PRATHAM

IIT BOMBAY STUDENT SATELLITE

Conceptual Design Report

Communication Subsystem.

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1. Communication 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 = 437MHz)
- Design a high bit rate (1.2kbps) Monopole for downlink of data. (Freq = 405MHz, we donot have uplink)
- Both the monopoles must be transmitting linearly polarized radio signals.
- 2 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.

2. Subsystem Requirements :

2.1 Power subsystem :

2.1.1 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.

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

2.2 OBC

2.2.1 The OBC team should provide AX.25 data packets to the CC1020 transmitter chip .

2.2.2 The OBC team will also control the power modes of the transmitter

2.2.3 The data provided to the chip should be in the NRZ format .

2.3 Structures

2.3.1 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

2.3.2 The parallelism of the two monopoles should be as specified by the payload team

2.4 Controls

2.4.1 We need attitude control upto 3 degrees so that the pointing losses are reduced .

2.5 Thermals

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

2.5.2 The heat dissipation of circuits and amplifiers is also looked into by the thermals subsystem

3. Downlink

3.1 CW beacon

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.The reason for going with CW instead of FSK were the following :

a) We are using the amateur band for our beacon .BY using OOK we allow the amateur community to track our satellite for us without any extra investment into components.
b) CW doesn't require any sophisticated chip or IC's to do the modulation and as we do not require high data rates it does not make sense to trade the simplicity of CW for the spectral efficiency of FSK
c) The link budget was not affected much by this change as the extra Eb/No required for CW is made up for by the low data rates
d) As we are not using a diplexer on board , the use of CW would have required us to make two transmitter boards with the CC1020 chip on them which is much more sophisticated than a simple OOK transmitter circuit.

3.1.1 Frequency

3.1.1.1 Central Frequency : The central frequency will be close to 437 MHz

3.1.1.2 Bandwidth: The bandwidth will be small enough , of the order of 10 MHz , so that the SNR doesn't fall below the required margin .

3.1.2 Transmitter Circuit

We have started working on the circuit but are yet to characterize it.

3.1.2.1 Circuit description :

The transmitter circuit for CW will consist of an Oscillator, a power amplifier to amplify the generated signal and a monopole antenna to transmit the signal .

3.1.2.2 Morse code implementation: We are thinking of using either a tristate buffer or a key between the oscillator and amplifier to generate the Morse code.

3.1.3 Antenna

We have decided to use a monopole for our beacon as well as for our main transmitting antenna. We analyzed a lot of antennae before we decided to go ahead with monopoles. The major advantages of monopoles were:

a) Easy to characterize and use
b) Easy to manufacture.
c) Polarization purity essential for TEC measurement .

