Project strato TV insights

NUS STAR UREx team:
Sai Wai Phyo [Flight Hardware & Firmware, RF architecture]
Nathan Bong Neng Quan[Tracking Antenna Rotator]
Alvin Tan Yean Liang[Battery Management]

Balloon Experiments with Amateur Radio team:
Payload lead: Wai Phyo 9V1WP
Resident-Rigging Expert: Fu Hang 9V1FH
Payload specialists and ground support: Liwei 9V1LW, Choong 9V1CV
Regulations, Clearance: Chew 9V1YP

CONOPS

Payload

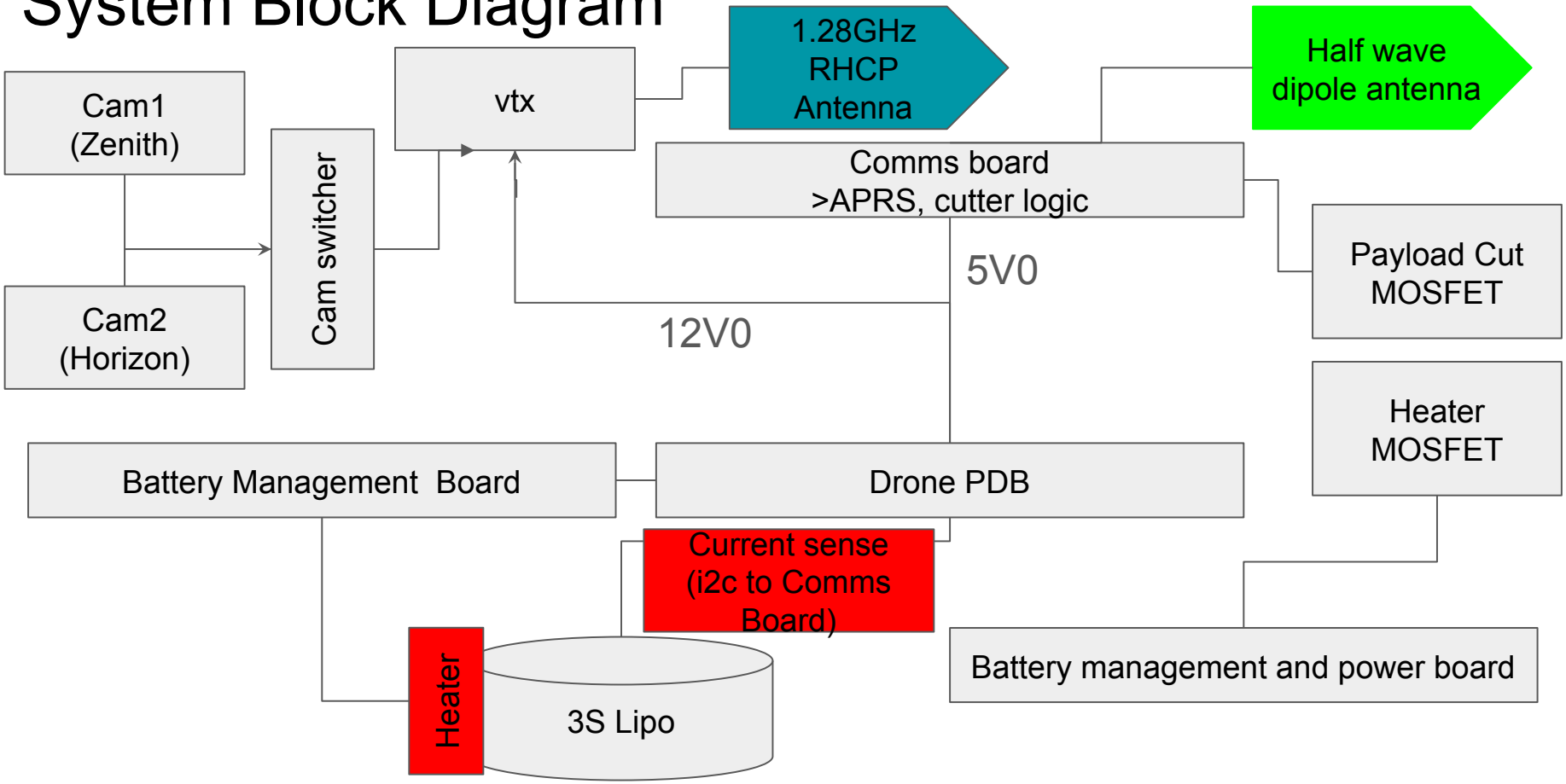
Vtx:1280MHz

- Switching Camera views every TX cycle
- Switch to Zenith Cam before payload cut for 5mins

APRS: 144.390MHz(every 30s)

