PRATHAM

IIT BOMBAY STUDENT SATELLITE

Preliminary Design Report

Communication and Ground Station Subsystem

By

Kartavya Neema

Jhonny Jha

Ashish Goel

Deepika Thakur

Siddharth Mahendran

Amol Patwardhan

Mayank Vibhuti Jha

Gaurav Varshney

Ajinkya Bapat

Department of Aerospace Engineering,

Indian Institute of Technology, Bombay

April, 2009

Preface

The Communication Subsystem has the primary aim of ensuring a one way link from the Satellite to the Ground Station. The primary constraints on the functioning of the subsystem have been due to the Payload, Power and Structural Subsystems. The Preliminary Design Review intends to present the progress made by the team in designing the on-board circuitry and the Ground Station and the problems that we are encountering for the final design.

The team has the added responsibility of implementing the social goal by helping the Universities around the country setup Ground Stations. The role of the team has been in the form of providing technical support to these Universities for antenna design and setting up a Ground Station facility in the purview of their campus.

Communication and Ground Station Subsystem,

Pratham, IITB Student Satellite

Table of Contents

List of Figures

Chapter 1: Introduction

In this chapter, we will give a brief introduction to the Communication Subsystem.

1.1 Introduction to Subsystem Goals

The primary goal of the communication subsystem is to establish a one way communication link between the satellite and the ground station. In order to achieve this goal, the subsystem has to perform the following tasks:

- Design a low bit rate Beacon that is functional for the entire lifetime of the Satellite and not connected to OBC. (Freq = 150 MHz)
- Design a high bit rate (1.2kbps) Monopole for downlink of data. (Freq = 437 MHz, we do not have uplink).
- Both the monopoles must be transmitting linearly polarized radio signals.
- 4 independent crossed yagi ground stations at IITB to receive data and measure their polarization.
- Low cost (<Rs20,000) ground station for other universities to measure polarization**.**

1.2 Subsystem Requirements

1.2.1 Power Subsystem

1) Monopole: 2 watts when operational. This includes the power consumed by the transmitter circuit as well as the amplifiers and other transmission line losses. The power required will drop to about 0.06 watts when the monopole is in power down mode.

2) Beacon: 2 watts when operational. This includes the power consumed by the transmitter circuit as well as the amplifiers and other transmission line losses.

1.2.2 OBC

1) The OBC team should provide AX.25 data packets to the CC1020 transmitter chip.
2) The OBC team will also control the power modes of the transmitter.
3) The data provided to the chip should be in the NRZ format.

1.2.3 Structures

1) The two monopoles should be deployed on the face opposite to the nadir surface. The correct orientation has already been specified to the structures team.

2) The parallelism of the two monopoles should be as specified by the payload team.

1.2.4 Thermals

1) The efficiency of the monopoles will be close to 50 percent. So the thermal subsystem should ensure that the heat generated is dissipated.

2) The heat dissipation of circuits and amplifiers is also looked into by the thermals subsystem.

Chapter 2: On Board System

2.1 Beacon Circuit

2.1.1 Proposed circuit, Space heritage

A low bit-rate Morse code encoded beacon will allow us to know the presence of our satellite. It will be using CW transmission technique and will be available for any amateur HAM operator to receive and decode.

We will be using ADF7020-1 as the transceiver for OOK beacon at 150 MHz .The IC is very versatile (over qualified) as its frequency range is 80 to 956 MHz Also, it supports OOK/GOOK/ASK/FSK/GFSK. This is overkill but we could not find a better COTS transmitter-receiver pair. We were looking at transmitter 2516 by RFMD but receivers were not available from RFMD itself.

Two boards of the concerned IC are needed for the final prototype. A mother board: **EVAL-ADF70XXMB (Z)** and a daughter board: **EVAL-ADF 7020-1 DB5** (general) and/or **EVAL-ADF 7020-1 DBZ8 (128-142 MHz)**

The major reason why we opted for this IC is because the IC is industrial grade and comes from a reliable source, something which was stressed upon by ISRO during CDR. In addition to this, this circuit satisfies all our constraints of power and data rate.

2.1.2 Testing of circuit

PFD - 5.5296 MHz
Min freq - 120.8 MHz   power ~ 8.3 dBm
Max freq - 132 MHz   power ~ 10.5 dBm

Power increases with the freq somehow...it was 10.5 dBm when no input and 11.1 dBm when input was given (square wave). A lot of noise is observed at lower power output (when signal is on). It is cleaner at higher power output. It has no default setting. Also, if we remove the power all the previous data is lost and has to be reprogrammed. We cannot set the frequencies at 145-150MHz in the current COTS daughter and mother board setup as there is an error message saying that the external VCO inductor doesn't support that frequency.

2.1.3 Proposed working of the circuit onboard

It has an 8-pin interface to the microcontroller and is a very complicated circuit. The following pins of the beacon chip are involved in the interfacing.

1] T_xR_xDATA - Transmitted and Received data
2] R_xCLK - Received clock
3] CE - Chip enable
4] INT/LOCK - Interrupt/Lock pin
5] SREAD - Serial read
6] SLE - Serial Latch Enable
7] SDATA - Serial Data
8] SCLK - Serial Clock

The serial interface allows the user to program the eleven 32-bit registers using a 3-wire interface (SCLK, SDATA, and SLE). It consists of a voltage level shifter, a 32-bit shift register, and 11 latches. Signals should be CMOS compatible. The serial interface is powered by the regulator and therefore is inactive when CE is low. Data is clocked into the register MSB first on the rising edge of each clock (SCLK). Data is transferred to one of the 11 latches on the rising edge of SLE. The destination latch is determined by the value of the four control bits (C4 to C1). These are the bottom 4 LSB, DB3 to DB0, as shown in the timing diagram in Figure 2. Data can also be read back on the SREAD pin.INT/LOCK Bidirectional Pin. In output mode (interrupt mode), the ADF7020-1 asserts the INT/LOCK pin when it has found a match for the preamble sequence. In input mode (lock mode), the microcontroller can be used to lock the demodulator threshold when a valid preamble has been detected. Once the threshold is locked, NRZ data can be reliably received. In this mode, a demodulator lock can be asserted with minimum delay.

It has 32-bit registers. Power microcontroller cannot write the registers of the beacon as they don’t have pins to spare. So it boiled down to the OBC team to program the beacon. However, in the **review with Professor Krithi**, it was said that if we're going for a second microcontroller for the Beacon, then it is bound to be a point of failure as far as the beacon is concerned. So the communication initially decided to implement the beacon separately, using just an EEPROM with a clock. This would have been a very small circuit in the configuration layout, close to the beacon. The power mu-c will just have to start the beacon and this circuit and of course, power them. Power required for this circuit will of course be negligible. However, we changed our decision and Instead of programming and sending data to Beacon using EPROM plus Counter, we have decided to use **PIC16C622A** , an 8-bit MCU with almost no junk peripherals and 2KB program memory. So it is as good as using a memory + PC with a more reliable control. The package is SOIC-18 and temperature range is -40-+85 degree Celsius. It is industrial grade, does not have space heritage but is suitable for space application as verified by the **Quality team.**

The other option that we were looking at was the **PIC MCU PIC18F8722** which has a space heritage being used by NASA in SUIT-SAT-1 but even that is not space grade but has extended Industrial grade specifications like temperature range from -40 to 125 degree Celsius, something which is available even in the PIC16C62xx series. The disadvantage of using the PIC18 series is that it has flash memory whereas the one chosen by us has EPROM MCU.

