Restricted

Critical Design Review Documentation Guidelines

For

IN- SPACe

CANSAT India Students Competition 2024-25

by

ASTRONAUTICAL SOCIETY OF INDIA

ASTRONAUTICAL SOCIETY OF INDIA
U. R. Rao Satellite Centre
Bengaluru 560017

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SUMMARY

CANSAT students’ competitions are being conducted worldwide including in India. It is noticed that Indian students are participating and winning laurels for the nation. Taking cue from this, Astronautical Society of India has decided to conduct IN-SPACe CANSAT India Student Competition from 2023-24. The first edition of IN-SPACe CANSAT India student competition was conducted on April 15-17, 2024. The critical design review documentation guidelines are provided in this document.

NB: *While due care is taken to prepare this document. The decision of organizers will be final in case of any discrepancies etc.*

TABLE OF CONTENTS

1 INTRODUCTION

The IN-SPACe CANSAT India student competition 2024-25, is being organized by Astronautical Society of India, to inculcate the space science and technology temperament among the student community. This competition involves the design, development & launch of a CAN sized satellite to an altitude of 1000 meters above the launch site. The competition will also help to create a wide scale ecosystem for Swadeshi Space activities in the country and bridge the industry academia skillset gap thereby enabling the future space force creation for the AatmaNirbhar Bharat.

This document describes the guidelines for the **Critical Design Review (CDR).** The detailed guidelines for the competition are already communicated by the organizing team. This document contains the axes definition to be followed by all teams, mounting of CANSAT on the launcher, the suitable antenna systems selection & mounting, CANSAT deployment mechanism and first parachute folding method.

The teams are assigned a unique team identification number. Please use it in all the correspondences with the organizers.

The detailed guidelines along with timeline for flight readiness review (FRR)/pre-shipment review (PSR) and post flight review (PFR) shall be notified in due course.

2 MISSION REQUIREMENTS

2.1 MISSION REQUIREMENT FOR CANSAT INDIA 2024-25

Design a CANSAT weighing under 1 kg (+/- 0.050 kg), with dimensions not more than 0.15 m diameter and 0.4 m height. The objectives for the 2024-25 competition are as defined earlier:

- **Innovative Mechanical Gyro-control** system that shall demonstrate the descent control of the CANSAT.
- **CANSAT descent control system** that shall open at an altitude of 500 m.

CANSATs will be launched to an altitude of 1000 m from the ground level and above the launch site & deployed near the peak altitude. During the ejection from the rocket, orientation of the CANSAT is not controlled. The CANSAT must remain intact during the course of the entire mission and send the data to the ground station through a telemetry link.

2.2 Indicative Optional Objectives

Few indicative optional objectives are listed below. However, teams are encouraged to propose novel techniques that they can demonstrate within the specified mass, power and budget constraints.

a) Novel descent trajectory control, Innovative materials,

b) Additional innovative sensors and communication systems

c) Provision of video capture from separation till final touch down

d) Innovative recovery techniques viz. HAM radio/Advanced beacons.

e) Innovative Quality and reliability analysis methodologies.

3. Critical Design Review

Critical Design Review is a comprehensive document which ensures how the final product (here CANSAT) would look like along with detailed subsystem level analysis. The CDR is a multi-disciplinary document providing broad guidelines for CANSAT fabrication, testing etc. The CDR must contain the details of all subsystems, viz the components of the subsystems, their configuration and functionality. Testing philosophy and plan must be worked out. Test results for characterization and evaluation of the components/subsystems should be carried out and presented to committee for assessment. Teams can expect campus visits by organizers for assessing the progress at any stage of the competition. The visits shall be coordinated in consultation with faculty advisor.

During the CANSAT integration stage the teams shall ensure that they have thoroughly tested each and every subsystem and will be required to produce the test results during the review.

A successful CDR determines that the subsystem requirements, subsystem design & analysis, test results and evaluation is satisfactory to the objectives of the competition.

After the successful completion of CDR, the teams should prepare themselves for the CANSAT FRR/PSR followed by the CANSAT launch.