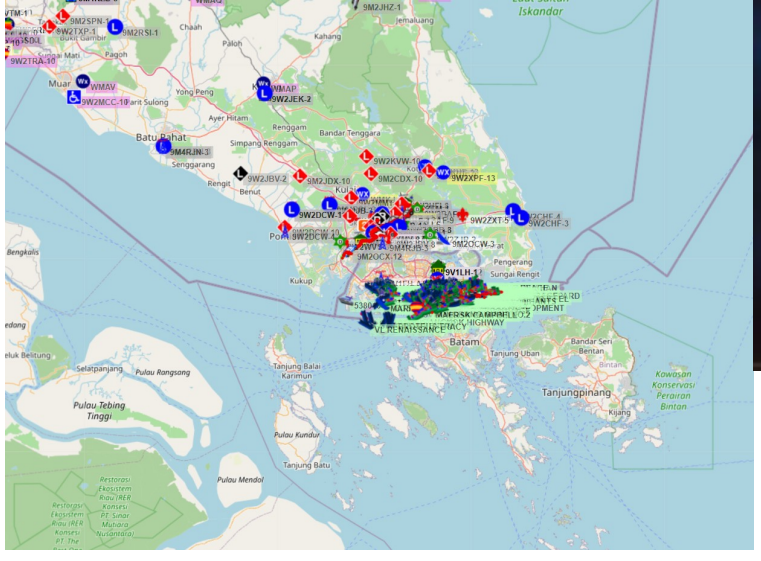
Payload Cut altitude: 30km

System Block Diagram

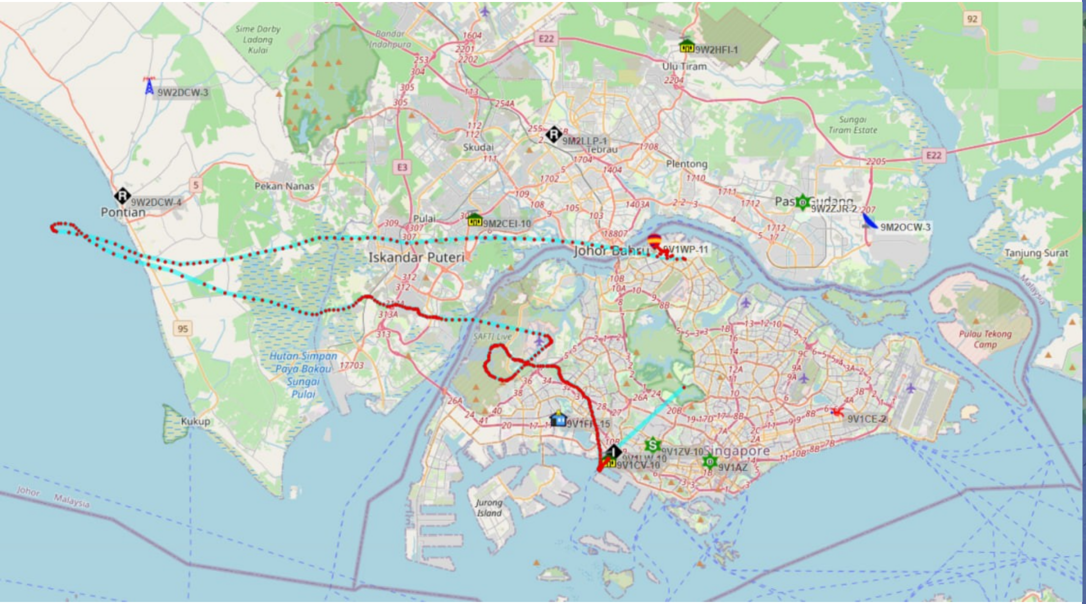


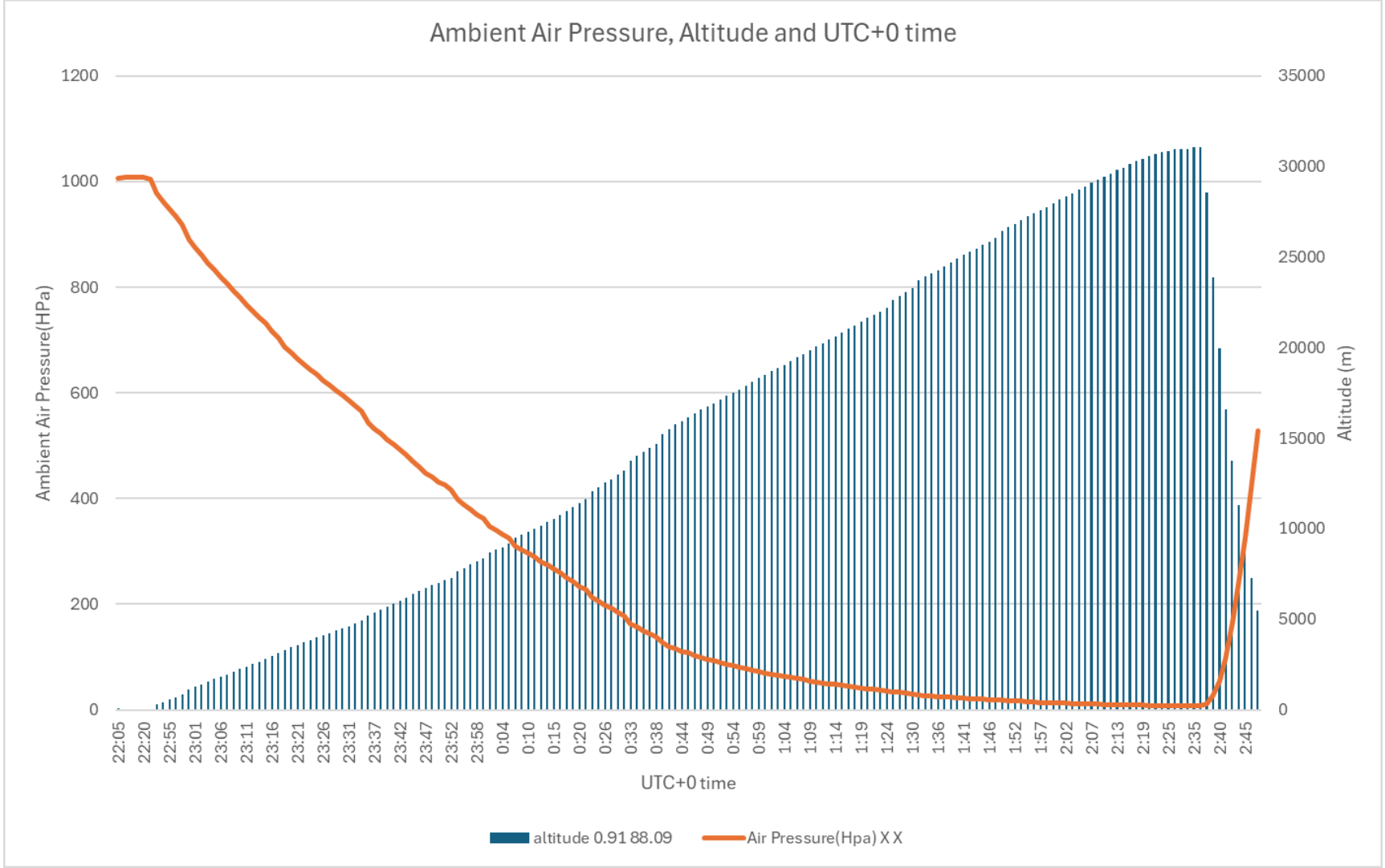
APRS 101

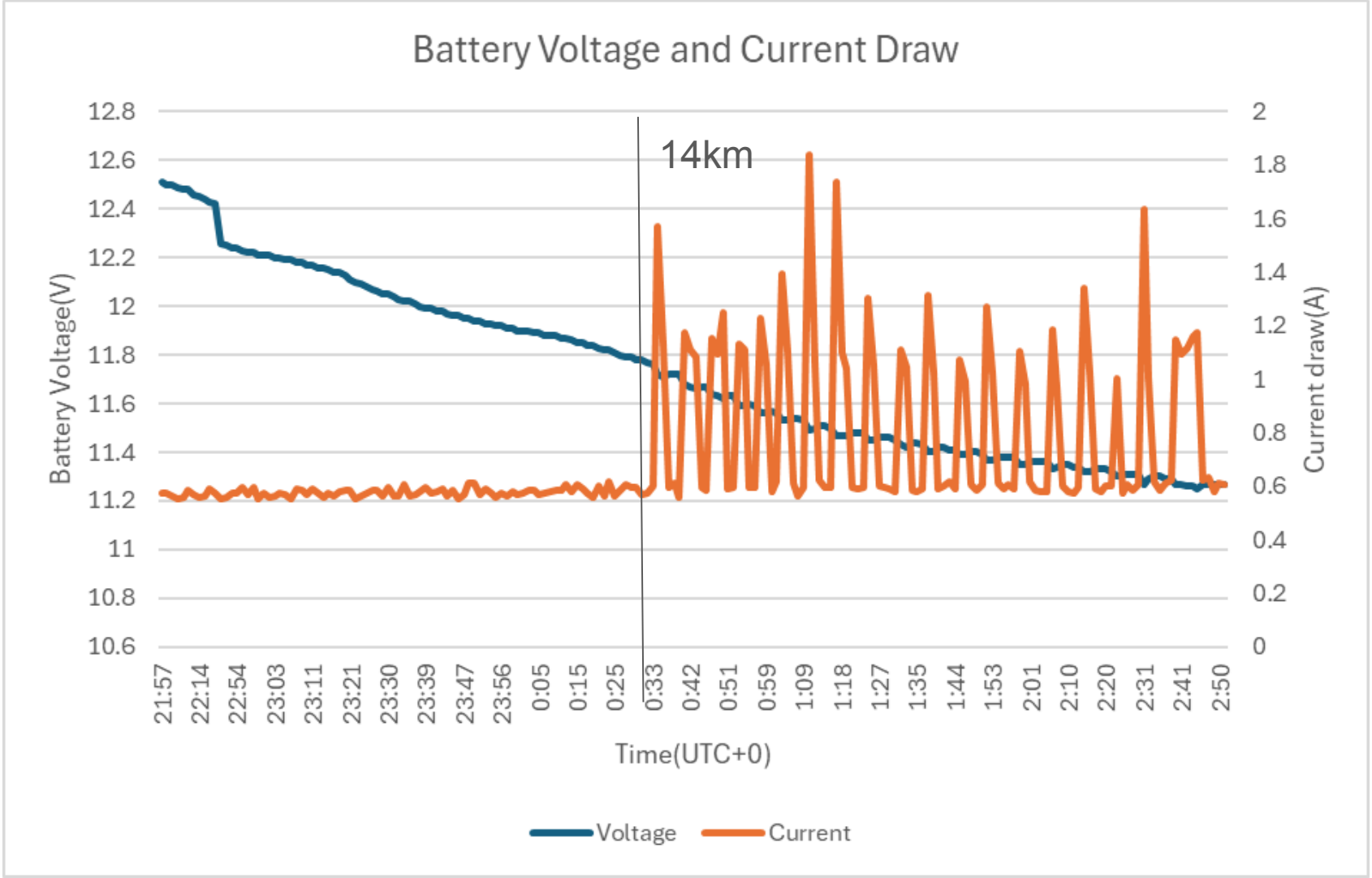
- Uses two tones at baseband to encode data, baud rate of 1200.
- Usage of VHF and amateur APRS repeater network extends range to beyond line of sight(BLOS)
- Transmits telemetry such as location,speed,heading etc.