2.1.4 Link margin

a) Operating Frequency: 150 MHz

b) Transmitted power: 0.2 watts

c) Total inline losses: 2.2 dB

d) Receiver antenna gain: 7-8 dB from characterization in co-polarized mode. The measurement however was a bit faulty as we couldn’t get an anechoic chamber for testing purposes at our frequency.

e) Polarization purity: 20 dB as characterized using a commercial monopole and a yagi.

f) LNA gain: 80 dB with all the 4 LNA’s combined. We will need just one of them for us to satisfy our link margin constraint, according to calculations.

g) Noise figure of the LNA: less than 1 dB for a LNA (as mentioned in the datasheets)

h) Transmitting Antenna gain: -3 dBi

i) Transmission line losses : 2 dB

j) Antenna Efficiency : 1 percent (assumption)

k) Antenna EIRP : -11.3 dBW

l) Minimum Power required at receiver : -150 dBW

m) Efficiency of receiver antenna : 1 percent (assumption)

n) Atmospheric loss : 139 dB

o) Humidity loss : 0.1 dB

p) Antenna pointing loss : 0.1

q) Antenna polarization loss : 1 dB to max 3 dB

r) Receiver losses : 2 dB

Power at Receiver = EIRP – atmospheric loss – humidity loss – antenna pointing loss – antenna polarization loss – transmission loss – receiver losses – 10 log (efficiency of transmitter antenna) – 10 log (efficiency of receiver antenna) = –151.9 dBW

Considering that this figure is without the LNA, we can assume a healthy signal strength value once the LNA has been included in the loop. The SNR value taking into mind the above considerations is approximately 9 dB.

2.2 Monopole 2 transmitter circuit

2.2.1 CC 1020 circuit

The following are the operating characteristics of the CC1020 transmitter chip:

a) Operating voltage: 2.3 – 3.6

b) Operating frequency: 402 MHz – 470 MHz

c) Operating Temperature: – 40^{o}C to 85^{o}C

d) Max Data rate: 153.6 kbps

e) Current consumption: 19.9 mA

f) Max transmitting power: 10 dBm

The chip would have to be interfaced with a microcontroller for the purpose of interfacing. The details regarding the same have already been covered in the Conceptual design Review

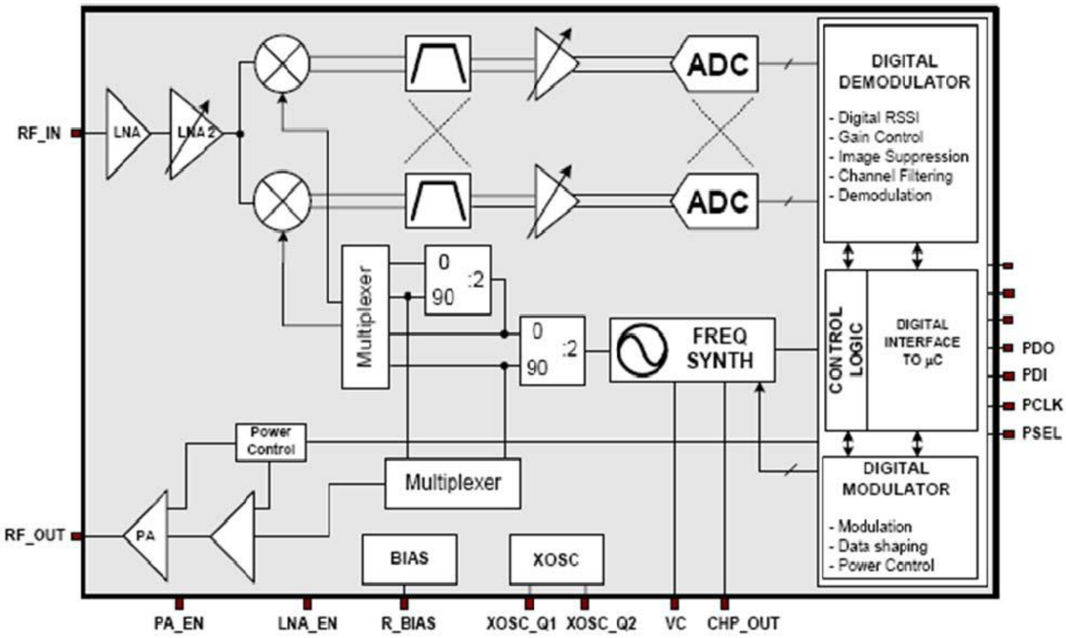

Figure 1: CC 1020 Transmitter Chip

2.2.2 Work done on the CC circuit

Step 1: Pre testing activity

- Going through datasheets
- Understanding the evaluation kit
- Learning the associated software (SmartRF studio)

Step 2: Testing in Antenna lab

- Signal was given to the transmitter by programming the evaluation module through the given software. We used NRZ encoding in our module.

- Measured output power (9.54dBm to 9.62dBm @ 433MHz) on spectrum analyzer.

- Measured the input current: 27mA at Input voltage of 5V to 7.5V.

- Checked the output of the DIO (Const 2.8V) and DCLK (Alternating 3V and 0.3V @4.8kHz when I/P were 4.8kbps) pins on CRO.

- Checked the transmission and reception of Data using two evaluation boards at 433MHz and 4.8kbps since the components on the board were optimized for those values.

- Changed the data rates and the corresponding values for frequency separation. RF studio allowed only discrete values for these two parameters

- It was found that transmission and reception was perfect for input frequencies that were integral factors (unanimously christened as "multiples") of half the data rate value fed through the RF studio. e.g. when we gave a value of 4.8kbps, the circuit transmitted and received without noise at input frequencies of 2.4kHz, 1.2kHz and so on.("multiples" of 2.4KHz)

- On connecting the parallel port of the PC to the receiver chip of CC1020, the signal is found to be a better looking (undistorted) square wave with a peak of 3V (instead of 2.4V earlier). Exact cause of this is unknown.

Step 3: Testing with microcontrollers

- The CC1020 chips in transmitter and receiver mode were tested by connecting 1 microcontroller to the transmitter and one to the receiver.

- The receiver was coded to receive the data and give visual LED signals to indicate progress and errors.

- Initially the testing was done with UART at 2400 baud with delay (to make it visible) and without it.

- Then we implemented AX.25 at slow rate to make it visible.

- Problem faced: The output of the Rx circuit is 3V for high and ~0.4V for low. Hence we had to use an ATMEGA 16L instead of an ATMEGA16 to make 3V recognizable as a high output

Step 4: RSSI testing

- We tested the RSSI (Received signal strength indication) of the CC1020.