4. Critical Design Review objectives

During the PDR stage teams have been evaluated to assess their understanding in terms of technical aspects, systems engineering, innovation and skills requirements. The next stage of the CANSAT competition is Critical Design review (CDR). The main objectives of the CDR are to assess:

a) the response to suggestion made by jury during the PDR
b) final design implementation

c) mechanical, electronics and various interfaces
d) test results and validation of various subsystems of CANSAT
e) structural simulation as well as CG MI computation
f) RF link margin and antenna characterization (both On-board and Ground systems)
g) the power requirements and battery selection
h) quality and qualification plan
i) various failure modes and analysis
j) mission display
k) mission simulations demonstrating the expected performance
l) Ground Station Configuration & software

5. KEY REQUIREMENTS

The basic requirements have been outlined in Mission Requirement & Preliminary Design Review Documentation Guidelines. Based on the PDR review few more requirements emerged, which are suggested to teams to address and implement in the CANSAT:

a) The axis of CANSAT are defined as in Fig. 1. In the figure yaw (X_C) axis is pointing towards the Earth, Roll (Y_C) axis is into the page and Pitch (Z_C) completes the right handed triad.

b) The axis definition of launcher with CANSAT mounted is shown in Fig. 2. In the figure roll (Y_L) axis is pointing upward along the nosecone, pitch (- Z_L) axis is into the page and yaw (Z_L) completes the right-handed triad. Please note that CANSAT negative yaw axis (-X_C) will be aligned to the launcher roll (Y_L) axis.

c) Teams are required to present detailed specifications of all the sub-system components etc.

d) Teams are suggested to mount GNSS antenna in CANSAT such that it should have clear FOV towards zenith (with an angle) for GNSS signals and other antennas towards ground for TM & TC i.e., along yaw axis. (refer Appendix-A) for further details)

e) It is suggested that RF transparency to be ensured while selecting the structural material

f) During the second descent control mechanism activation, teams must ensure that there is no entanglement due to first descent control mechanism

g) Selection of battery (‘s) should be as per the CANSAT power requirement.