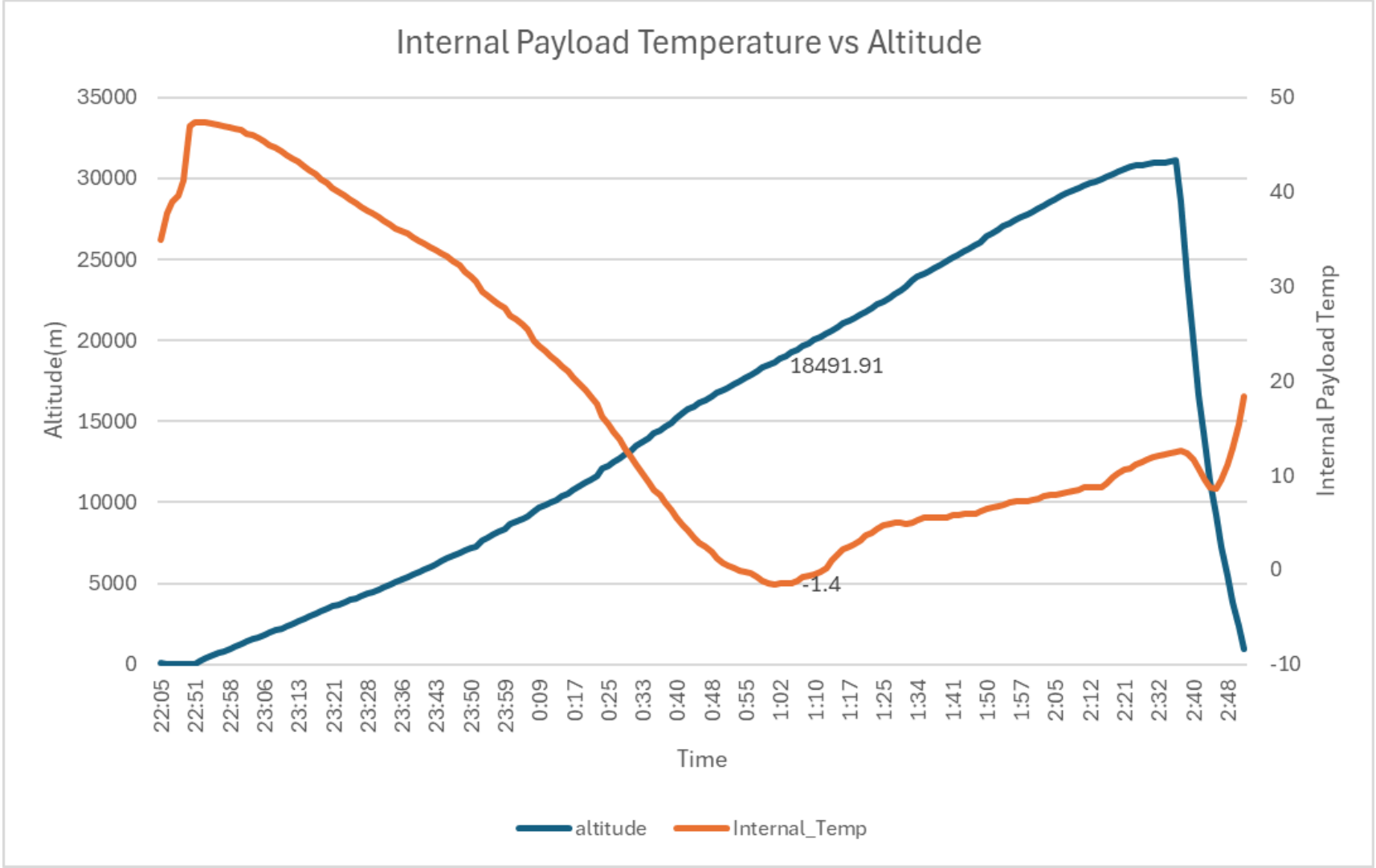


Flight Path




Ambient Air Pressure, Altitude and UTC+0 time
Ambient Air Pressure(HPa)
Altitude (m)
UTC+0 time
altitude 0.91 88.09
Air Pressure(Hpa) X X


Battery Voltage and Current Draw
14km
Battery Voltage(V)
Current draw(A)
Time(UTC+0)
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
21:57
22:14
22:54
23:03
23:11
23:21
23:30
23:39
23:47
23:56
0:05
0:15
0:25
0:33
0:42
0:51
0:59
1:09
1:18
1:27
1:35
1:44
1:53
2:01
2:10
2:20
2:31
2:41
2:50
Voltage
Current