- We recorded the RSSI readings with

    1. Both monopoles intact

    2. One of the monopoles removed

    3. Both the monopoles removed

- The results were as expected, showing a significant decrease at each step, but the least count of the RSSI was 1.5dBm, which is a very poor resolution compared to what we need for TEC measurements

2.2.3 PLL problem

In the CC1020 circuit we have some serious issues with PLL locking. We'll need to find some method to confirm how it is to be done. We know for sure that if we press the calibrate button twice in the SMART RF software it is programmed at the correct frequency. We tried doing calibrate twice for the board via Atmega by writing the calibrate register twice but it didn't work. One method suggested during review with Professor Krithi was that we overcome the problem of Phase loop locking (PLL) by checking the CC chip registers more often.

2.2.4 Link Margin

a) Operating Frequency : 437 MHz

b) Transmitted power : 0.8 watts

c) Total inline losses : 2.2 dB

d) Receiver antenna gain: 7-8 dB from characterization in co-polarized mode. The measurement however was a bit faulty as we couldn't get an anechoic chamber for testing purposes at our frequency.

e) Polarization purity: 20 dB as characterized using a commercial monopole and a yagi.

f) LNA gain: 80 dB with all the 4 LNA's combined. We will need just one of them for us to satisfy our link margin constraint, according to calculations.

g) Noise figure of the LNA : less than 1 dB for a LNA (as mentioned in the datasheets)

h) Antenna gain : 2.15 dBi

i) Transmission line losses : 6 dB

j) Antenna Efficiency : 1 percent (assumption)

k) Antenna EIRP : -1 dBW

l) Minimum Power required at receiver : -150 dBW

m) Efficiency of receiver antenna : 1 percent (assumption)

n) Atmospheric loss : 148.3 dB

o) Humidity loss : 0.1 dB

p) Antenna pointing loss : 0.1

q) Antenna polarization loss : 1 dB to max 3 dB

r) Receiver losses : 2 dB

Power at Receiver = EIRP – atmospheric loss – humidity loss- antenna pointing loss – antenna polarization loss – transmission loss – receiver losses –10 log (efficiency of transmitter antenna) – 10 log (efficiency of receiver antenna) = –150.9 dBW

Considering that this figure is without the LNA, we can assume a healthy signal strength value once the LNA has been included in the loop. The SNR value taking into mind the above considerations is approximately 9 dB.

2.3 Monopoles

2.3.1 Polarization purity

The simulations showed that a monopole designed from aluminium and having radius 1mm will have an axial ratio of more than 30 dB. The experimental verifications showed an axial ratio of close to 20dB.

2.3.2 Directivity towards earth: Simulation Results

The simulations were done using IE3D and the following was the pattern observed towards the earth when both the monopoles are radiating:

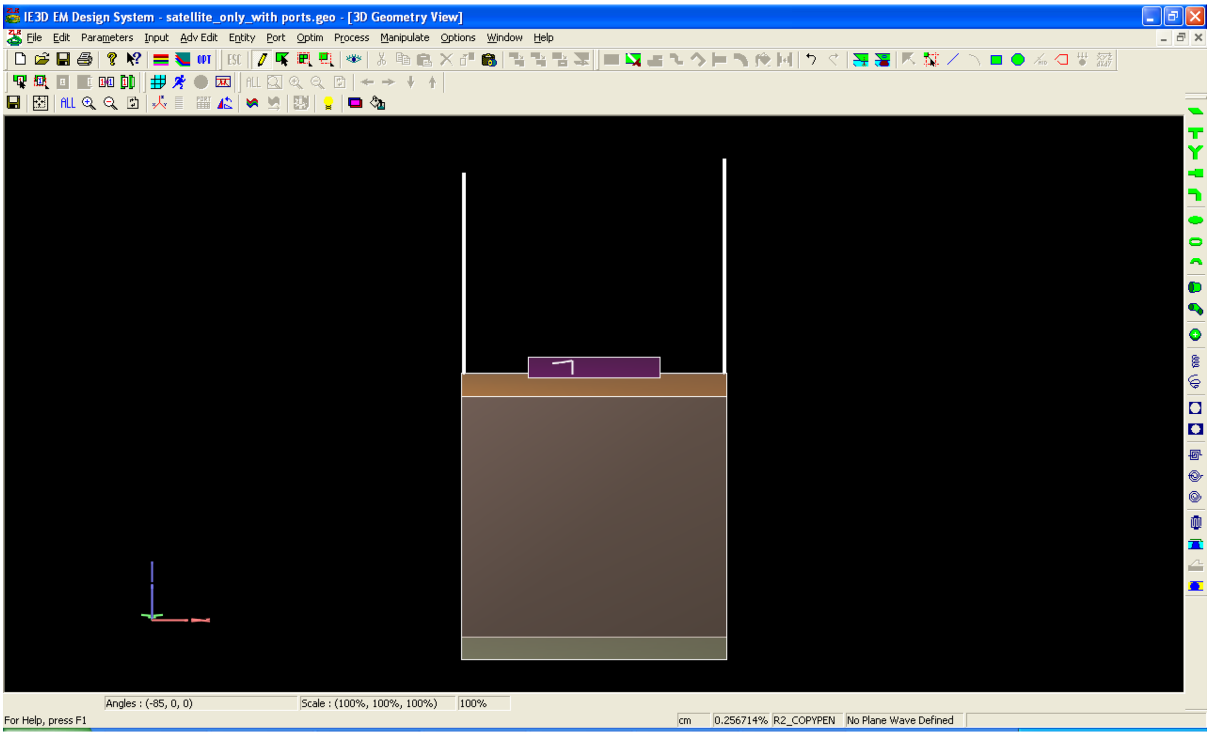

Figure 2: Satellite Modelled in IE3D

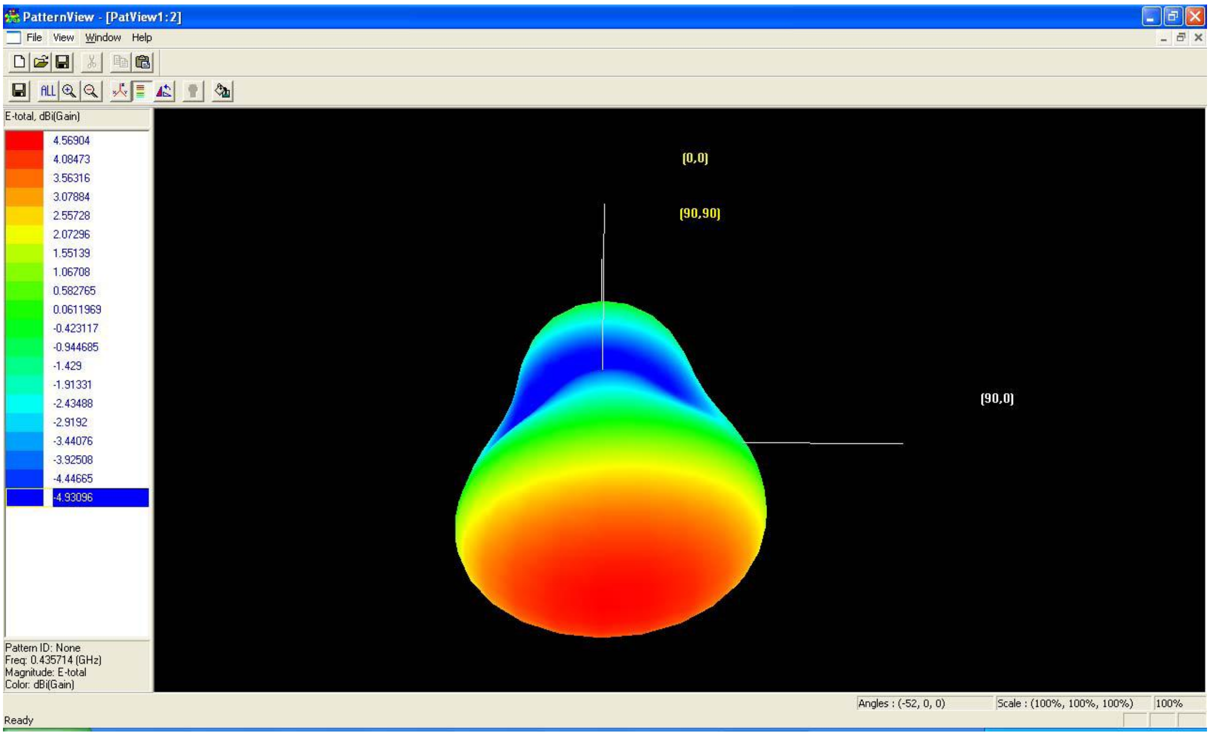

Figure 3: Satellite Modelled in IE3D

The red portion is towards the earth. The maximum gain is in the direction of earth and the value observed is 4.5 dB

2.3.3 Effect of coating monopoles with dielectric: Simulation results

The gain of the antenna decreased by about 2-3 dB on being coated with a dielectric with a dielectric value of 6. The reduction was more or less uniform throughout the pattern and the directionality of the pattern remained constant. Thus the only effect this had was to reduce the efficiency of the antenna drastically.

2.3.4 Effect of change of Satellite size on the monopole simulations: Simulation Results

There was hardly any change (~0.1 dB) due to change in the satellite dimensions. The reasons for the same can be sighted as the wavelength of two monopoles are 70 cm and 200 cm respectively and hence the critical distance at which electrical properties change significantly is the lambda by 4 wavelength which in either case is high compared to a change of 3 cm. We tried to verify this claim by making our satellite dimension of the order of 17 cm and we did observe a sharp change in the pattern and after that the results did not vary much even after changing the satellite body dimension from 20 to 30 cm.

2.3.5 Effect of the LVI at the base: Simulation Results

We weren't able to model the LVI in IE3D. We had asked for expert help regarding this when we went to ISAC for CDR but even they said that such things are experimentally verified and are not modeled.

Chapter 3: Ground Station

3.1 Location

3.1.1 Factors affecting site selection

a) Height of the site

b) Interference from surroundings

c) Horizon to horizon angle

d) Ease of accessibility

e) Availability of power, LAN etc

3.1.2 Data storage and analysis

We haven't thought about the methods of storage and analysis but as we did for noise modeling we might have a storage device connected to the spectrum analyzer at our Ground Station and could store the details being sent by the Data transmitting Monopole in real time. As far as the analysis part is concerned we will be having a Strength detecting IC which will measure the Relative strengths of the two signals coming from the two feed points of the crossed yagi and we would use the output given by the IC for further analysis of the Faraday Rotation and TEC.

3.2 Noise Modeling

We decided to model the band between 436.5 MHz and 437.5 MHz using the designed yagi. Our goal was to obtain information regarding the base noise level in this band throughout the day and night i.e. with variation in time as well as with directions. So we kept the yagi at different azimuths and elevations and carried on this experiment for 8 different configurations of the yagi. We recorded the readings for one particular configuration continuously for a period of 24 hours using a Spectrum analyser and Image capturing software. We stored the images, taken at an interval of 1 minute each, in a storage device connected with the spectrum analyzer. After recording the readings, we analysed the images with the help of an image processing code developed in MATLAB.

3.2.1 System Characteristics under different configurations

With Coax

Parameters :	Antenna Gain	7.75dB
	Antenna Temperature	290K
	Waveguide Loss	6dB
	LNA-to-Amplifier Cable (1) Loss [dB]	0.1dB
	Amplifier-to-Rx Cable (2) Loss [dB]	3dB

	System Noise Temperature	System Noise Figure	Power
1 LNA :	489.696	4.2953	1.352E-16
2 LNA :	485.499	4.2718	1.341E-16
3 LNA :	485.457	4.2716	1.340E-16

Without Coax

Parameters :	Antenna Gain	7.75dB
	Antenna Temperature	290K
	Waveguide Loss	0dB
	LNA-to-Amplifier Cable (1) Loss [dB]	0.1dB
	Amplifier-to-Rx Cable (2) Loss [dB]	9dB

	System Noise Temperature	System Noise Figure	Power
1 LNA :	321.501	3.2399	8.876E-17
2 LNA :	302.935	3.1061	8.365E-17
3 LNA :	302.735	3.1046	8.359E-17

Without LNA:

Parameters	:	Antenna Gain	7.75dB
		Antenna Temperature	290K
		Waveguide Loss	6dB
		LNA-to-Amplifier Cable (1) Loss [dB]	0dB
		Amplifier-to-Rx Cable (2) Loss [dB]	0dB

System Noise Temperature	System Noise Figure	Power
874.224	6.036	2.414E-16

3.2.2 Results

The following are some of the images we obtained from our experiments:

Figure 4: Noise Modelling with Yagi with elevation equal to 90°

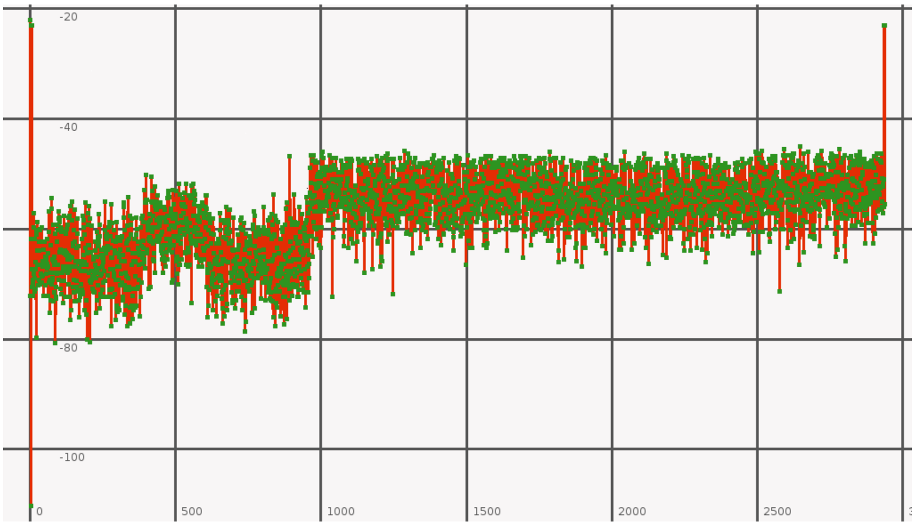

Figure 5: Noise modelling with yagi 30^o from the ground towards north

3.2.3 Errors in the current method or reasons for failure

We weren't able to obtain any results from the experiment though. The possible reasons for failure being:

a) No bandpass filter : One possible reason might be the amount of k*t*B noise that increases the noise floor making it difficult for us to decide any peaks due to any source of noise or even due to a satellite passing overhead.