3.1.3.1 Dimensions :

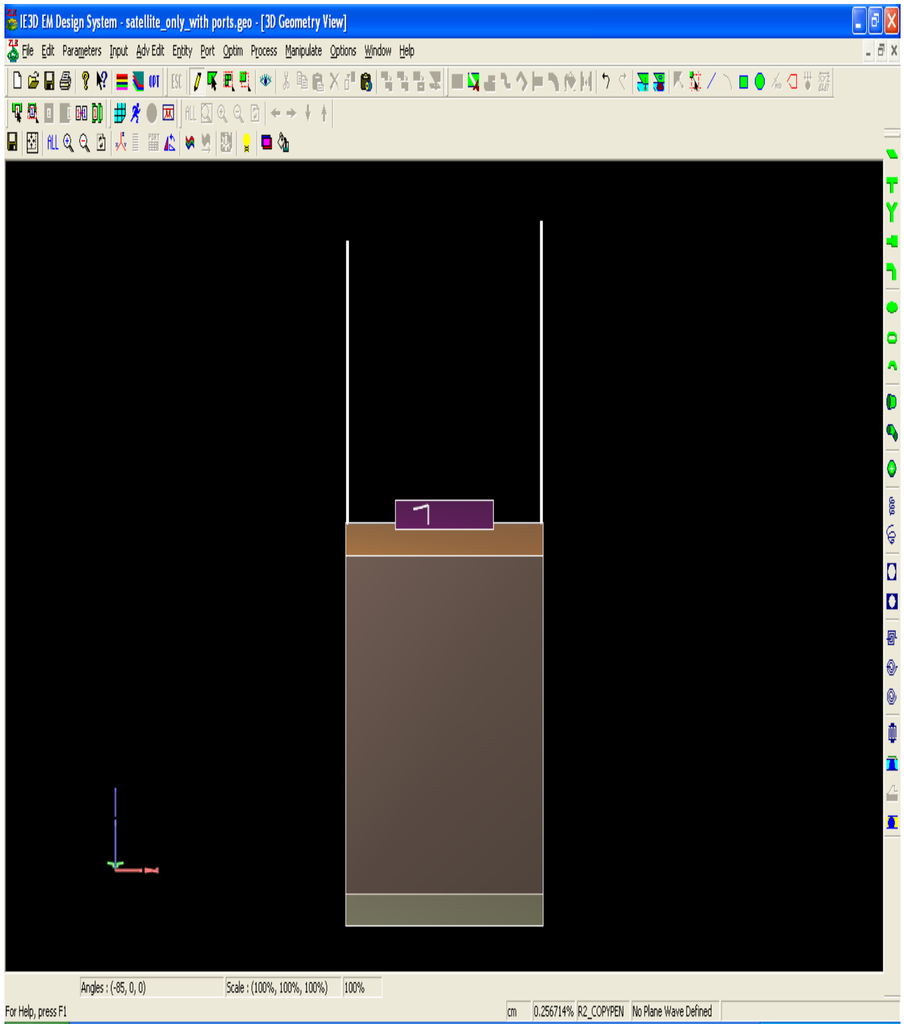
The dimensions that we arrived at using calculations and simulations were just right to fit into our satellite. The radius of the antenna was obtained from an optimization process .

