station crossing the sky via SMS or Email. It provides many information about the satellites such as its NORAD ID, launch date, uplink downlink frequency, and inclination etc., the data obtained from the website for SRMSAT satellite on March 11, 2020 is shown in **Figure 8** [11].

The Radio communication system that utilizes software for modulation and demodulation of radio signals is depicted as the Software Defined Radio (SDR) system. The hardware system consists of a super heterodyne RF front ends, A/D and D/A converters which converts analog RF signals to digitized IF signals. This console renders facilities for both tracking and reception of the satellite signals based on the satellite definitions with available TLE files. The future passes of the satellite can be predicted and can be scheduled for automatic tracking and reception .The **Figure 9** depicts the signals received during the passes of SRMSAT.

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In order to receive a highly efficient signal, the elevation angles of the antenna should be maintained properly. In case of automatic tracking, the frequency in the SDR Console automatically gets changed to the satellite frequency of SRMSAT (i.e. 437.425 MHz). While manually tracking the satellite, the bandwidth and frequency is selected in the frequency spectrum to receive the signal. The strength of the received signal depends upon the position of the antenna during its pass over Line Of Sight. SDR console also provides a provision for satellite tracking which involves uploading of current location and thereby enables Doppler correction.

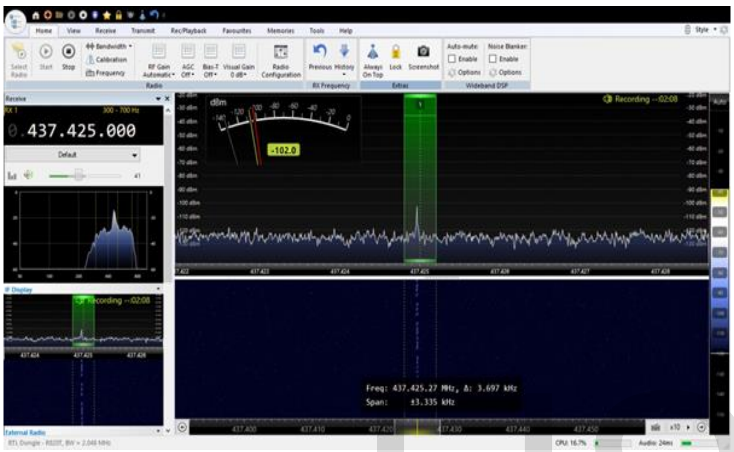

Figure 9 : Signal received using SDR Console

5 DECODING SOFTWARE

5.1 FLDIGI

Fldigi (Fast Light Digital) is an open-source program which is preconceived for Amateur Radio Digital Modes operation using a PC which can run on different operating systems. It can be hence used for decoding data received from the satellite to extricate useful information mainly to decode CW beacon signals. The signal obtained from the SDR console is in the form of .ogg file. After converting the .ogg file to wav file. Then in fldigi the required .Wav file is chosen from File->Audio->playback and then center frequency is adjusted to where the CW signal appears on the waterfall display.

```
Character 6: Satellite Mode
1. P - Sensing Mode
2. X - Communication Mode
3. C - Normal Mode
4. Z - Detumbling Mode

Character 7: Magnetometer Status
1. C - On
2. P - Off
3. X - Error
4. Z - Ready

Character 8: GPS Status

Character 9: Payload Status

Character 10: Temperature Status
1. C - Less then 0 degree celcius
2. P - 0 to 10 degree celcius
3. X - 10 to 20 degree celcius
4. Z - 20 to 30 degree celcius
5. 6 - 30 to 40 degrees celcius
6. 4 - Above 40 degrees celcius

Character 11: Battery Status
1. C - Less than 7 V
2. P - Between 7V and 7.3V
3. X - Between 7.3V and 7.6V
4. Z - Between 7.6V and 7.9V
5. 6 - Between 7.9V and 8.1V
6. 4 - Larger then 8.1V
```

Figure 10: Telemetry Data format of SRMSAT

Encoding of the data can be done in two ways namely manual method or by using software. Here we have encoded the data manually by comparing the original data of the satellite. Here we encoded the data for SRMSAT. Below **Figure 10** shows the telemetry data format of SRMSAT.

The process of encoding can be done easily by using software. Each satellite has independent encoding methodologies especially built for that satellite alone. But those techniques are highly secured. Hence, another method is to calculate manually by analyzing the telemetry data formats formulated for each satellite. Hence, after obtaining the decoded data from SRMSAT it is compared with this telemetry data for obtaining the useful information. The **Figure 11** shows the decoded data of received signal from the SRMSAT.

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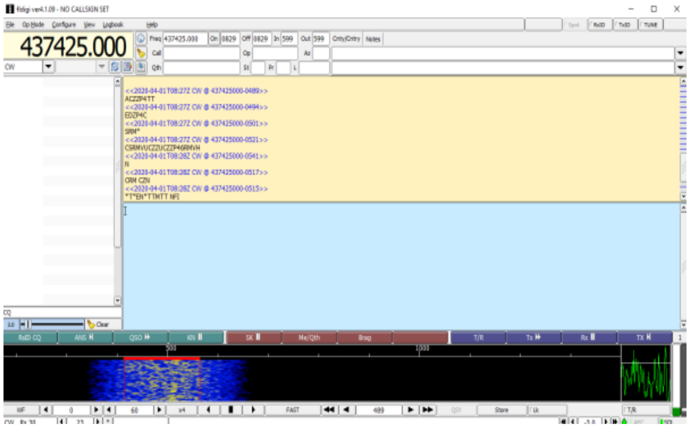

Figure 11 : Decoded data of SRMSAT

By comparing the data in both the **Figures (10&11)**, we obtained the data SRMVUCZZP4C. The definition for each character is explained below. This is the useful data obtained after manual calculation. Similar procedure can be followed for extracting data from other satellites.

SRMVUCZZP4C

1-5 character [SRMVU] - Call sign of the satellite
6th character [C] - normal
7th character [Z]-Ready
8th character [GPS] - Status
9th character [P] - Pay load status
10th character [4] - above 40 deg C
11th character [C] - less than 7 v

6 CONCLUSION

Since the designing and development of cost effective and portable antenna is the greatest hardship nowadays, this paper serves as a solution by designing a Ground Station antenna for tracking amateur satellite operating in symmetrical polarization at VHF and UHF band has been designed, manufactured and tested to very stringent specification. This ground station segment can be further developed by implementing automatic tracking using rotor and rotor controller with WispDDE being linked with the prediction software. Hence, by this method we can reduce the human error and also track the satellites for more time automatically.

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