b) Very weak signal strength due to satellite passes or due to lack of any strong source existing in the frequency bands nearby

c) Miscellaneous Reasons: There might be other reasons but we are not able to gauge them.

3.3 Single Yagi antenna (with wooden frame)

3.3.1 Simulations

Simulations were done in the antenna design software NEC and the results were optimized giving maximum weight age to the Impedance of the antenna being as close to 200 as possible to give perfect matching.

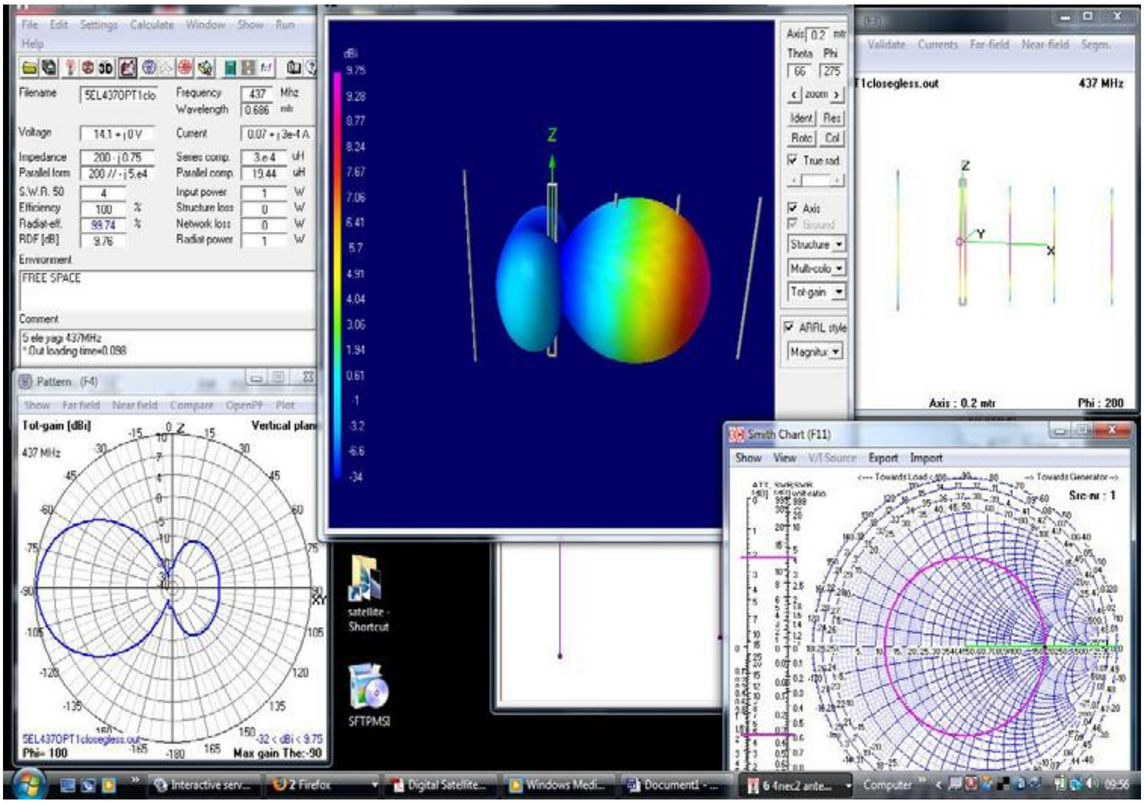

Figure 6: NEC Simulation

The simulation results were the following

a) Gain : 9.75 dB

b) Beam width : 50 degrees

c) VSWR : 1

d) F/B ratio 19.6

3.3.2 Impedance Matching

The impedance of the antenna was designed to be 200 ohms +- 10 ohms and as little reactive como Testing of balun was done with the help of Simple resistances and Surface mount resistances

Testing of yagi:

The performance of the yagi was tested with the help of a network analyzer and the following results were obtained

SWR vs. frequency 437MHz - 1: 1.1667

S11 vs. frequency 436.95MHz -1: -25.047 dB

Smith chart 46.9 ohms

3.3.3 Experimental characterization

a) Transmitted using CC 1020 at 433MHz and received directly on the spectrum analyser.
b) -52.5 dBm gain of monopole in copolarised cond.
c) -44 dBm gain of yagi in copolarised cond.
d) -37 dBm to - 39 dBm gain of yagi in crosspolarised condition.
e) However, the testing was not done in a free environment, even our slight movement resulted in huge fluctuations.
f) The circuit is for 433MHz whereas the yagi is best suited for 437 MHz, although the bandwidth of yagi is 5MHz.

3.4 Satellite Tracking

3.4.1 Details about CUTE 1.7

- Orbit: Sun Synchronous Elliptic
- Inclination: 98 deg.
- Altitude: 630km

They are currently using a continuous CW beacon at 437.275 MHz and they have used a Morse code protocol. Their transmitting power is 300 dBm which translated into a link budget of

3.4.2 Satellite tracking: The experiment

We selected CUTE1.7 for the purpose of testing our downlink setup. The reasons for the same being the central frequency of operation of CUTESAT which lies in our Bandwidth of operation and hence it was easy for us to track them. The second reason was that their power of transmission and orbit details were very similar to ours giving us a hands on experience for tracking our own satellite.

We kept a track on the overhead passes of CUTESAT and planned our setup accordingly. The pass went on for duration of about 10 minutes during which we connected the Antenna output to the LNA which in turn was connected to the spectrum analyzer. The central frequency of operation of the beacon was adjusted in the spectrum analyzer so that we could see the peak of the satellite's CW signal. We did this experiment more than thrice but were unable to get any peak in the spectrum. We concluded that the Link margin is less than what our system can sustain or perhaps we are missing some element in our link budget analysis. We are in consulting with Professors of the electrical department of IIT Bombay and Professor K.P. Ray of SAMEER in order to find the problem areas of the experiment.