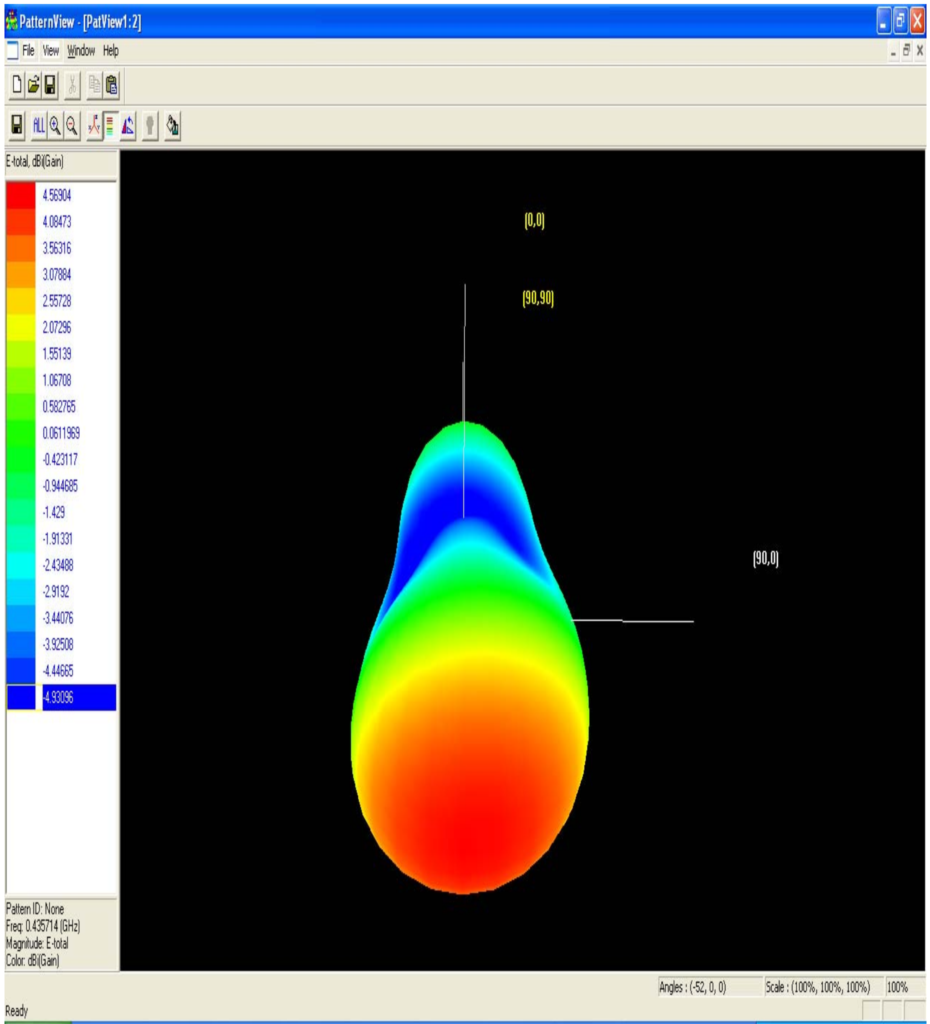
Length : 164.9 mm

Radius 1.1.mm

3.1.3.2 Simulations:

We simulated the antennae using various length in both IE3D and NEC and got the VSWR in the range of 1-1.5 for the above mentioned dimensions. We are yet to check the polarization purity that the antennae are generating .





3.1.3.3 Results

We have fixed the antenna length to above mentioned dimensions . Also the antenna should be positioned on the face opposite to the nadir as the maximum gain is in the direction opposite to the face where the monopoles are being deployed

3.1.3.4 Impedance Matching :

3.1.4 Bitrate

We are planning to send a Morse Coded signal using the beacon. One baud is equal to one bit of information (or one “state change”) per second. There are two state changes per dit in a word – one where the carrier turns on, the other where it turns off. Our calculations with “IIT BOMBAY” as the test word gave us a value of 126 baud. The maximum bit rate assumed for the beacon is 0.5 kbps or 1000 baud .

3.1.5 Modes of Beacon

It is planned to keep the beacon on for most of the times. However, we could think of the beacon transmitting every 3 minutes in power down mode if the power subsystem desires so.

3.2 FSK modulated data transmission

3.2.1 Frequency

As we plan to undertake ionospheric studies via our payload we would like to get frequencies allocated in the 400-405 band which has been reserved for meteorological purposes.

3.2.1.1 Central Frequency:

400 MHz will be the central frequency.

3.2.1.2 Bandwidth:

Bandwidth will be close to 10 MHz. As our bit-rate is less we do not require a large bandwidth. Also lesser the bandwidth more will be the SNR.

3.2.2 Protocol :

We will be using the AX.25 protocol for data transmission as it is a standard protocol being used by most of the student satellites. The data in the form of packets will be made available to the transmitter chip . The transmitter chip does not offer a built-in packet engine (as opposed to the, e.g. CC1100), so the controlling microcontroller (the OBC) must perform the Start of Frame (PREAMBLE), pattern recognition and CRC checking/generation etc.