Internal Payload Temperature vs Altitude
Altitude(m)
35000
30000
25000
20000
15000
10000
5000
0
Internal Payload Temp
50
40
30
20
10
0
-10
18491.91
-1.4
22:05
22:51
22:58
23:06
23:13
23:21
23:28
23:36
23:43
23:50
23:59
0:09
0:17
0:25
0:33
0:40
0:48
0:55
1:02
1:10
1:17
1:25
1:34
1:41
1:50
1:57
2:05
2:12
2:21
2:32
2:40
2:48
Time
altitude
Internal_Temp

Regulatory Approvals

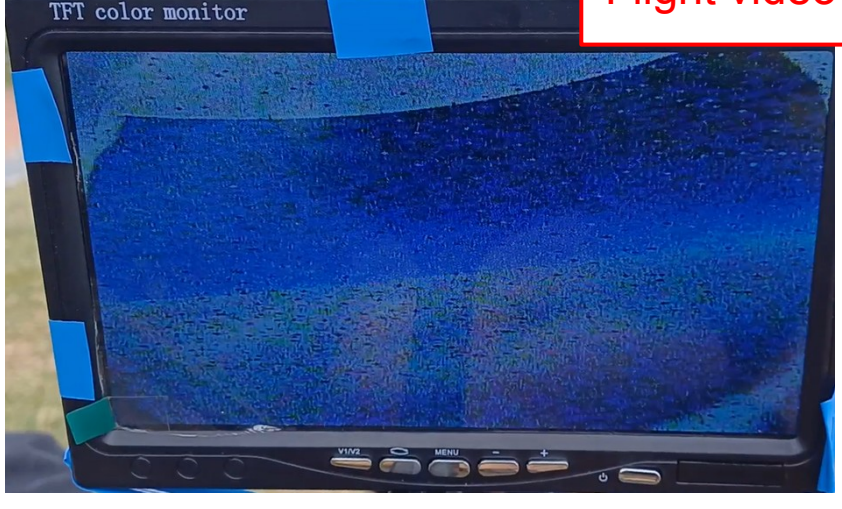
Federal Aviation Administration

A0979/26 NOTAMN
Q) WSJC/QWLLW/IV/BO/W/000/999/0118N10346E001
A) WSJC B) 2603282245 C) 2603290445
D) MAR 28 2245-2359, 29 0000-0445
E) ONE MET BALLOON, 2M IN DIAMETER, WILL BE RELEASED HOURLY AT
011752N1034541E (WI WSAP CTR)
F) GND G) UNL