3.5 Crossed Yagi Antenna (Al frame)

3.5.1 Design and production

We decided to design the Crossed yagis to be used at our Ground station ourselves after receiving encouraging results from the Yagi that we had designed earlier. We decided to use an Aluminium boom instead just to make the yagi more rigid and robust. We verified that the electrical characteristics of aluminium would not affect the characteristics of the yagi by a great deal using simulations and by consulting with Professor K.P. Ray of SAMEER.

We designed couplers to be used with the help of professionals. The designs for the couplers were made in Solidworks and the same were forwarded to professionals. The Couplers too were of aluminium and their design was approved by Professor K.P. Ray. We have assembled the two crossed yagis at 150 MHz and 437 MHz but are yet to make their Feeding elements and characterize them.

3.5.2 Errors during design:

There were some errors committed during the design of Couplers as the gap between the holes that were slotted for the two crossed feeding elements was less as compared to the distance between the two arms of the folded dipole. However, simulation results showed that even after accounting for the error the impedance of the antenna changed very slightly.

The results of the simulations were:

1) Change the length between folded dipole to 18mm. 200+12.2j

2) Change the length between folded dipole to 16mm. 200+6.66j

3) Move the dipole by 3mm above (towards director). 205-6.65j

4) Move the dipole by 3cm below (towards reflector). 194+4.67j

3.5.3 Experimental characterization of this antenna

To be done**.**

3.5.4 Impedance matching with this antenna

To be done.

3.6 Receiver Circuit

The CW and Data transmitting Circuits are both transmitter receiver pairs and hence we will be using the same at our Ground station> in addition to these we will be using a LNA on ground. The LNA's have been purchased from Minicircuits and each one is a discrete unit offering approx 20 dB gain and less than 1dB noise figure. The LNA's were connected in series and the gain was observed to be addition of the individual values and the Noise figure was reduced below 1 dB which was in accordance with Friis Law.

3.6.1 Need for 14 LNAs and 4 antennas (2 crossed, 2 simple yagis)

The reason we opted for having 2 pairs of antennas at 150 MHz and 437 MHz was because we wanted to avoid any phase delays in our system due to use of devices like Hybrid couplers or power dividers. The signal received from the antennae serves the dual purpose of demodulation and signal strength measurement. In case, we did not have 2 independent crossed yagis at the Ground station at each frequency we would have to use a Hybrid Coupler or power divider to divide the signal strength into two at each feeding point leading to a whole lot of inherent system delays which could have jeopardized the TEC measurement by the Payload team.

The reason for using 14 LNA's was a result of Link budget analysis and the requirement of a minimum Signal strength by the Signal Strength measuring IC. The minimum signal strength required by the IC is 60 dB which means we would need at least 3 LNA's of 20 dB each to raise the signal strength from the expected signal strength value of -110 dB at the Ground Station. Thus , we will be needing 6 LNA's for each crossed yagi, 3 for each feed point, which makes it 12 for 2 crossed yagis and we will be needing a LNA each at the other 2 yagis for the purpose of meeting the Link Margin for demodulation. Thus the sum total comes out to be 14 LNA's.

3.6.2 Rotor and Tracking Software – working, testing and characterization

Connection of Antenna Rotator System (ARS) to RCI-SE Board

The RCI-SE has the following connectors:

1. **J1**: The azimuth antenna rotation is controlled by means of this connector. It is attached to 3 relays at the RCI-SE Board. One of the relays (AUX) is able to control a brake or speed control if it's applied.

2. **J2**: Similar than J1, it's used for elevation control.

3. **J3:** Power input. It requires a power supply: 12 - 14 VDC.

4. **J4**: Input to the A/D converters for the azimuth & elevation rotators. This input is used to read the antenna position. This point will be connected in parallel with the wires attached to the rotor's potentiometer allowing the antenna position readout.

5. **DB-25**: Female DB25 connector to be attached with the parallel port at the computer.

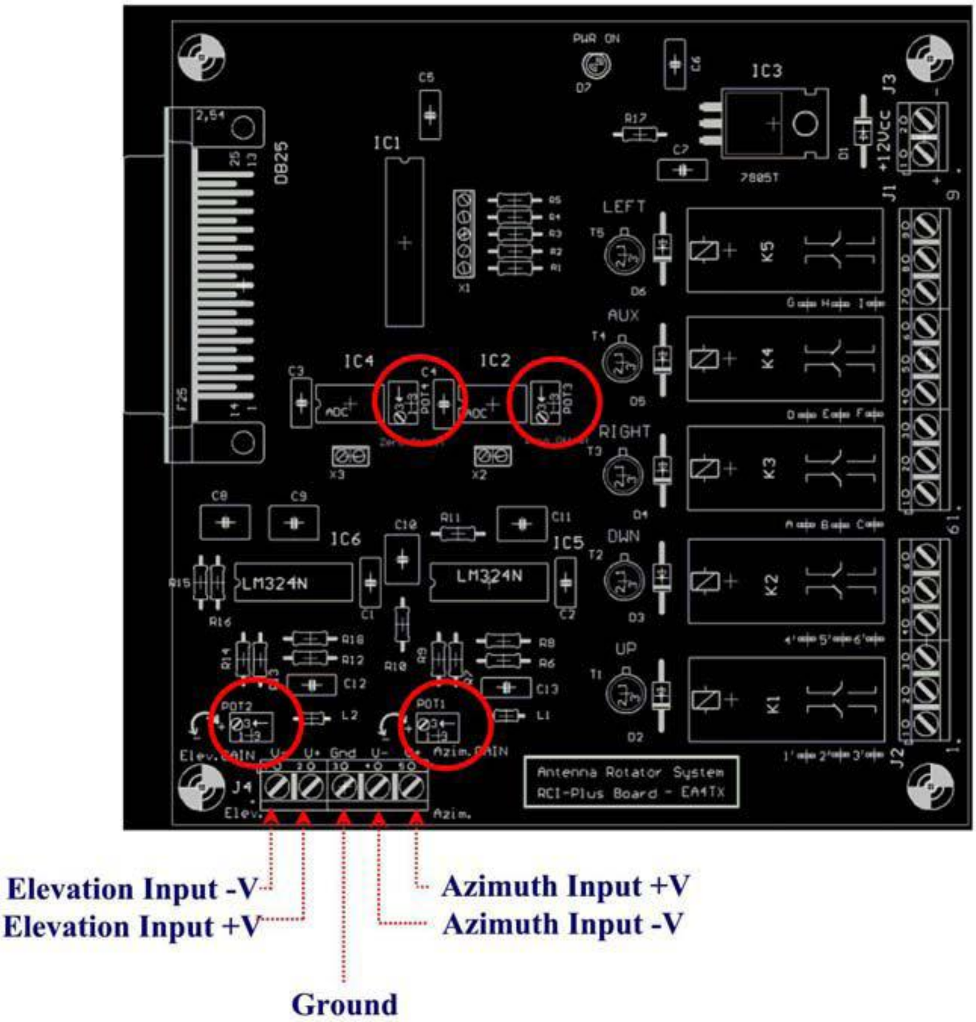

Figure 7: RCI-SE Board

Elevation Relay Connection (J2):

