ANURAG GROUP OF INSTITUTIONS
An Autonomous Institution

Department Of Mechanical Engineering

Electro-Mechanically activated proof of life transmitter for CubeSat

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Abstract

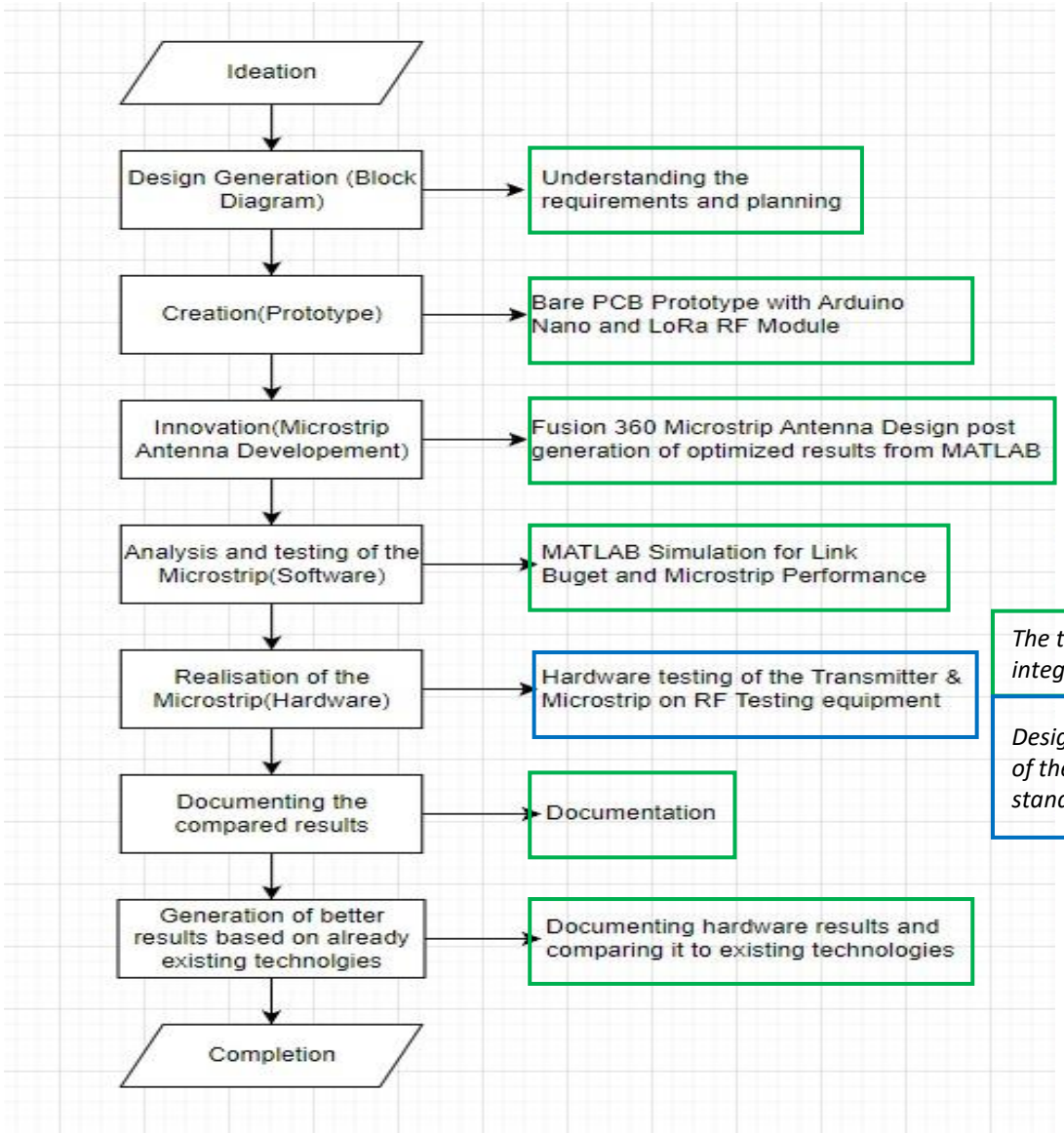
- The design and development of a Mechanically activated by dual redundant deployment switches Proof-of-life transmitter to be flown on nanosatellites is described.
- The Transmitter is activated by a composite based mechanically actuated deployment switch which activates the transmitter that has a power output of 500mW minimum over the whole of India, the design is based on a low power ARM/AVR architecture-based processor and LoRa FSK Modulation.
- The final transmitter utilises a novel microstrip/Tape measure antenna and coaxial technologies to obtain the specified output level and stability for an in-orbit performance and a life expectancy of at least 12 Months, under significant constraints on size, weight and power consumption.

Description

- The Mechanically activated dual redundant deployment switches are designed to be actuated at the time of satellite deployment from the deployer as and when the satellite is released from the deployer the switches are then released closing the circuit enabling the transmitter to start its transmission as we all know failure is not an option in space systems we have made sure the system is redundant by adding two such deployment switches even when a failure of one switch occurs the system still comes to life as the second switch deployment is independent of the first and the system detects this.
- Also developed under this project is a tape measure dipole antenna which is crucial for the satellite as real estate is a concern on nano satellites the tape measure antenna can be folded/wrapped around the satellite structure and will be released automatically as the satellite is deployed from the deployer and due to the tape measure being a memory alloy it tends to assume its original form and deploys into a dipole antenna.

Methodology

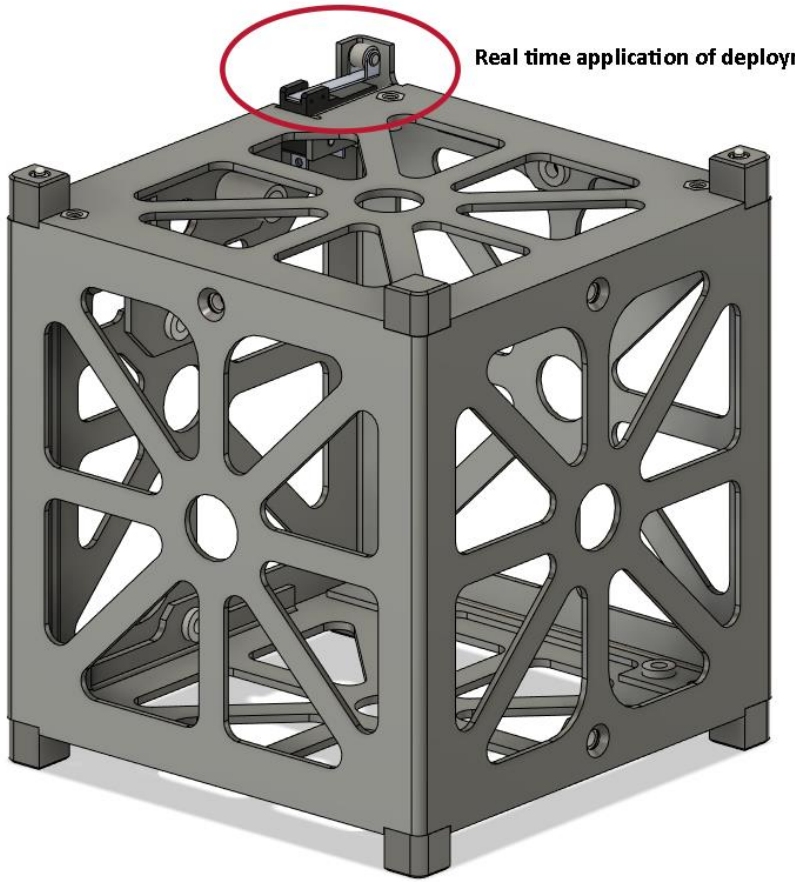
The flowchart describes the flow of the project development as stages.