3.2.3 Transmitter Circuit

3.2.3.1 Absolute Maximum ratings :

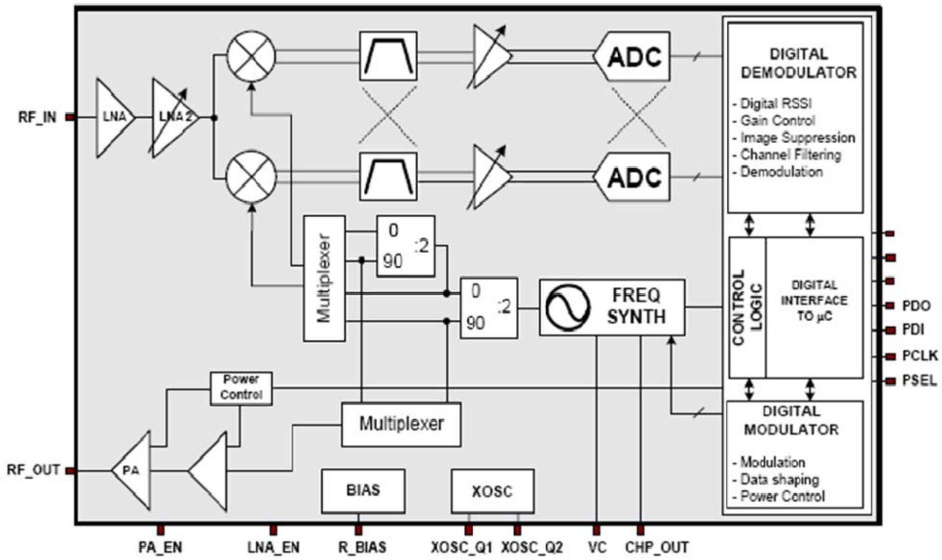
Parameter	Min	Max	Unit	Condition
Supply voltage,	VDD -0.3	5.0	V	All supply pins must have the same voltage
Voltage on any pin	-0.3, VDD+0.3	5.0	V	
Input RF level		10	dBm	
Storage temperature range	-50	150	°C	

3.2.3.2 Operating characteristics

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 – 85 (celsius)
d) Max Data rate : 153.6 kbps
e) Current consumption : 19.9 mA
f) Max transmitting power : 10 dBm

3.2.3.3 Circuit description



3.2.3.4 Microcontroller Interfacing :

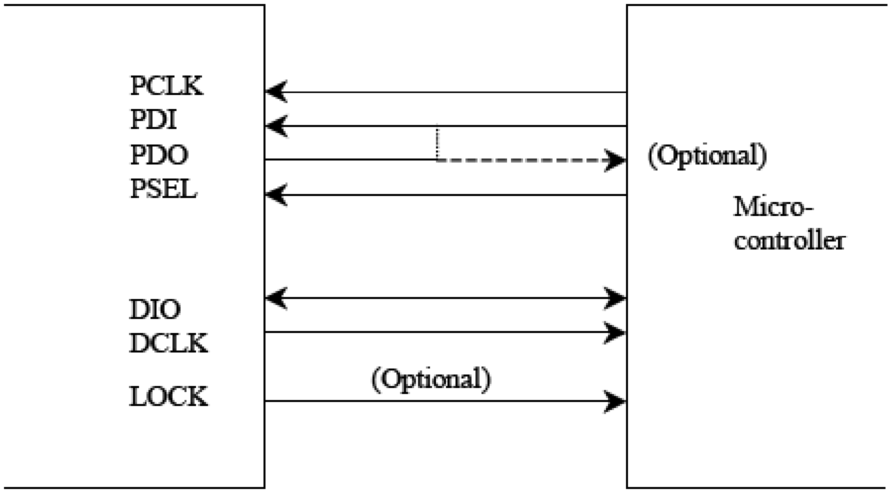
Used in a typical system, CC1020 will interface to a microcontroller which in this case will be the OBC. The microcontroller must be able to

a) Program **CC1020** into different mode via the 4-wire serial configuration interface (PDI, PDO, PCLK and PSEL).

b) Interface to the bi-directional synchronous data signal interface (DIO and DCLK)

The microcontroller can also monitor the LOCK pin for other information like the frequency lock status, carrier sense status and other status information.

The following is a diagram indicating the Microcontroller Interface.



3.2.3.5 Data rate Programming

The data rate is programmable and depends on the crystal frequency and the programming of the clock (Clock _A and Clock _B) Registers.

The data rate (baud rate) is programmable and depends on the crystal frequency and the programming of the *CLOCK* (*CLOCK_A* and *CLOCK_B)* registers.