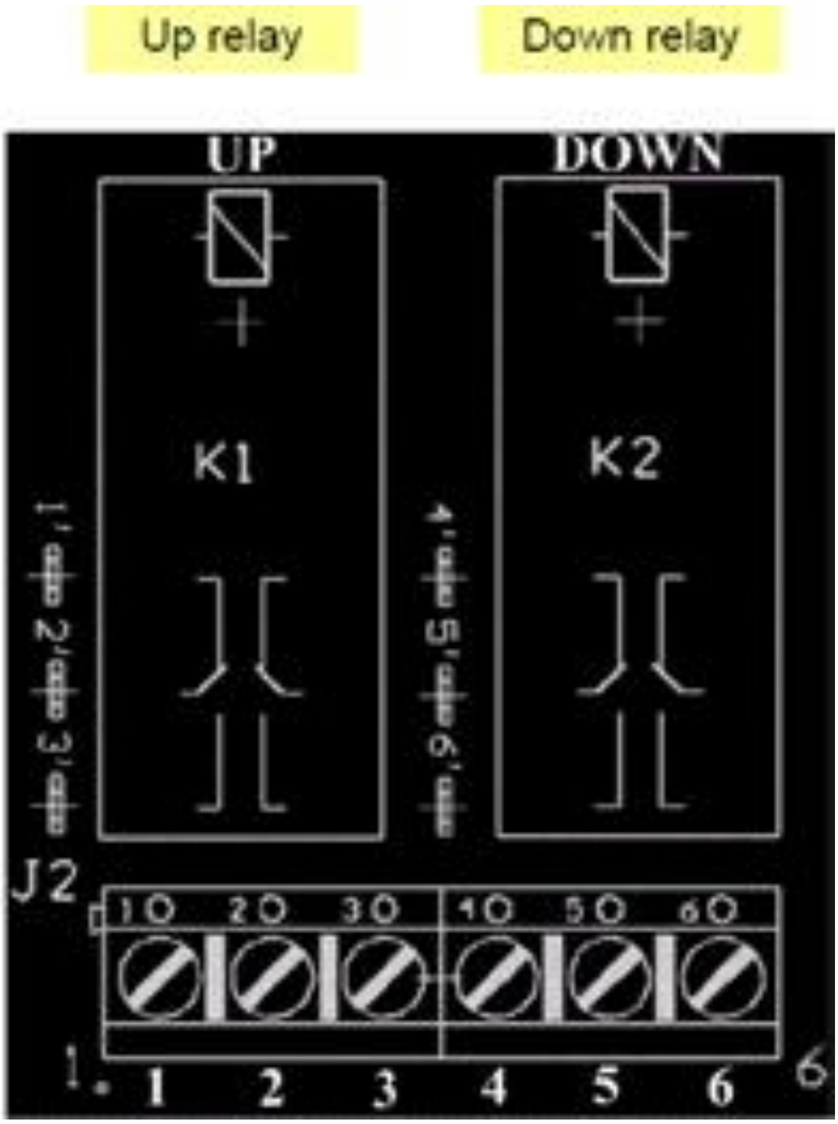

Figure 8: Up and Down Relay of RCI-SE Board

	Relay OFF	Relay ON
UP	J2-2 to J2-1	J2-2 to J1-3
DOWN	J2-5 to J2-4	J2-5 to J2-6

Power Input (J3):

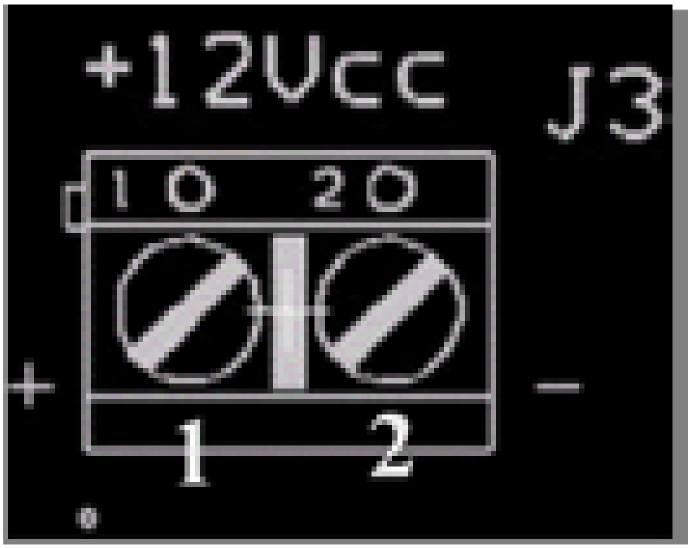

Figure 9: RCI-SE Board Power Switch

The RCI-SE Board must be powered at 12-14 VDC.

1. **J3-1** is the positive terminal.

2. **J3-2** is the negative terminal.

Pin Diagram:

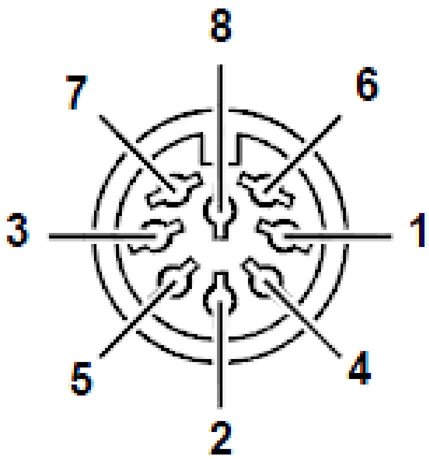

Figure 10: Pin Diagram

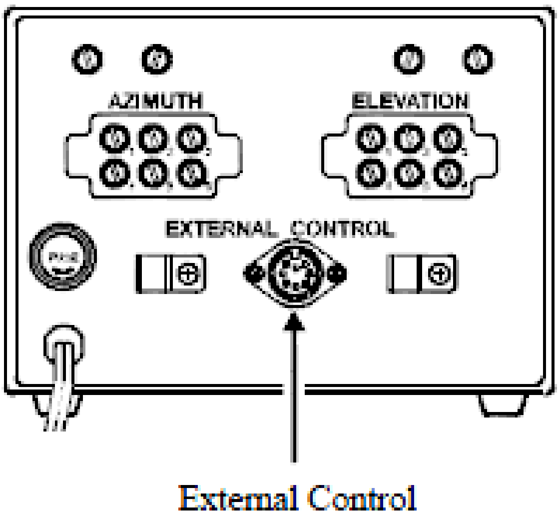

Figure 11: Rotator Control Pin Connections

Pins			
6	Provides 2 to 4.5 V DC corresponding to 0 to 4500	Azimuth position detector	J4 –5 Azimuth Input +V
1	Provides 2 to 4.5 V DC corresponding to 0 to 1800	Elevation position detector	J4 –2 Elevation Input +V
4	Connect to Pin 8 to rotate left (counter clockwise)	LEFT Turn Control	J1–9
2	Connect to Pin 8 to rotate right (clockwise)	RIGHT turn Control	J1–3
5	Connect to Pin 8 to rotate DOWN	DOWN turn Control	J2–6
3	Connect to Pin 8 to rotate UP	UP turn control	J2–3
7	Provides DC 13 V to 6 V at up to 200mA	Not Used by RCI Board	
8	Common ground	Ground	J1–8 & J1–2 + J2–5 & J2–2 + J3–2 + J4–1 & J4–4 & J4–3

A DIN 45326 (8 Pin, 2700) with diameter 13.2 mm is required for connecting the **External Control** jack on the rear panel of the control box to the RCI-SE board.