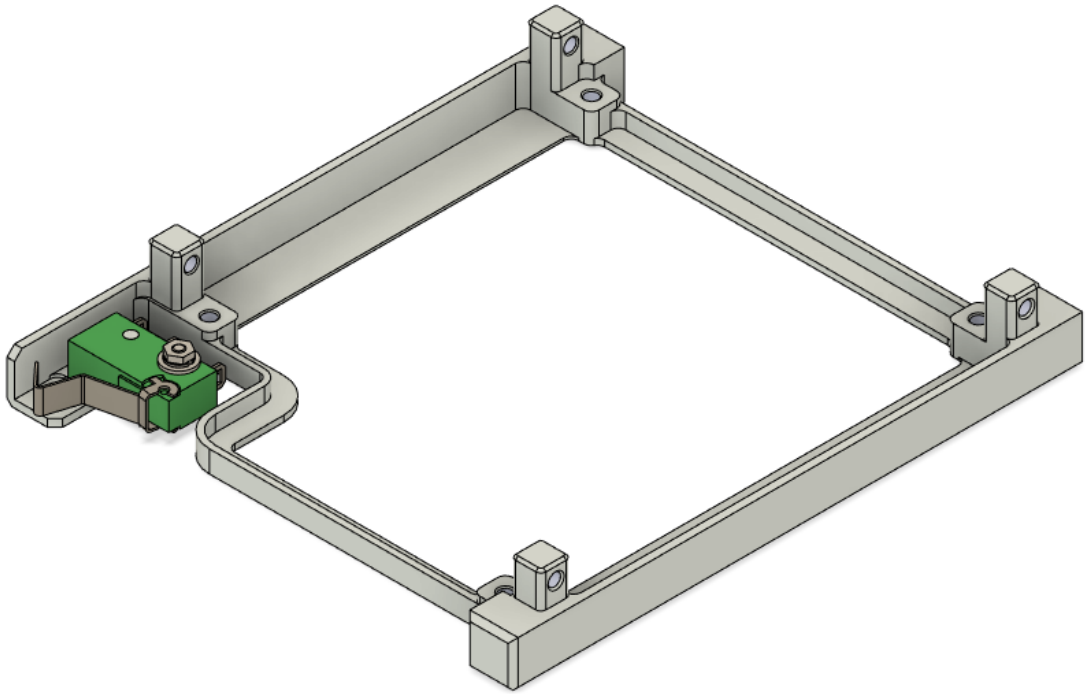


The tape measure antenna is integrated and tested with the system

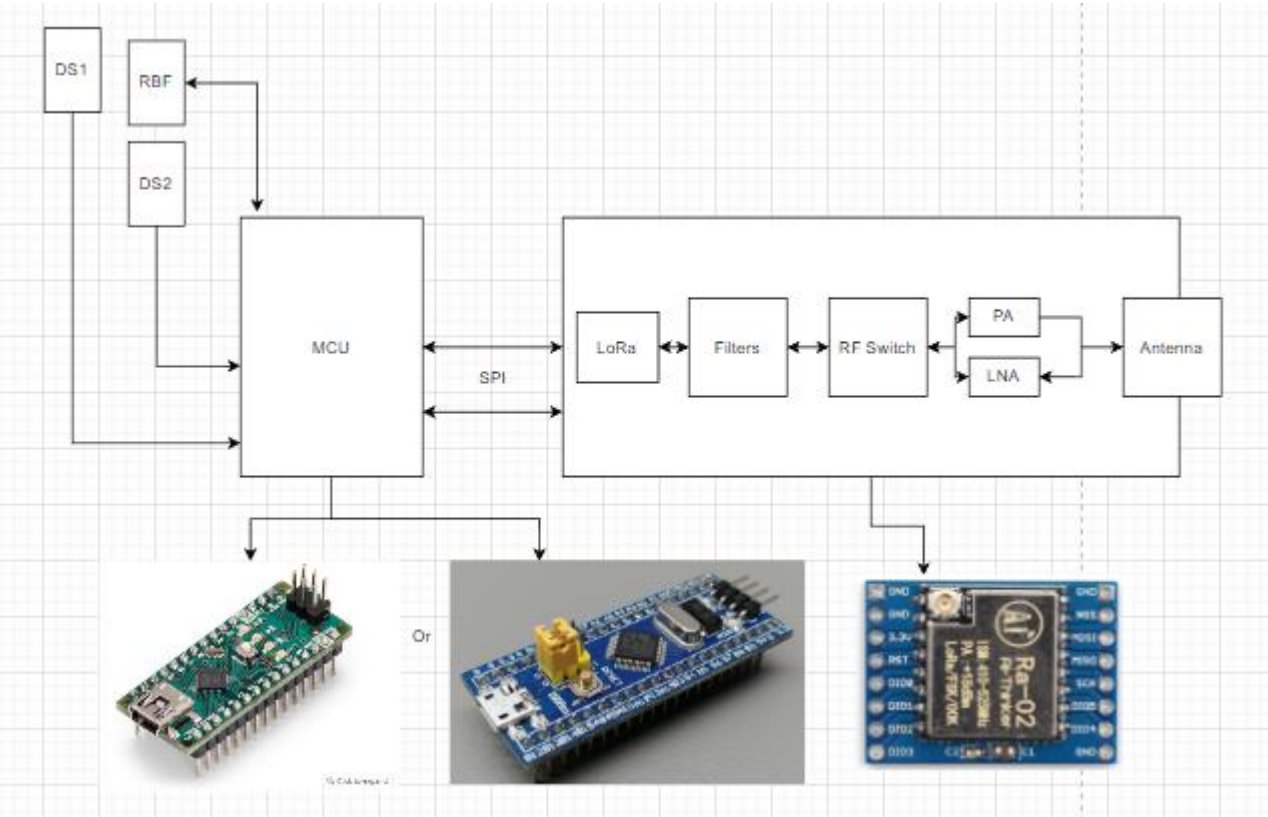
Design, Development and simulation of the Microstrip patch antenna stands completed