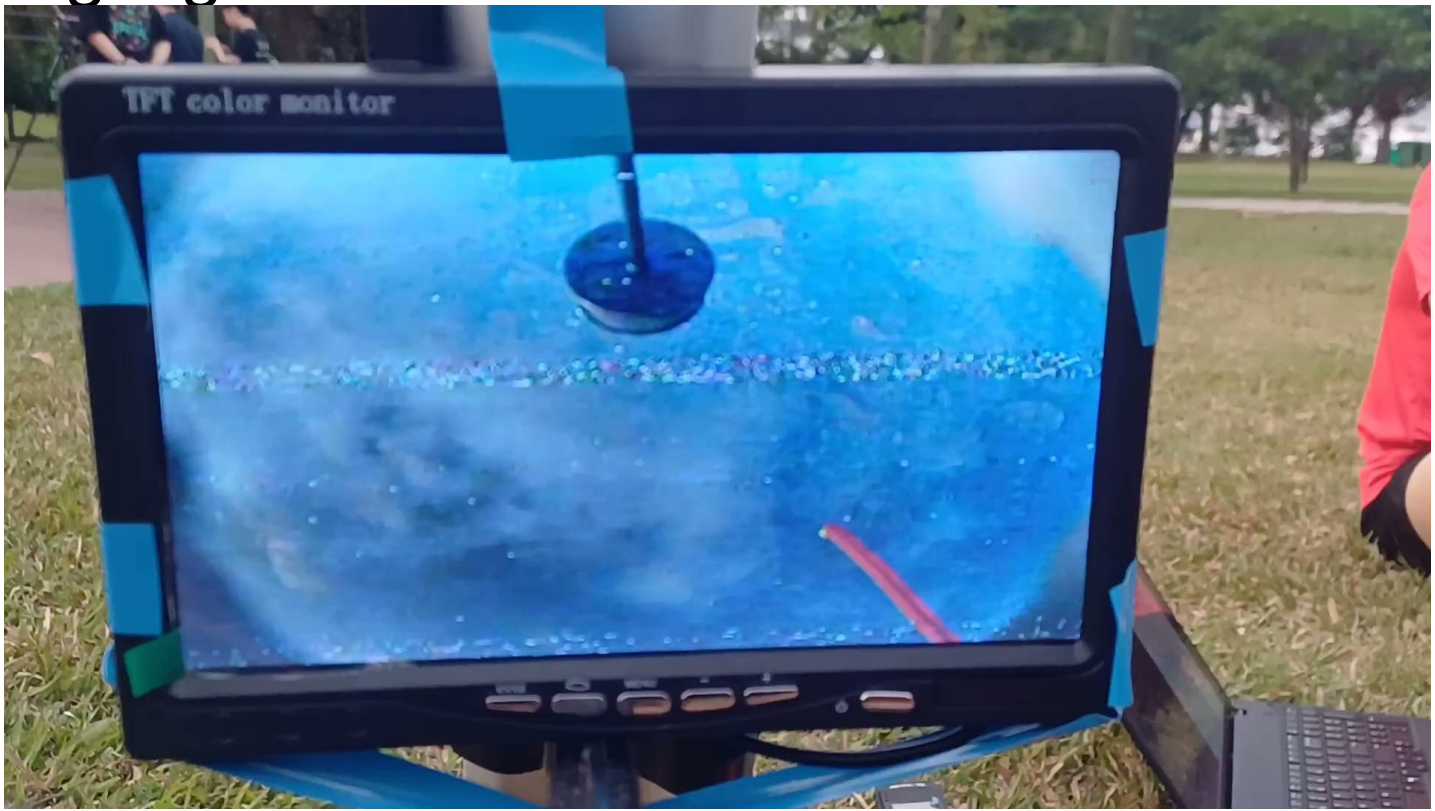
- RSAF(203 Squadron)
- IMDA
- CAAS

Footage Highlights

Flight video highlights!