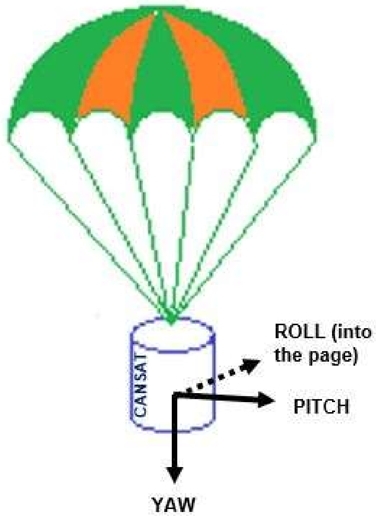


FIG. 1: CANSAT AXIS DEFINITION

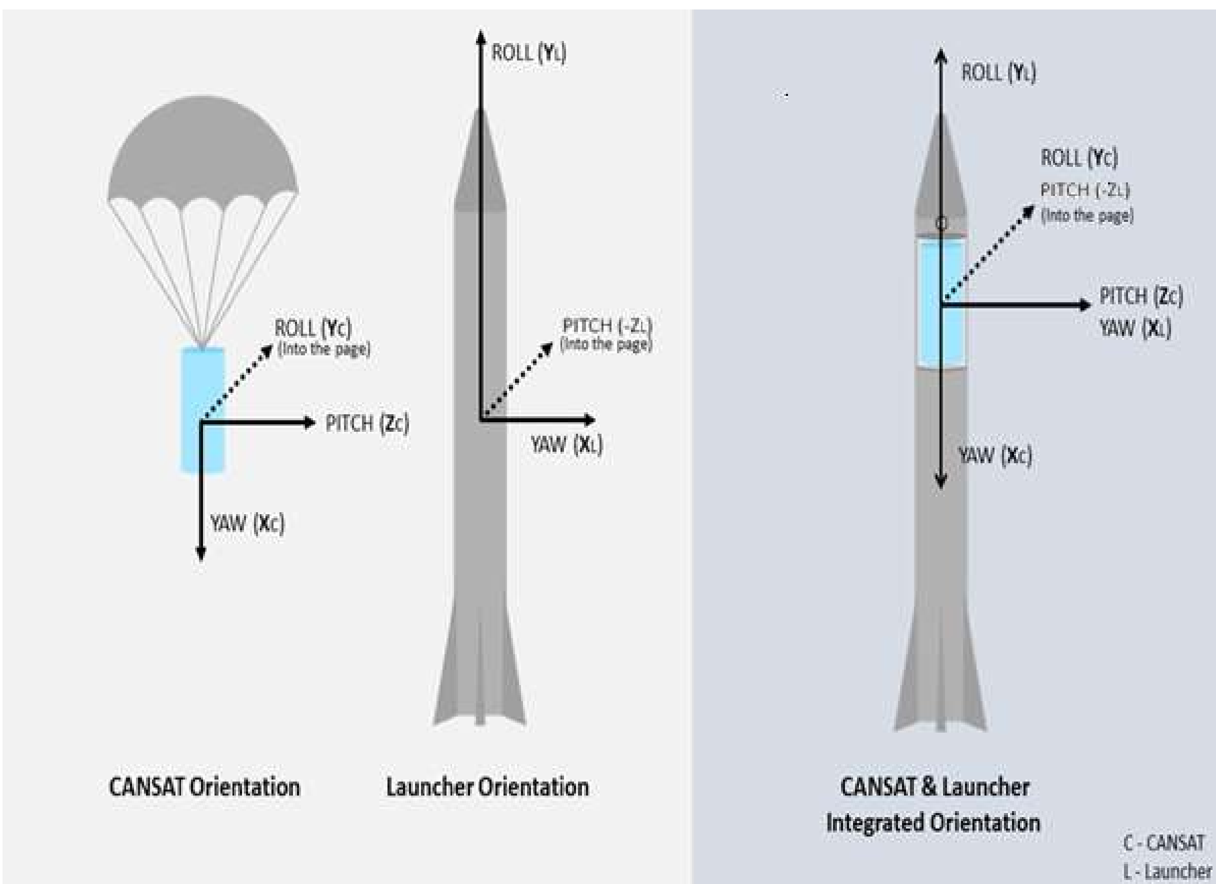


FIG. 2: CANSAT LOCATION ON LAUNCHER

6. Critical Design Review Documentation Guidelines

Critical Design Review (CDR) - is a detailed design review of the system to ensure that the sub-systems can be analyzed in details and can meet the mass, dimension, budget, schedule and other specified constraints of the competition. It shall consist of:

a) CANSAT Mission Overview
b) Team description
c) List of acronyms
d) System overview:
- **i** Brief summary of the mission
- **ii** Any changes made from the PDR stage
- **iii** Overview of system level requirement
- **iv** Entire CANSAT activities from design stage to the CANSAT launch, recovery and data retrieval
- **v** Deviations, if any
- **vi** CANSAT physical layout
- **vii** Material procurement details
- **viii** System and sub-system level analysis and test results
- **ix** Flight readiness Parameters
- **x** Pre-flight Analysis

e) Sensor systems summary, characterization and test results
f) Actuator summary shall include:
- **i** the control mechanisms of the actuator, if any
- **ii** the system level gyroscopic attitude control
- **iii** descent control mechanisms incorporated in the CANSAT
- **iv** Simulation analysis, characterization and test results summary

g) Block diagram of Attitude control loop and Actuator control loop should be brought out clearly
h) Detailed description of realized Subsystems:
- **i** Payload Subsystem
- **ii** Housekeeping Subsystem:
  - Mechanical Subsystem
  - Actuators
  - Communication and Data Handling Subsystem
  - Electrical Power Subsystem
  - Sensor Systems
  - Parachute deployment and recovery
- **iii** Detailed description of changes made from the PDR stage and, reason thereof
- **iv** Subsystem level testing and results
- **v** CANSAT integrated module simulated test results (Stress-Strain, Vibration, TTLC fit check, RF jamming within the structure)

- **vi** Environmental test results

i) Design details, including parameters considered for design and simulations wherever applicable and available.

j) CANSAT algorithm, final test results, along with any deviations, if observed

k) TTLC link margin realized

l) Ground station final test results, along with any deviations, if observed

m) CANSAT Integration and Testing

n) Mission Operations & Analysis

o) Pre-flight requirement-check analysis

p) Logistics and Transportation

- **i** CANSAT transportation and handling
- **ii** Any special permits requirements

q) CANSAT ready to launch and final comments

r) Conclusion

NB: The CDR document should be submitted latest by 28 February 2025, along with participation fees.