Real time application of deployment switch on Cubesat



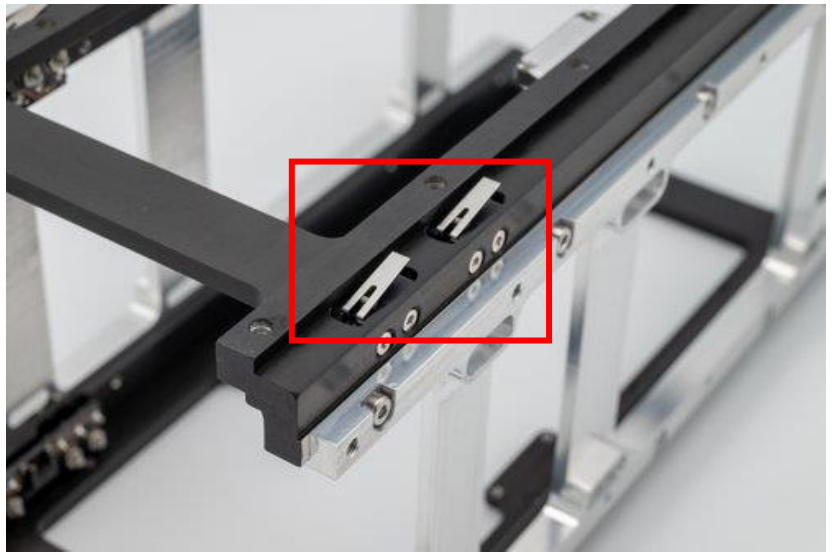


Construction



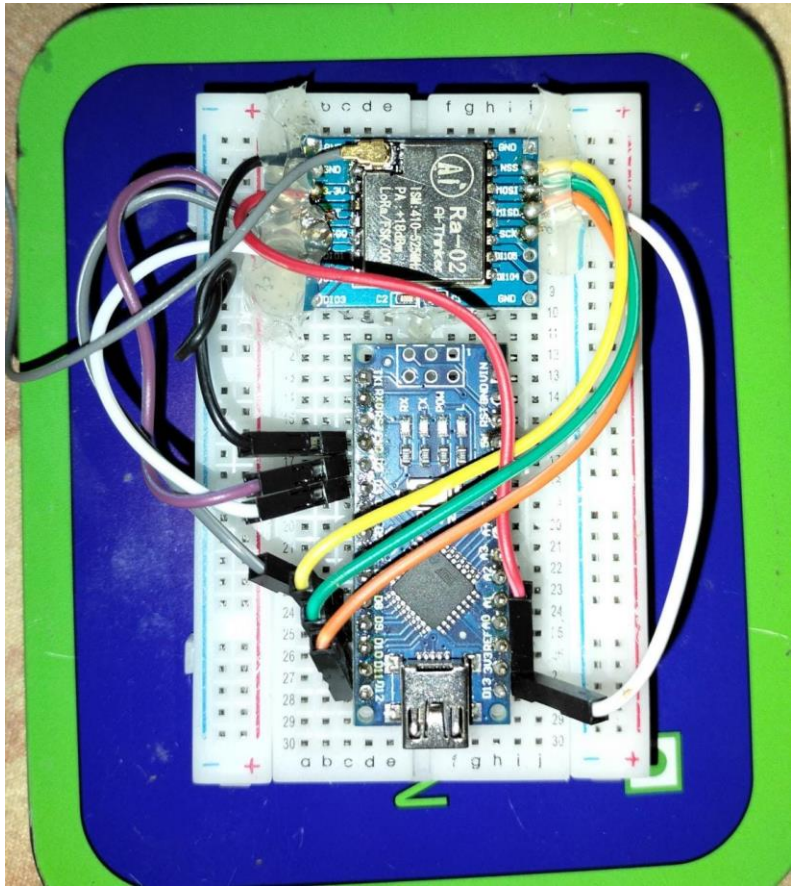
List of chosen items for the prototype:

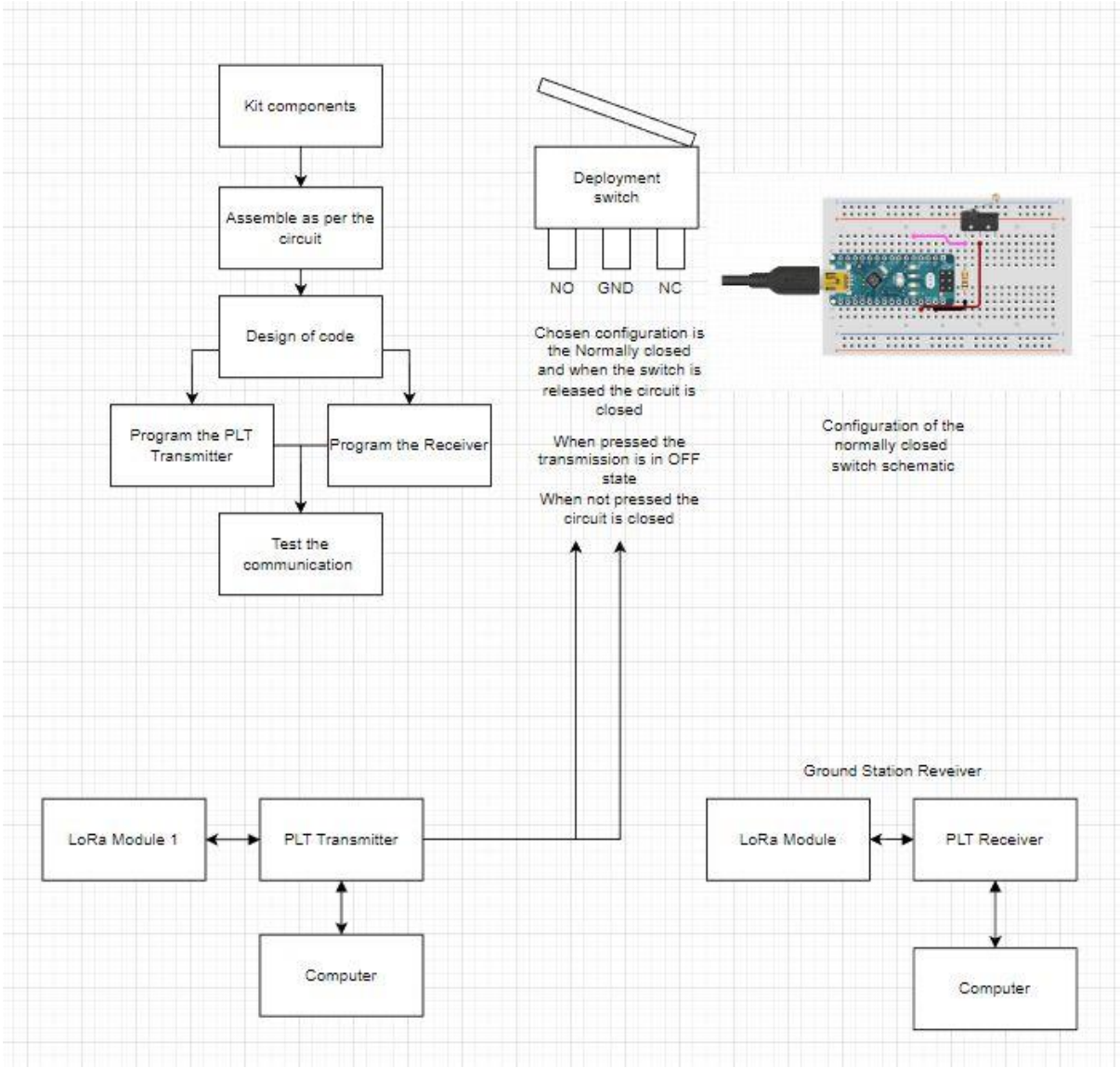
a. Arduino Nano Microcontroller
b. LoRa RA-02 500mW Transmitter module
c. SPST Switch for Deployment