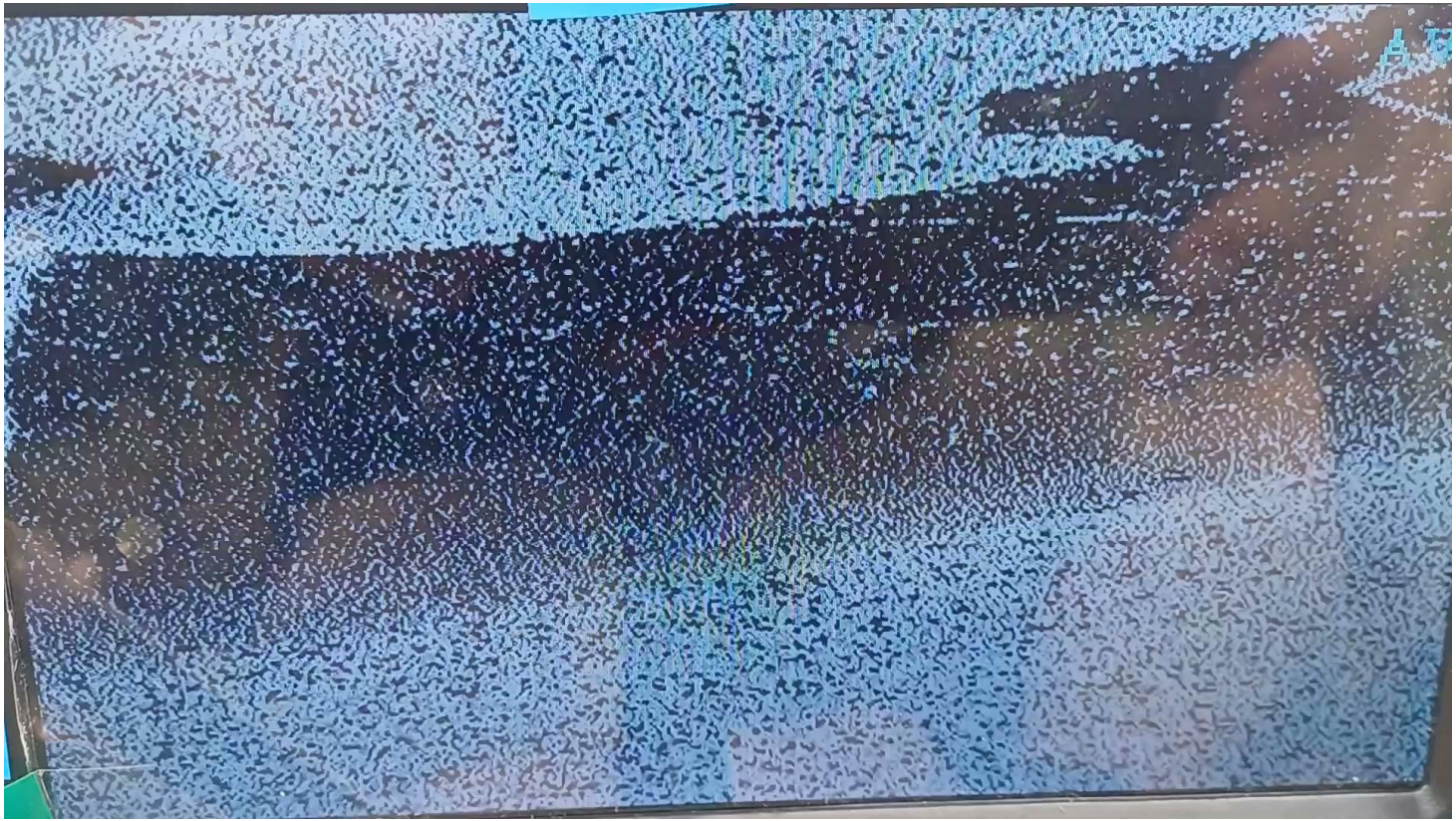
Highlights



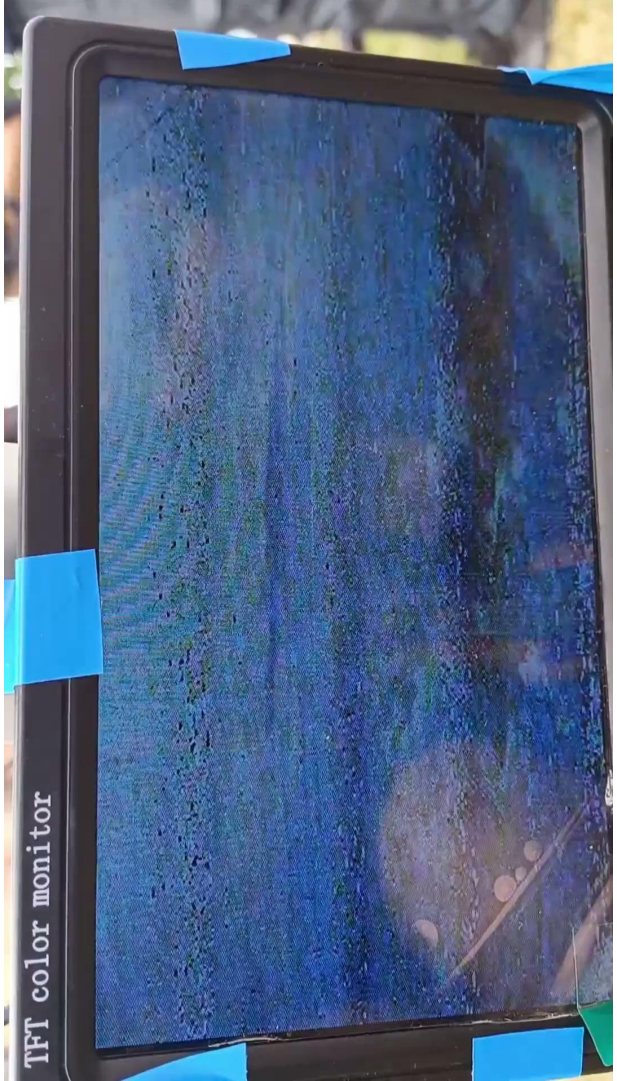
14km halo

20km

25km



Descent



Why 1280MHz and why analog video?

Analog Transmitters have a NTSC/PAL video signal that modulates a FM carrier, they are commonly used by drones, each is quite cheap at $60. However they take up a lot of bandwidth of ~20MHz. Which means there is no bandwidth at UHF and VHF amateur bands but 40MHz of bandwidth at 1240-1300MHz amateur band(subject to IMDA approval)

Either:

We use a SDR to transmit digital TV = Expensive!! LimeSDR has been used by Horus flights that Transmit 720x404 at 445MHz @800mW w/ QPSK FEC ½ DVBS-S2 encoding , transport stream encoding designed on Gnuradio then implemented on a RPI.