7. CANSAT LAUNCHER INTERFACES

The CANSAT shall be placed inside a cylindrical box, pressed on both sides. The CANSAT shall not be attached to the rocket by any mechanism, to avoid any complication during separation from the rocket. The payload area is covered by two aluminum panels. These panels are ejected at the specified altitude (i.e., ~ 1000 meters) and the CANSAT is released by the compressed spring push mechanism. The release mechanism is designed to hold a compressed spring adjacent to the payload with CANSAT inside the payload bay. The spring is fixed to holding bracket affixed to the spars-load bearing structure inside the payload bay. Compressed spring rests inside the bracket with a nylon polymer line. A resistor wire such as nichrome wire is then placed on the polymer and heated up by electricity. This melts it and the tension in the cable is released. After successful cut the spring extends to its natural length. Set of separation springs are then used to further separate the payload.

A mechanical switch opens the payload-bay panels outside, opening up the CANSATs which are then ejected with Spring Push mechanism. Inside structure consists of four Aluminum U-beams with the specified dimensions and they create the main bearing structure of the rocket. ***Students are expected to fold the parachute properly and place their CANSAT into the payload bay and close with panel covers.***

In the launch sequence, rocket achieves the apogee of ~1000 m, onboard sensor avionics senses the desired altitude reached and then sends command to a mechanical switch that opens the payload bay panel. Immediately after ~1.0 sec the panel opens, Nichrome resistor wire of the push spring mechanism heats up, releases the tension in the spring. The later eventually ejects the CANSAT out of the payload bay. The flight then further releases the parachute of the recovery system, safe landing the rocket motor assembly. The first parachute shall be deployed immediately after separation from the launcher through atmospheric drag.

8. Critical Design Review Presentation Guidelines

Subsequent to submission of the CDR document a presentation to made by the team to jury for evaluation. The other guidelines remain same as provided in the PDR document. The tentative dates of CDR review will be announced by the organizers. **The teams are advised to prepare the CDR document using Microsoft word/LaTeX document and submit as pdf.** The CDR presentation shall be in the format already communicated during PDR stage.

9. Conclusion

This section shall contain summary of the design of various subsystems and mission analysis along with the derived conclusions to achieve the desired mission objective.

APPENDIX-A

Antenna Systems for CANSAT

1.0 Introduction:

The mission requirement for the IN-SPACe CANSAT India students' competition by Astronautical Society of India includes Navigation and Communication systems as part of the CANSAT payload. The Navigation system comprising of a GNSS/NavIC receiver shall generate position velocity and time (PVT) information about the CANSAT and the Communication system shall support the telecommand and telemetry signals between the CANSAT & its Ground Station. Both the systems inevitably need antennas to establish the navigation and communication links as shown in the Fig. 3. Typical antenna placement in a CANSAT is shown in Fig. 4.