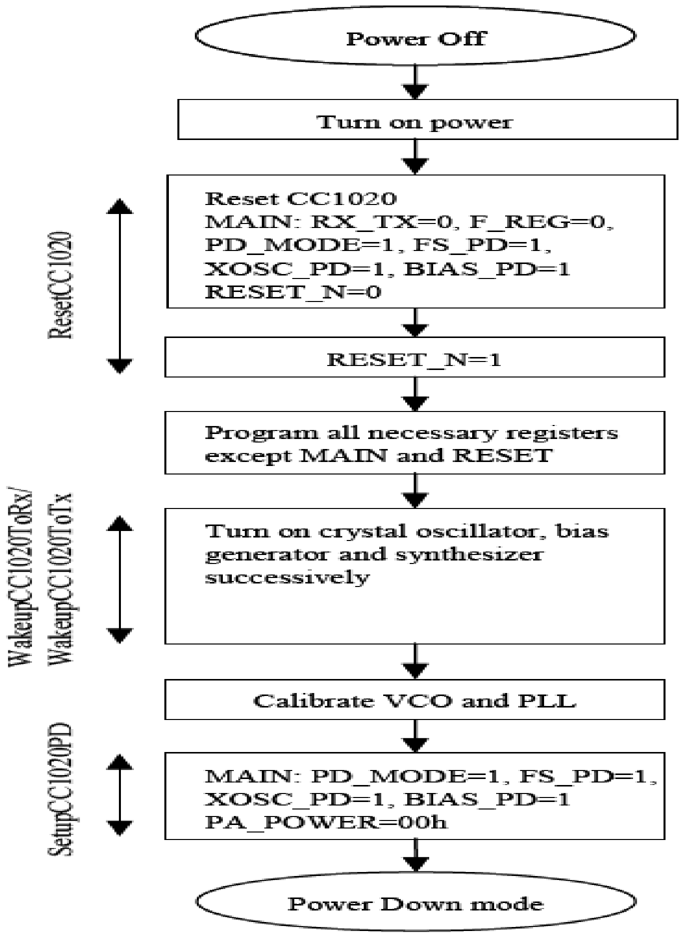
The baud rate (B.R) is given by

$$B.R. = \frac{f_{xosc}}{8 \cdot (REF\_DIV + 1) \cdot DIV1 \cdot DIV2}$$

3.2.3.6 Power programming :

CC1020 offers great flexibility as far as power management is concerned . the power down mode is controlled through the MAIN register. There are separate bits to control the TX part, the frequency synthesizer and the crystal oscillator in the MAIN register.Thus the lowest possible current consumption can be achieved in each part.

Here's a typical sequence to switch to TX/RX mode from power down mode for lowest power consumption .



3.2.4 Antenna

Our main transmitting antenna will also be a monopole having its resonant frequency at 400 MHz. As I have already mentioned before that our main reason for going with monopole antenna was its polarization purity which is essential for the payload .

3.2.4.1 Dimensions :

Length :18.5 mm

Radius: 1.1mm

3.2.4.2 Simulations :

The simulations yielded results similar to those of the beacon .

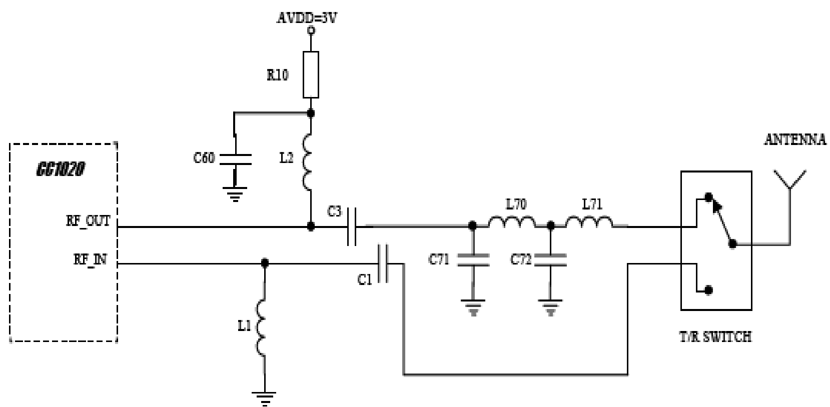


Figure 25. Input/output matching network

The values for the capacitors and other components are yet to be found using RF smart studio.