Representation of deployment switch application on Cubesat platform

Final Prototype





Procedure

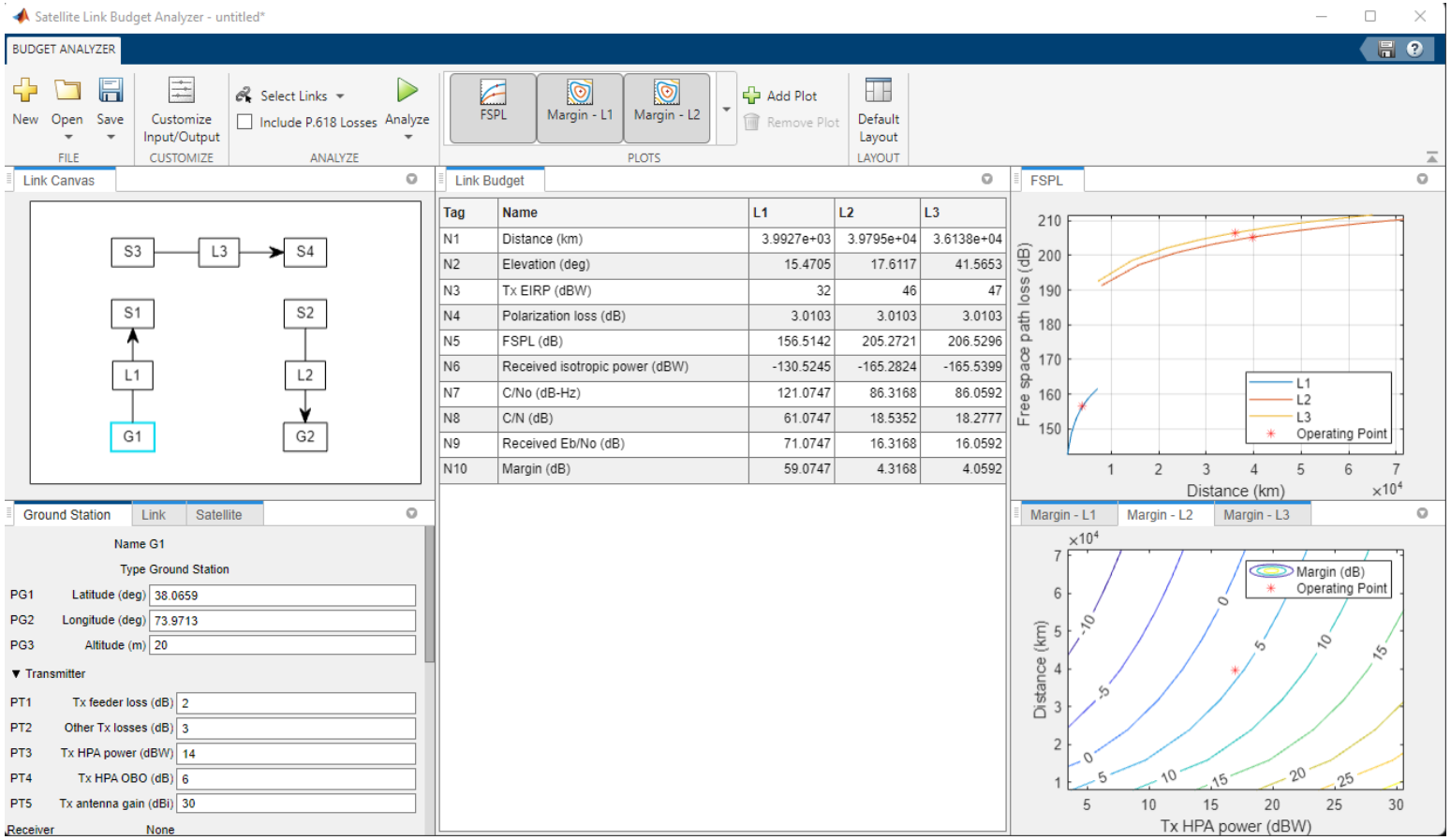
- Based on the flowchart that defines the workflow for realising the project

1. Ideation, we understood the idea of the whole system which should comprise of the transmitter, microcontroller and the Deployment switches and hence choosing the right component for the prototype of the PLT System.

2. As the block diagram suggests the PLT system comprises of a microcontroller which comprises of the Deployment switches and RF module and its associated antenna for data transmission.

3. Link Budget simulation for the chosen Radio module’s power output and assuming the PLT system is put on a satellite orbiting in Low Earth Orbit. At 350km with a transmission power of 500mW and Anurag University as the Ground Station.