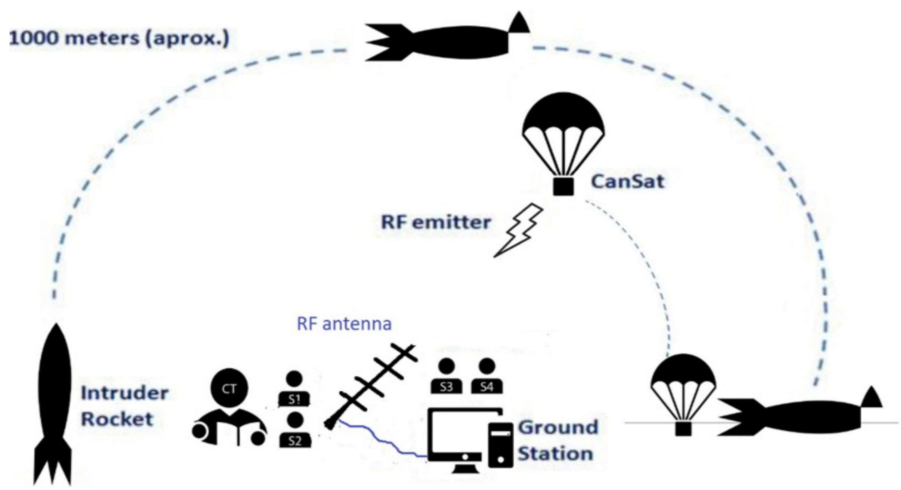


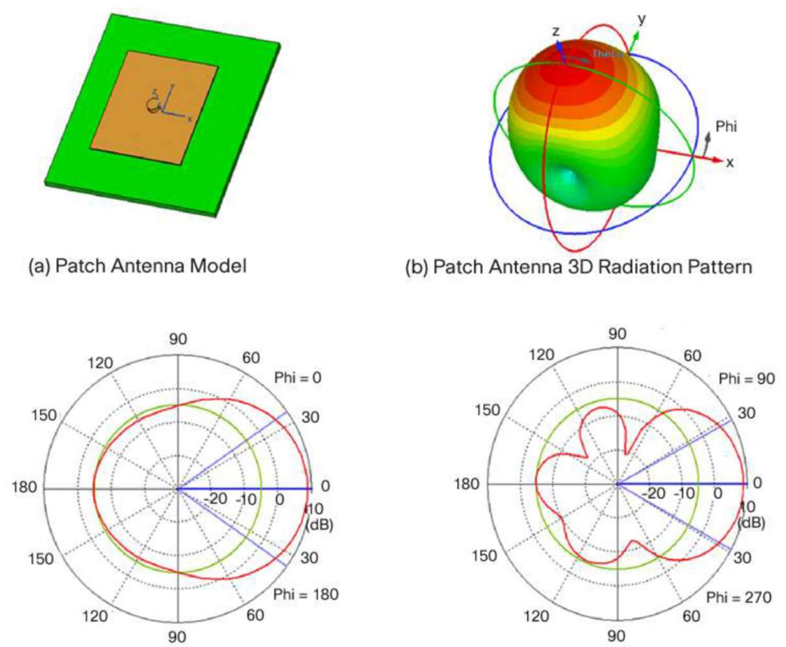
Fig. 3: Typical Scenario of CANSAT Antenna Operations

Fig. 4: Typical Antennas on CANSAT

2.0 CANSAT Antenna System

2.1 GNSS/NavIC Antenna Systems:

The GNSS/NavIC receiver's antenna is right hand circularly polarized (RHCP) and operates in the L-band. It needs to have a wide beam radiation pattern with unobstructed field of view in order to capture signals from maximum no. of GNSS/NavIC satellites. Typical it is mounted on the top deck of the CANSAT pointing towards space. Various antennas for this purpose include **patch, helix, choke horn and cross-dipole**. The patch antenna is preferred due to low profile design, low cost and ease in integration with the receiver circuit. A typical patch antenna has 6-8dBi gain and its 3-D & 2-D radiation patterns are shown in Fig. 5.



(a) Patch Antenna Model (b) Patch Antenna 3D Radiation Pattern

(c) Patch Antenna Azimuth Plane Pattern (d) Patch Antenna Elevation Plane Pattern

Fig. 5: Radiation Patterns of a Patch Antenna (2-D and 3-D)

2.2 Communication Antenna Systems:

The CANSAT communication system shall have two antennas *viz.* Onboard Communication antenna mounted on the CANSAT and Ground Station Communication antenna on the ground.

The **Onboard communication antenna** operates in the allowed frequency band (IMS 2.4 GHz or sub-1GHz bands) and has to be compact in size to fit inside the CANSAT container. As the CANSAT's orientation varies throughout its descent, the radiation pattern of the Onboard antenna inevitably needs to be Omnidirectional. Various antenna options for this purpose includes ***Whip antennas (λ/2 dipole or λ/4 monopole), rubber ducky & patch array***. The whip antenna & rubber ducky antenna are preferred due to their simple structure and desirable radiation pattern as shown in Fig. 6. These antennas are linearly polarized and must be mounted such that the length of the antenna is along the axis of CANSAT cylinder. These antennas typically have a gain of 2.2-4.0dBi.