3.2.5 Bitrate :

We will be transmitting GPS data and health monitoring data over the ground stations . The maximum bitrate that we are currently looking at is around 1.2 kbps. The maximum allowable bitrate by the transmitter chip is 153.6 kbps

3.2.6 Modes of transmission :

The FSK transmission will have two modes of transmission .It will transmit GPS and health monitoring data when it is above Our own Ground station . It will only transmit GPS data when it is above other Ground Station . It will be switched off when it is not above either of the two.

4. IIT - B Ground station

4.1 Location Of Ground Station

4.1.1 Factors considered

a) Height of the site

b) Interference from surroundings

c) Horizon to horizon angle

d) Ease of accessibility

e) Availability of power , LAN etc

4.1.2 Conclusions

a) The ANANTA building and GG building were the two choices that fulfilled most of these conditions.

b) The GG building might be a better option due to its proximity to the academic area.

4.2 Tracking

4.2.1 GPS Tracking system

4.2.1.1 Introduction

GPS is a network type positioning system who works with contingency of at list 24 satellites. A GPS receiver receives the signal from at list 4 satellite and calculates its position by triangulation method with respect to the GPS satellite and thereafter calculates its exact position.

The distance calculation is carried by the atomic clock. Actually each GPS satellite have a atomic clock and the signal that transmitted have time information at the beginning a receiver receives the data and compare it with its one local time and than calculate the distance. After calculating the distance from 4 GPS satellite calculates its latitude, longitude and altitude. In our system we attached a GPS receiver to our satellite and make it to transmit the current position.

4.2.1.2 Norad Data :

We will be using NORAD data and a tracking software in order to get the azimuth and elevation to feed top our rotors.

4.2.1.3 Tracking software :

Tracking software gets input from the GPS signal transmitted by satellite when it is visible region and based on this software track the path for next times on the basis of planetary motion fundamentals and this prediction used for the tracking of antenna to visit the satellite next time. Also is used to display the satellite orbit for the controlling purposes. We may use "TRAKSAT Version 4.0 created by Paul E. Traufler, 111 Emerald Drive, Harvest, AL 35749 USA" for tracking purpose. It gives wide range of tracking station and the tracking parameters. Also it has wide range of menu option and time format of Real time as well Delta time. This software fully developed in C coding and compatible easily with most of the PC configuration. It requires minimum configuration of *"386-33MHz with 4 Meg Ram, 387 coprocessor, Super VGA color graphics, 130 Meg hard drive, 1.44M floppy, mouse, DOS 5.0 or6.2, Windows 3.1"*. A pictorial view of output is shown in Fig.