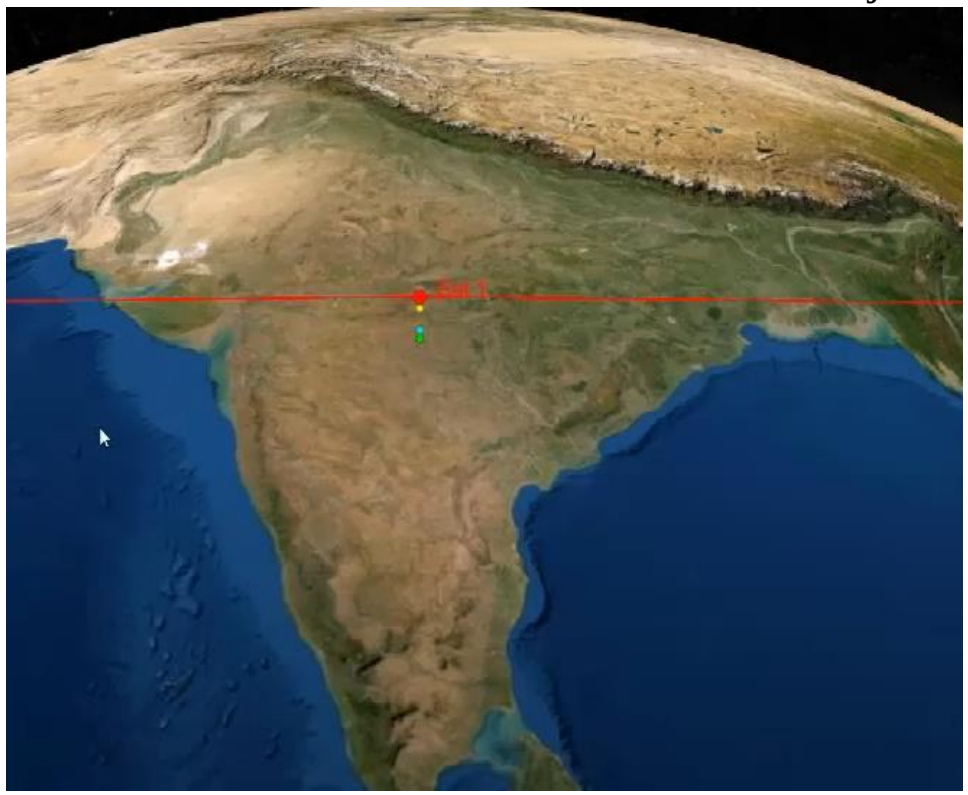
Matlab Simulation result

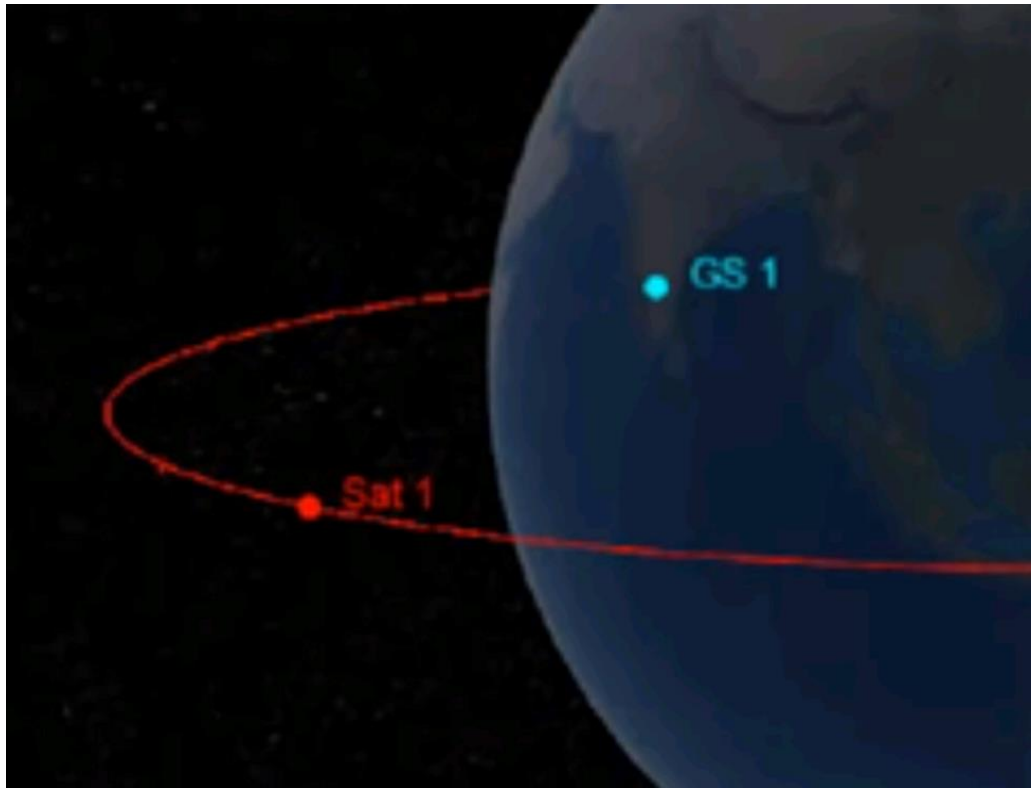


Matlab Simulation result assuming the conditions provided we have a sufficient margin of visibility and power of reception at the ground station with a 500mW transmitter

Result

- Matlab visualisation of simulated satellite trajectory





Code uploaded into PLT for transmitting satellite data

```
#include <RadioLib.h> // Library for Operation of radio module
#define DEP_SWITCH_PIN1 4 // RBF Switch 1 Pin
#define DEP_SWITCH_PIN2 5 // RBF Switch 2 Pin
bool switchState1 = HIGH; // Normally Closed Circuit
bool switchState2 = HIGH; // Normally Closed Circuit
SX1278 radio = new Module(10, 2, 9, 3); // Pin Definitions
void setup() {
  Serial.begin(9600); // Programmer Communication data rate
  Serial.print(F("[RA02 PLT] Initializing ... "));
  int state = radio.begin(); // Radio Initializing
  radio.setFrequency(433.0); // Set Radio frequency
  radio.setBandwidth(250); // Set Radio Bandwidth
  radio.setSpreadingfactor(7); // Set Radio Spreading Factor
  radio.setCordingrate(4); // Set Radio Coding Rate
  if (state == RADIOLIB_ERR_NONE) {
  Serial.println(F("success!"));
  } else {
  Serial.print(F("failed, code "));
  Serial.println(state);
  while (true); }}
```