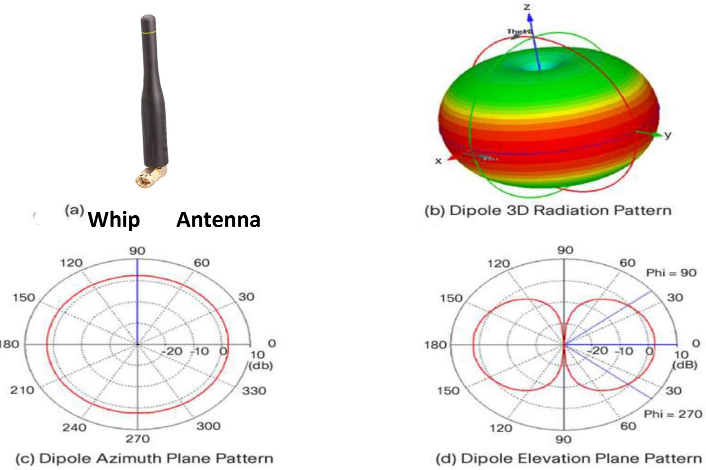


Fig. 7: Radiation Pattern of a Dipole Antenna

The **Ground Station Communication antenna** is either fixed on the ground or handheld by the user. G/S antenna polarization (to the extent possible) should be aligned with the Onboard antenna polarization. It should be possible to rotate the G/S antenna along its axis for this purpose, either mechanically or manually by rotating the wrist, in case of handheld. It operates at the same frequency as the Onboard communication antenna & has larger size and higher gain to have a stable communication link for sending & receiving Telecommand & Telemetry signals. Various antenna options for this purpose includes paraboloid reflector, Patch array, Yagi-Uda, Double Biquad antenna etc. However, the Yagi-Uda antenna is preferred due to simplicity, easy construction and low cost. Typical radiation pattern is shown in Fig. 8 and 10-14 dBi gain can be achieved by varying the no. of elements.

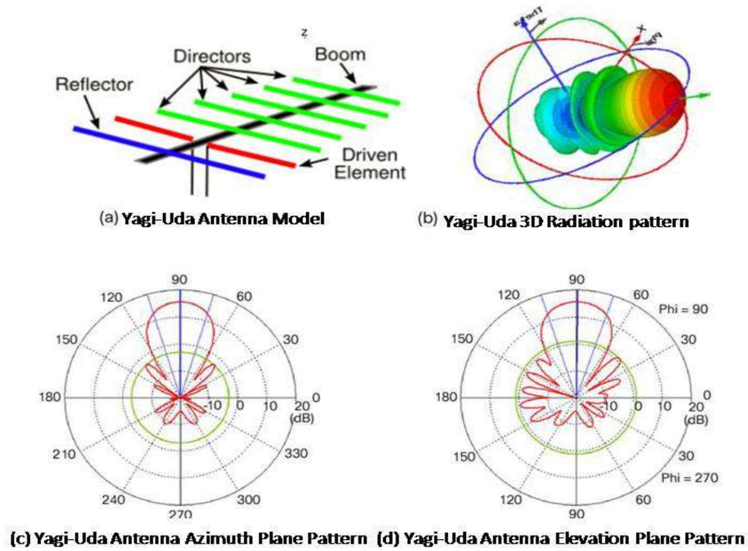


Fig. 8: Radiation Pattern of a Yagi-Uda Antenna

3.0 Material of CANSAT Container/Body:

While the Ground Station antenna can be easily positioned to operate in open space, care must be taken in choosing the material of the CANSAT container/body and placement of the onboard GNSS/NavIC & communication antennas. As RF signals are reflected and blocked by electrically conducting material the onboard antennas should be either placed outside the enclosure or suitable openings should be provided in the CANSAT container/body so that they can radiate properly.

4.0 Basic Antenna terms [1, 2]:

4.1 Radiation Pattern: An antenna radiation pattern or antenna pattern is defined as a graphical representation of the radiation properties of the antenna as a function of space coordinates. That is, the antenna's pattern describes how the antenna radiates energy out into space (or how it receives energy). The antenna pattern is actually three-dimensional and is commonly described with two planar patterns, called the principal plane patterns. These principal plane patterns can be obtained by making two orthogonal slices through the 3D pattern through the maximum value of the pattern or by direct measurement. It is these principal plane patterns that are commonly referred to as the antenna patterns, as shown in Fig. 9.

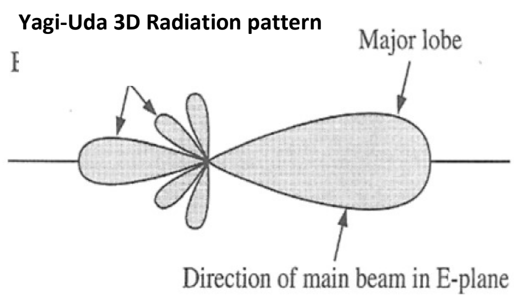


Fig. 9: Typical Radiation Pattern of a Directive Antenna

4.2 Gain: Gain of an antenna (in a given direction) is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotopically. Note that an isotropic radiator would be lossless and that it would radiate its energy equally in all directions. That means that the gain of an isotropic radiator is G = 1 (or 0 dB). It is customary to use the unit dBi (decibels relative to an isotropic radiator) for gain with respect to an isotropic radiator. Hence, gain of an antenna is a measure of directional nature of its radiation pattern. Gain does not include losses arising from impedance mismatches (reflection losses) and polarization mismatches. Typical gain values of a dipole/monopole are 2.2dB to 4.0dBi whereas that of a Yagi-uda antenna varies from 10-14dBi depending upon the no. of director elements & type of driven element (ref. Fig. 10).