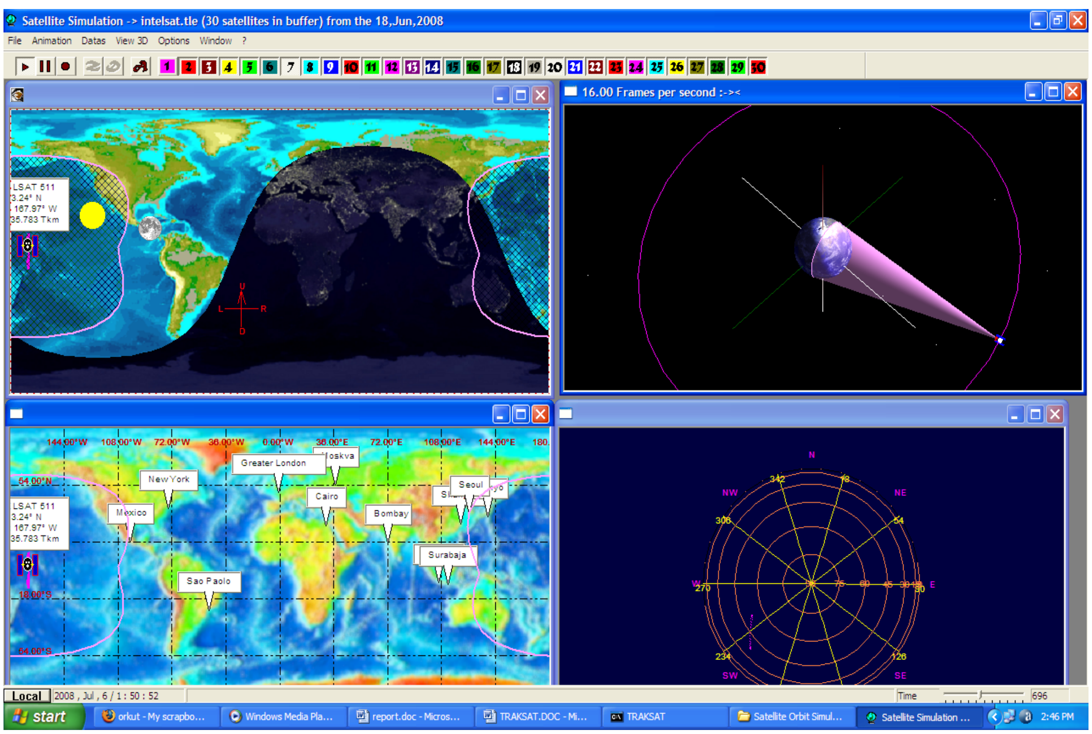


Fig. 5.1

Files needed for the software:

Following are the files which is used by the program in order to simulate and find the orbit of corresponding satellites,-

TRAKSAT.EXE: The program.

TRAKSAT.INI: The default data for TRAKSAT.

TRAKSAT.CTY: The cities file for tracking stations.

EARTH.DAT: World map data file.

EARTH.BIN: World map data file.

TLE.TXT: This is the latest NORAD satellite data set,

MODERN.FON: This is a font file used for the graphics.

FONT.VGA: This is a font file used for the menus.

ORDER.FRM: This file contains TRAKSAT order forms.

STAR6A.BIN: This is a star data base that is NOT required to run TRAKSAT, it is optional. This data file can be used in the external star data option. It has all stars to magnitude 6.0 in it.

4.2.1.4 Rotor :

We will be using the G5500 azimuth elevation rotor by YAESU and the GS232A computer interface for our ground station. We have gone for the above components because they have been used by a large number of student satellites at their ground stations.

4.3 Antenna

We need to measure the polarization of the incoming signal in order to compute TEC. We will have to measure the signal strength in two perpendicular directions and then use those values to compute polarization angle . For this purpose we have decided to use a crossed yagi at our ground station .

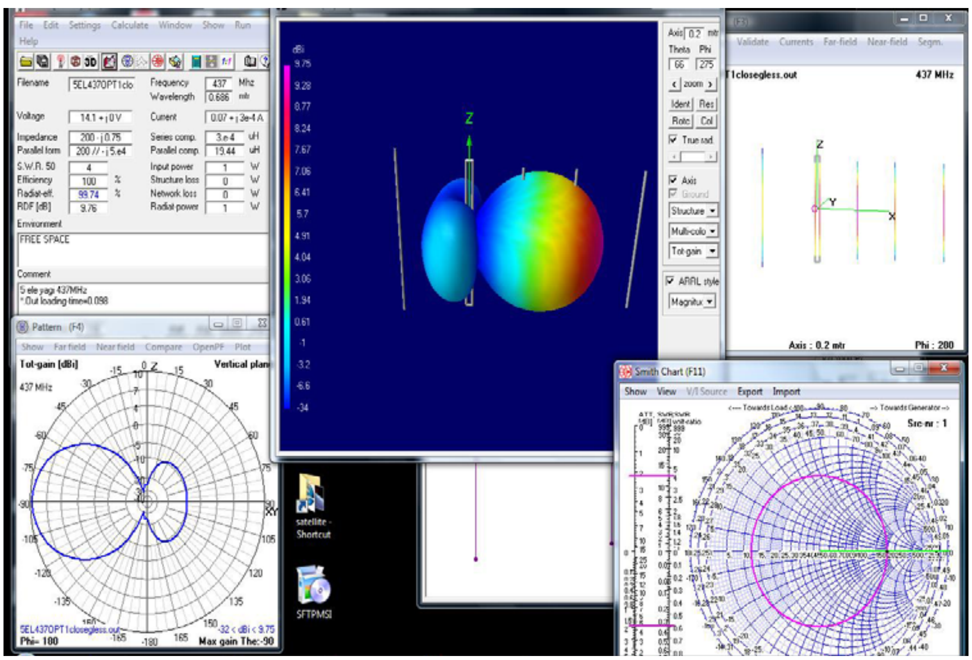
4.3.1 Dimensions :