Setup of ARSWIN

1) General Station Setup

   Latitude: 18.9750N

   (Or write MK68JX in the Grid)

2) RCI Board 1

   Parallel Port: Select Lpt 1

   RCI Board: Select Az. + Elev & 8 bits

   I/O Method: Win NT/2000/XP

3) Azimuth Setup

   Set Total Rotation Angle to 4500

   Advanced

   Hardware Revision: Ver. 2(new)

4) Elevation Setup

   Set Total Rotation Angle to 1800

   Advanced

   Hardware Revision: Ver. 2(new)

5) Tracking Setup

Select Tracking Program as Nova .Check the Activate Tracking option (To connect to the program when it is loaded.)

6) Search

Country

Choose India

Grid

(Write MK68JX in From Grid or the Local Long and Local Lati selecting the mode appropriately)

7) Memo

Modification

(Memory Preferences): Change any Memory Location to India and corresponding Heading to 65. This creates a shortcut for this Azimuthal location which can be accessed by Shift + F1 to Shift + F11 (Heading may sometime vary)

8) Opt

Satellite Tracking

Select Nova for Windows (DDE)

Path: Short should be selected

9) RCI Board 1 or 2

Parallel Port

- Select the LPT port where RCI-SE Board is attached
- ISA Cards use 3 digits range, by default, LPT1 = 0x378 or LPT2 = 0x278

- PCI Cards use 4 digits range, as 0xD400
- RCI Board: Only 8 and 10 bits are supported. Care to be taken in matching correct bit, otherwise the ADC won't work
- I/O Method : Select the OS

10) Azimuthal A/D Setup

- Enter the rotation angle for the Azimuth rotator
- Left/CCW Limit: Usually 0
- Resolution Stop: When the appointing is activated, this resolution angle value will be used for considering a correct appointing, and stop it. It's not suggested to use a too low value, because it will cause to make more tries on the appointing, so the rotator will work too much
- Display Resolution: The resolution used by the program to display the antenna position
- Calibrate: To save both limits of ADC
- Offset: To align offset with the control unit
- Advanced: Select Ver. 2(new) under "Hardware Revision"
- Elevation A/D Setup: Similar to Azimuthal A/D Setup
- Parking: Select the parking angles.
- Antenna Boards: In case of multiple antennas, these and the RCI-SE Boards can be associated with this menu. Offsets (900) can also be added to multiple antennas sharing a rotator
- TCP/IP Setup: If activated, ARSWIN acts as a Telnet Server. Require LAN Adapter with the TCP/IP Stack loaded and running (DDE doesn't require any parameter)

11) Tracking Setup

  - To exchange data between programs
  - Horizon Limit: Any angle under this value will not be used for tracking. This value will be normally 0 or any value close to 0. The Disable Tracking Under Horizon option must be selected

- Tracking Program : Required program can be selected
- Activate Tracking : To connect to the program when it is loaded
- Start Automatically : If the ARSWIN program detects that the tracker program is not loaded, will try to run it, so will use the Path to the tracker Program
- Enabled Trace : This option will display a window, and all exchange data between the tracker (DDE Server) and ARSWIN (DDE Client) will be displayed
- Disable Azimuth/Elevation Value: This values are used by some programs to indicate to stop the rotator *(Generally -1 is used)*

• Antenna Parking: Activate the antenna parking option

• Antenna 1: Displays the currently selected Antenna (Antenna 1 is checked)

• TCP/IP Server: The TCP/IP Monitor window will display if there is some client connected to the Server.

• Exit: Exit from the program

12) Calibrations:

Right Calibration

• Manually turn the rotor to CW (Right) limit

• Current A/D Value displays a value which is close to the maximum value – 250-255 for 8 bit; 1018-1022 for 10 bit

• If not, adjust POT1 (azimuth) on the RCI-SE Board to make it as close as possible to 255 or 1022, as the case may be

• Press the Right button

Left Calibration

• Manually turn the rotor to CCW (Left) limit

• Adjust the Current A/D Value to make it zero using POT3 (azimuth) on the RCI-SE Board, if it is not already zero

• Press the Left button

• If POT3 has been adjusted, then Right limit must be re-calibrated

Similar Procedure should be followed for calibrating Elevation using POT2 and POT4 in place of POT1 and POT3

13) Offset

• Some rotators like Yaesu display a different position than ARSWIN

• To adjust the ARSWIN to the values the control units provide Offset can be introduced in steps of 150.

3.7 Ground Station for other universities

3.7.1 Possible design of low cost GS

The design of a low cost GS was one of the essential parameters for the success of our social goal. The only way to make this possible was to reduce the number of COTS equipments that are to be used at the Ground Station and to replace them with indigenous models. A possible design for a low cost GS would include 2 crossed yagis at the two operating frequencies built and characterized by students themselves and a device to mount and hold the antennae in place. We won’t ask them to use a rotor because not using it would not harm their accuracy so much but using them would lead to a drastic increase in cost. They need to but just the signal strength indicating modules from the recommended manufacturers to be used at the Ground Stations.

3.7.2 Capabilities of GS

The social goal Ground station would have limited capabilities as they won’t be having all the features that the IITB ground station will possess. They won’t be able to demodulate the data but would just measure and store the signal strength readings which they can then forward to IITB for analysis. They also would not need 4 crossed yagis but only 2 as they won’t be demodulating the signal. Thus, they would contribute in making the TEC map of India.

Chapter 4: Social Goal

4.1 **Universities involved**

The names of the Universities currently involved in the Social goal are

a) Atharva College of Engineering, Mumbai University

b) VJTI, Mumbai

c) Saveetha Engineering College, Chennai

d) IIT Roorkee, (A M.Tech student from mechanical department)

e) I.E.Jiwaji University, Gwalior (M.P.)

f) IISER PUNE

g) BVCOE Ground station team, Navi Mumbai

4.2 First Task

Design a Yagi antenna having following characteristics:-

1) Frequency = 437 MHz

2) Gain = 10 dB approx.

Steps to complete this task:

- Read general concepts of antenna and Yagi antenna from “Antenna Theory: Analysis and Design" by Constantine A. Balanis. Chapter #1, #2 and a chapter on Yagi antenna.
- Download software nec2 (open source) and learn to simulate a Yagi antenna.
- Validate the parameters obtained from simulation with us or some of your professors
- Construct a Yagi antenna with the help of your parameters.