RBF Switch Config

Transmitter Config

Library fail checks

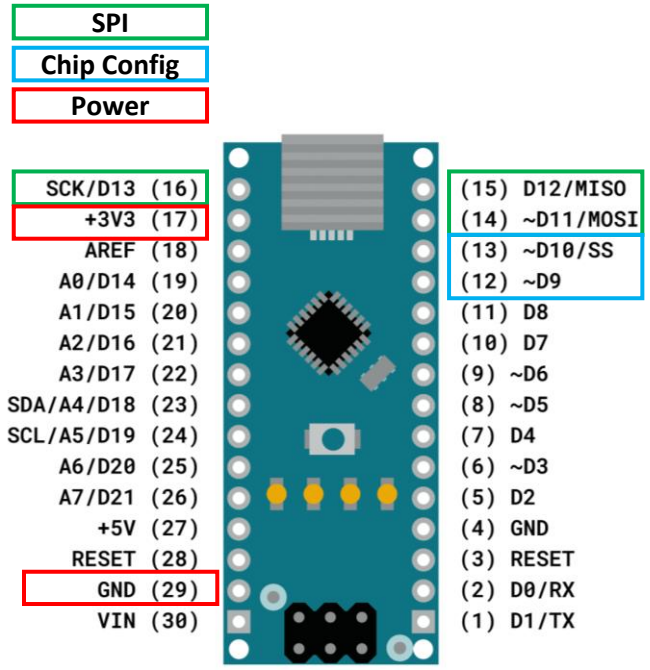
```
void loop() {
if ((newSwitchState1 == LOW && switchState1 == HIGH) ||
(newSwitchState2 == LOW && switchState2 == HIGH)) {
Serial.println(F("RBF Switch Released"));
  Serial.println("Transmitting packet ..."); int state = radio.transmit
(“Anurag Satellite Demonstration!"); // Data to Transmit
  if (state == RADIOLIB_ERR_NONE) {
    Serial.println(F(" success!"));
    Serial.print(F("[RA02 PLT] Datarate:\t"));
    Serial.print(radio.getDataRate()); // Print packet transmission data rate
    Serial.println(F(" bps"));
  } else if (state == RADIOLIB_ERR_PACKET_TOO_LONG) {
    Serial.println(F("too long!"));
  } else if (state == RADIOLIB_ERR_TX_TIMEOUT) {
    Serial.println(F("timeout!"));
  } else {
    Serial.print(F("failed, code "));
    Serial.println(state);
  }
  delay(1000); // wait for 1 second and transmit again
}
```

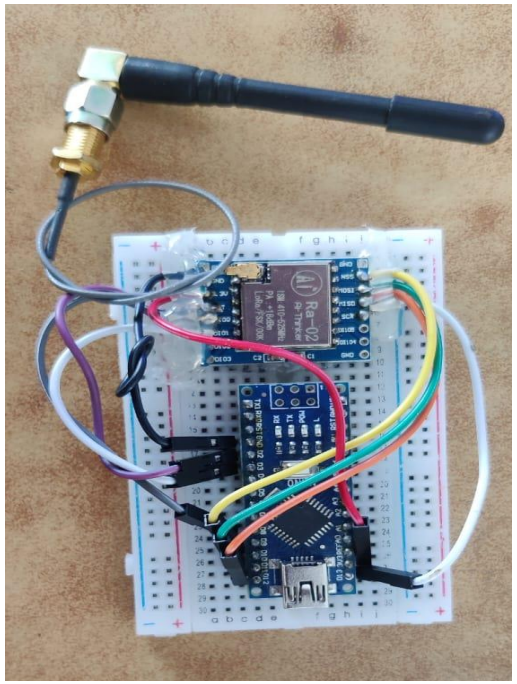
Packet fail checks

- Message to not be >256bytes
- Transmit Timeout if failure occurs
- Print FAIL code

Connections Between Arduino and Ra02 transmitter

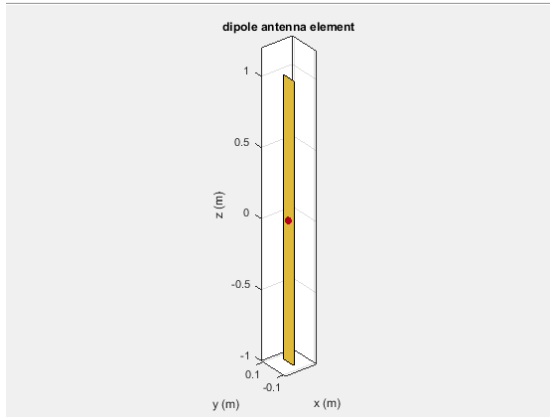
RA02 PLT Transmitter	Arduino Nano
NSS (Chip select)	D10
DIO0 (Digital interrupt)	D2
RESET (Chip reset)	D9
DIO1 (Digital interrupt)	D3
MOSI (SPI)	D12
MISO (SPI)	D11
VCC (Power)	VCC(3V3)
GND	GND