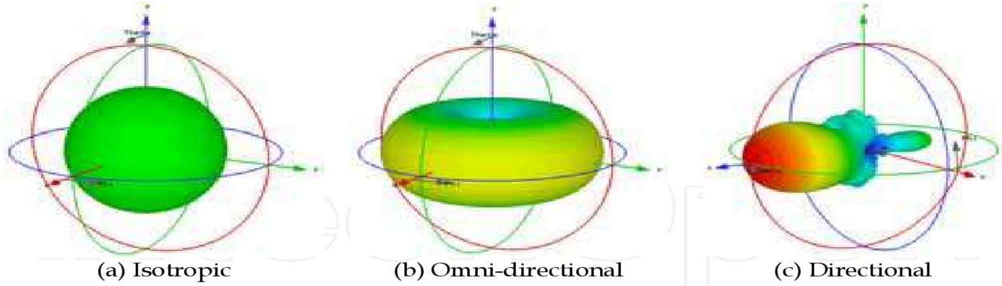


Fig. 10: Types of Antenna Radiation Patterns

4.3 Polarization: Polarization specifies the orientation of the electric field during one RF cycle. Polarization may be classified as **linear, circular, or elliptical.** If the vector that describes the electric field at a point in space as a function of time is always directed along a line, the field is said to be linearly polarized. In general, however, the figure that the electric field traces is an ellipse, and the field is said to be elliptically polarized. Linear and circular polarizations are special cases of elliptical, and they can be obtained when the ellipse becomes a straight line or a circle, respectively. Clockwise rotation of the electric-field vector is designated as right-hand polarization and counterclockwise as left-hand polarization (refer Fig. 11).

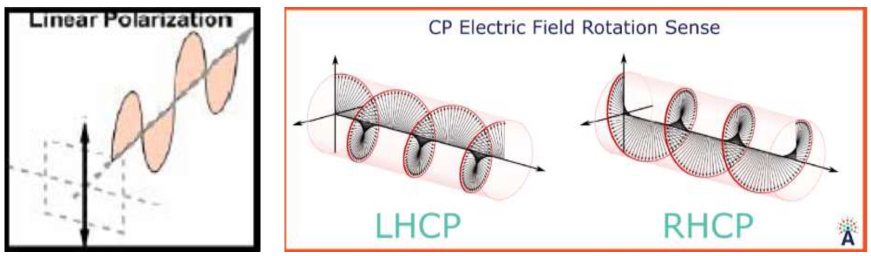


Fig. 11: Linear & Circular Polarization

Polarization alignment of transmit & receive antenna is of paramount important in establishing a stable communication link between the Onboard & Ground Systems as depicted in Fig. 12.

Fig. 12: Importance of Polarization alignment between Tx & Rx Antennas

References:

1. Balanis, C., *Antenna Theory- Analysis and Design*, 3rd ed., New York: Wiley-Inter-science, 2005.
2. Kraus JD and Marhefka RJ., Antennas for All Applications, 3rd ed. New York: McGraw-Hill; 2002.

APPENDIX B

- **The tentative timeline for the CANSAT India student competition 2024-25 are provided below (can be changed by organising committee, if required):**

S.No.	Activity	Start Date	End Date
1.	Registration and release of competition guidelines	06-06-2024	30-06-2024
2.	PDR Document Submission	01-07-2024	30-09-2024
3.	Preliminary Design Review Completion by Jury	01-10-2024	31-12-2024
4.	Critical Design Review Document Submission	01-02-2025	28-02-2025
5.	Critical Design Review Completion	01-03-2025	31-03-2025
6.	Flight Readiness Review	01-08-2025	30-08-2025
7.	Final Competition, Post Flight Review and Results Declaration (TBC)	01-10-2025	31-10-2025