The following are the dimensions of crossed yagis that we will be using at our ground station.

Radius	2.976mm
Driven length	0.30216m
Reflector length	0.34217m
Director length	0.28043m
Reflector spacing	0.1513m
Director spacing	0.10955m
Spacing b/w the 2 arms of folded dipole	0.01382m

4.3.2 Simulations :

The simulation of the yagis were done using NEC and the following pattern was obtained



4.3.3 Results :

a) Gain 9.75 dB

b) F/B ratio 19.6 dB

c) VSWR 1

d) Beamwidth 50 degrees

4.3.4 Impedance matching:

4.4 CW receiver Circuit

We have started working on the circuit but are yet to characterize it.

4.5 FSK receiver

4.5.1 Absolute Maximum ratings :

Parameter	Min	Max	Unit	Condition
Supply voltage,	VDD -0.3	5.0	V	All supply pins must have the same voltage
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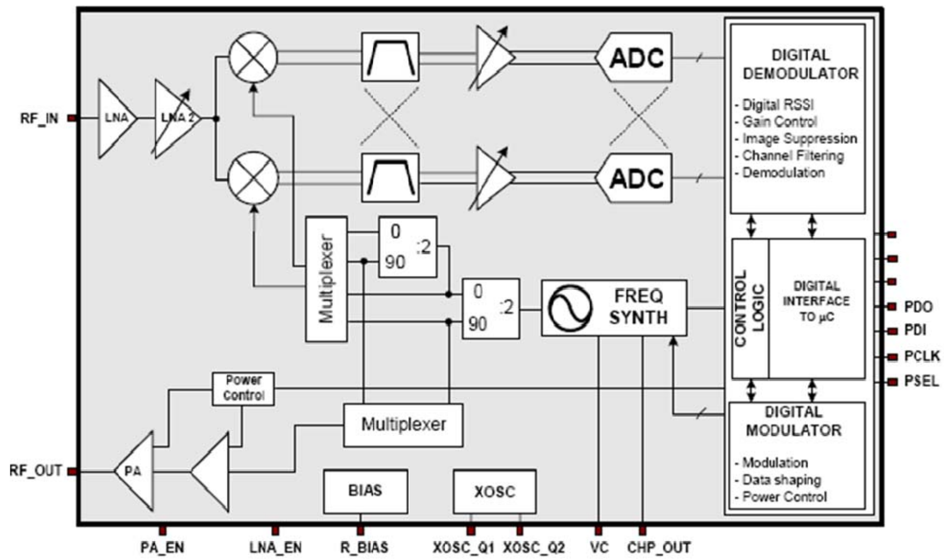

4.5.4 Packet Disassembler :

We will be using a packet Disassembler from YAESU in order to get the packet data from the CC1020 chip.

References :

a) Antenna Theory : Balanis
b) ARRL Handbook
c) Ncube Documentation
d) MEROPE Documentation
e) Compass Documentation.
f) AAUSAT Documentation
g) Antennas – J.D. Krauss
h) CC1020 Datasheet
i) Satellite Communication Engineering – Tri T. Ha

A heartfelt thanks to Prof. KP Ray of SAMEER and Mr . Ravindra from Antenna lab for helping us with our mundane doubts