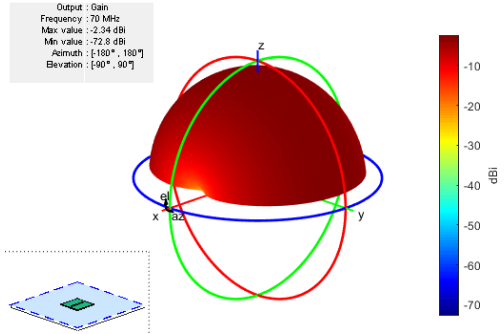


Novel Tape measure antenna & Microstrip Patch Antenna

Custom built tape measure dipole antenna for 433Mhz

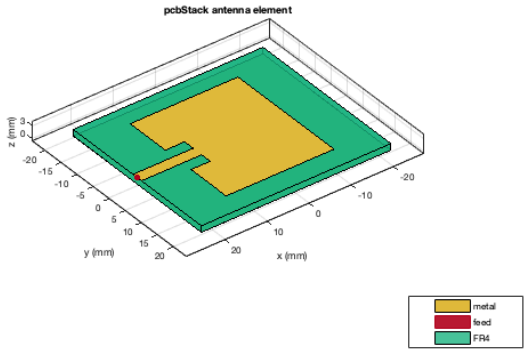


MATLAB Design of Dipole antenna

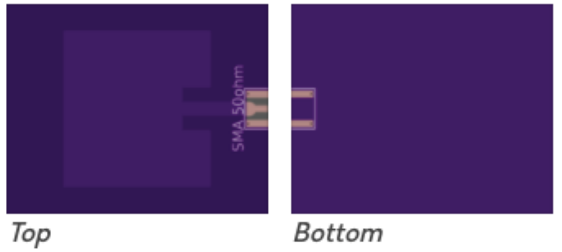


Simulated antenna radiation pattern

Custom Microstrip Antenna design for 433Mhz



MATLAB Design of Patch antenna



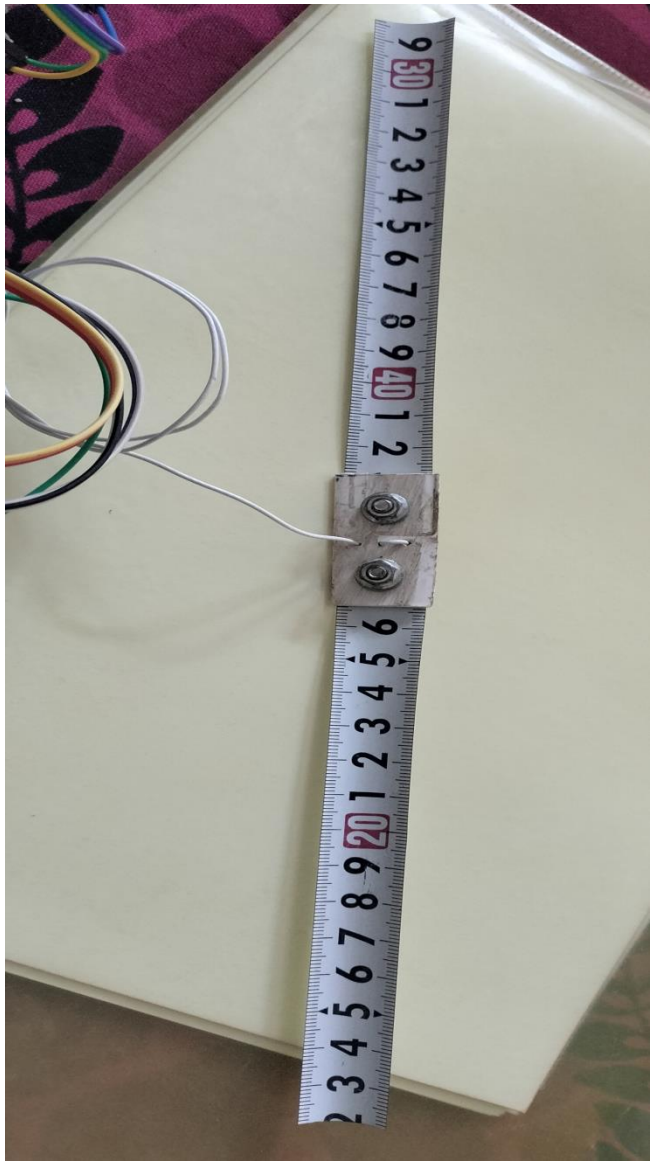
Patch antenna

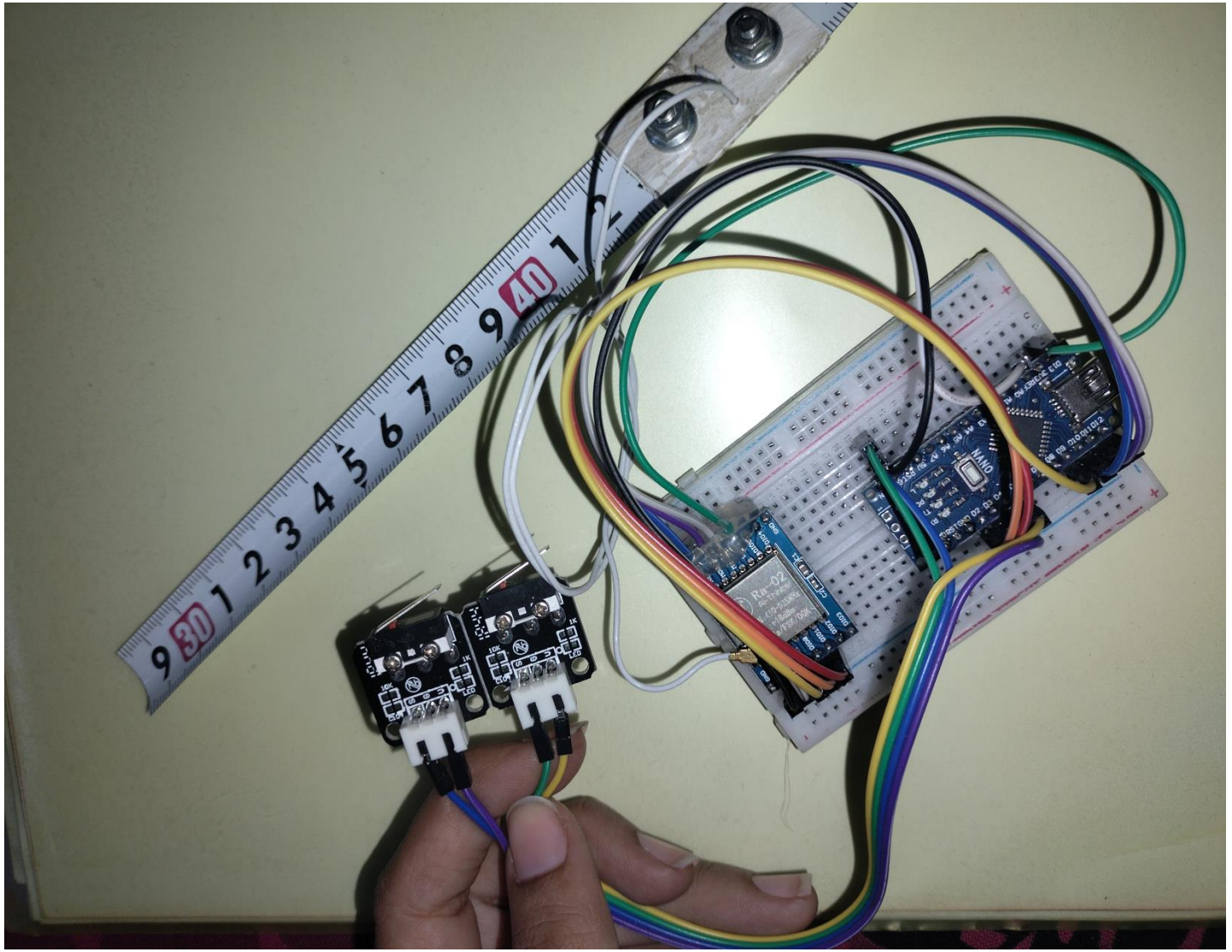
post manufacturing

Delivery of Microstrip patch antenna pending from manufacturer due to long lead time.

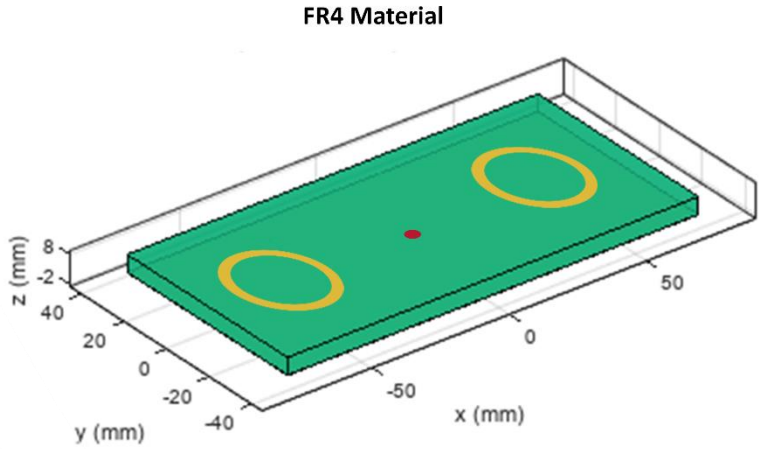
The tape measure antenna is an innovative solution as it can be flown on a satellite and the advantage is it is capable of self deployment.

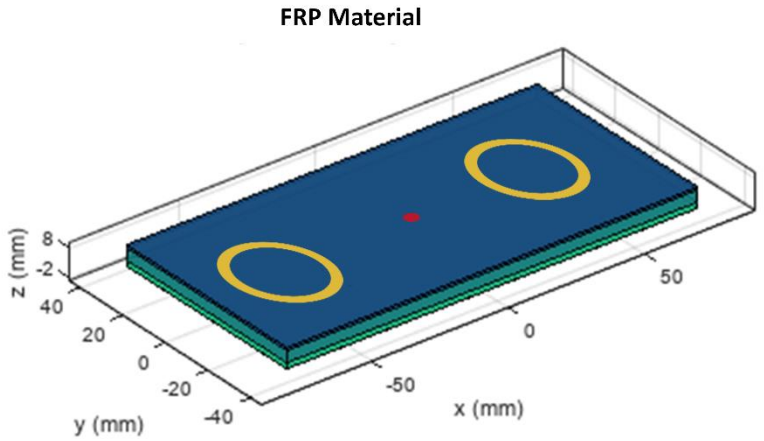
Construction of novel tape antenna and switches in transmitter



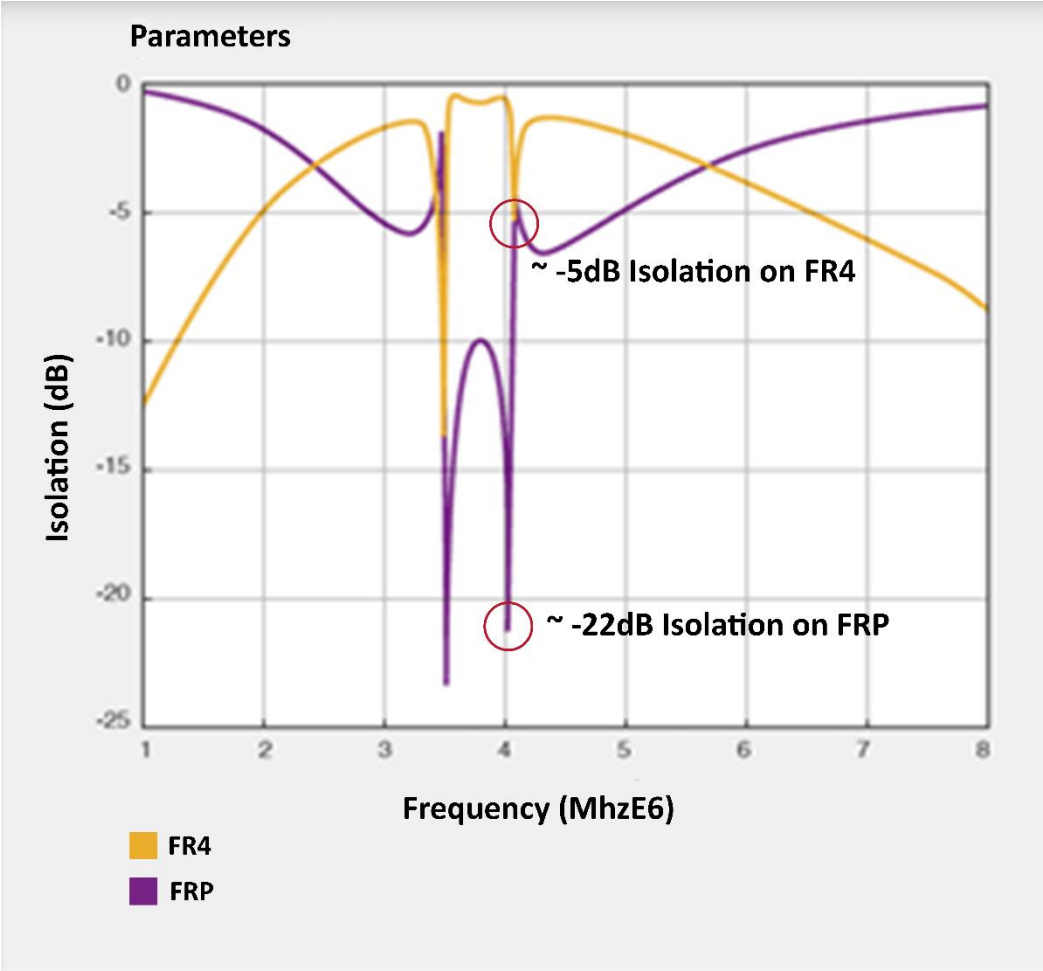


Setup of FR4 and FRP material on Matlab





Comparision of FR4 and FRP material in MatLab



Conclusion

- FRP can be a good material choice for antenna element holders in terms of its mechanical strength and durability. However, its effectiveness in providing RF isolation would depend on various factors,
- such as the thickness of the material, its dielectric constant, and the frequency range of the signal being transmitted.
- FRP has a relatively low dielectric constant compared to other materials such as metals or ceramics, which means it can potentially provide some degree of RF isolation.

- FR4 is not typically chosen for its RF isolation properties,
- As it is a type of fiberglass-reinforced epoxy laminate sheet material that has a relatively high dielectric constant.
- A high dielectric constant can result in the material absorbing and storing more electromagnetic energy, leading to signal losses and reduced RF isolation.
- While FR4 is a popular material for use in printed circuit boards and electronic applications due to its excellent electrical insulation properties and mechanical strength, , it may not be the best choice for antenna element holders if RF isolation is a primary concern.

Thank You