https://www.areg.org.au/archives/category/horus-datv

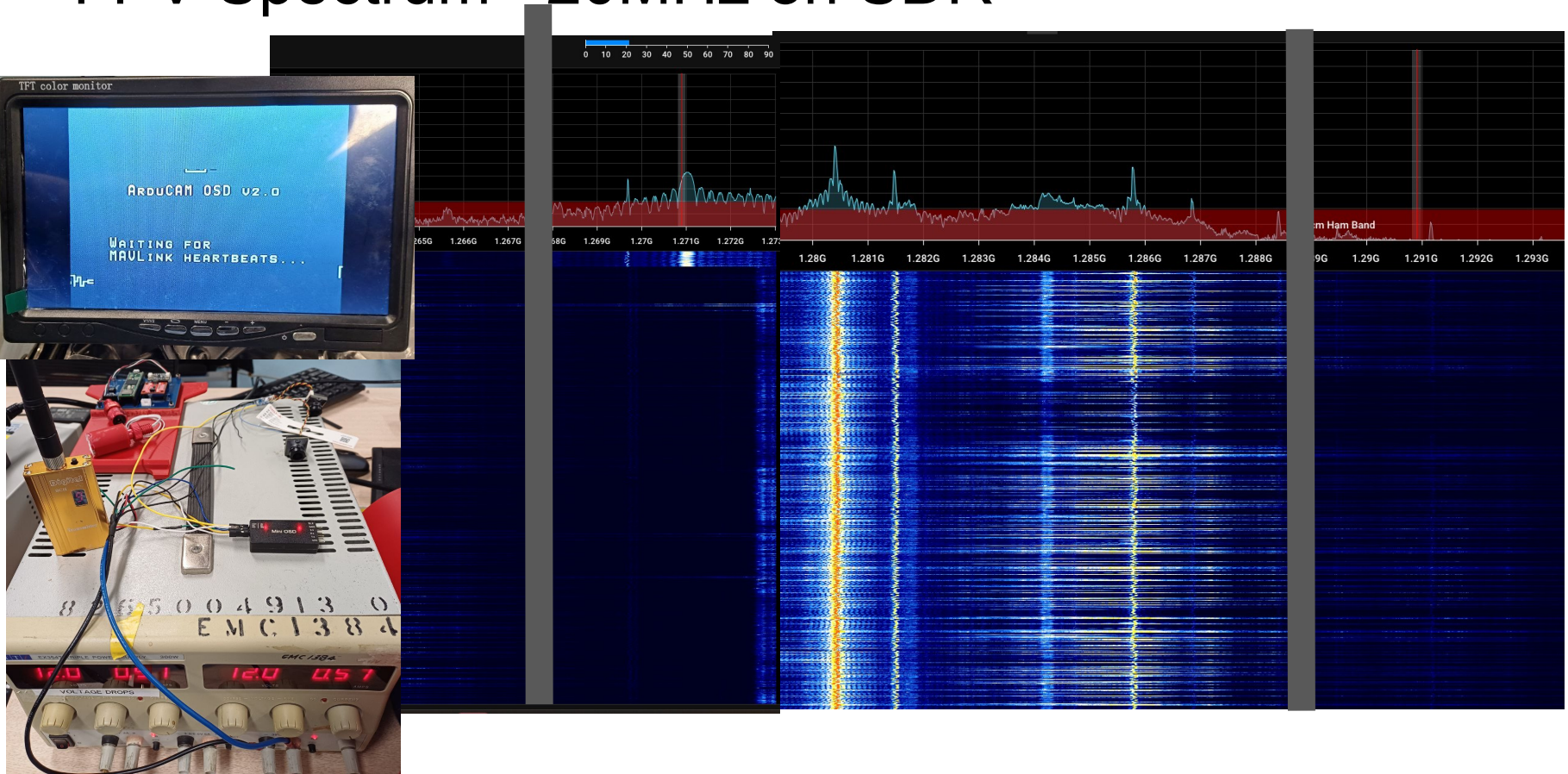
Or

We go through regulations!

Digital Video(~2MHz BW)

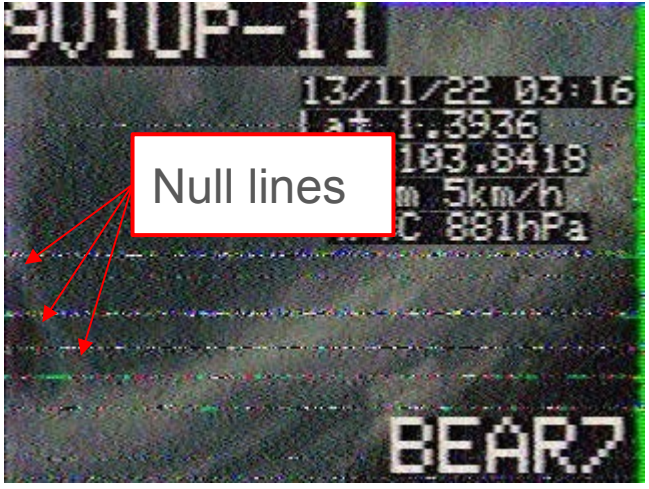
Analog Video(~20MHz BW)

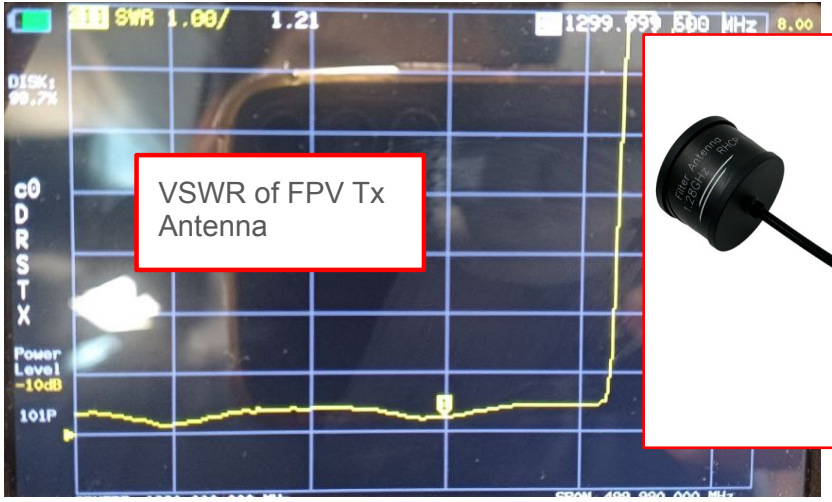
FPV Spectrum ~20MHz on SDR



FPV Antenna selection

- Experience from SSTV: Rolling payload produces null lines possibly due to polarization mismatch
  - Rolling payload possibly causes horizontally polarized antenna to become circular polarized, leading to polarization losses.
- Selected circular polarized antenna



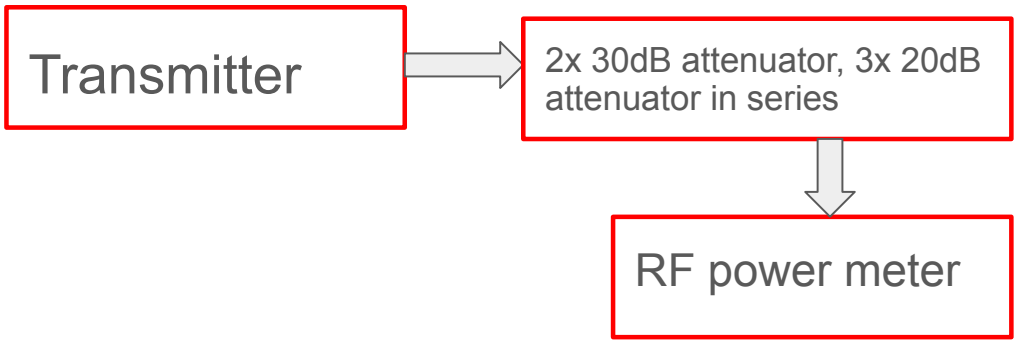


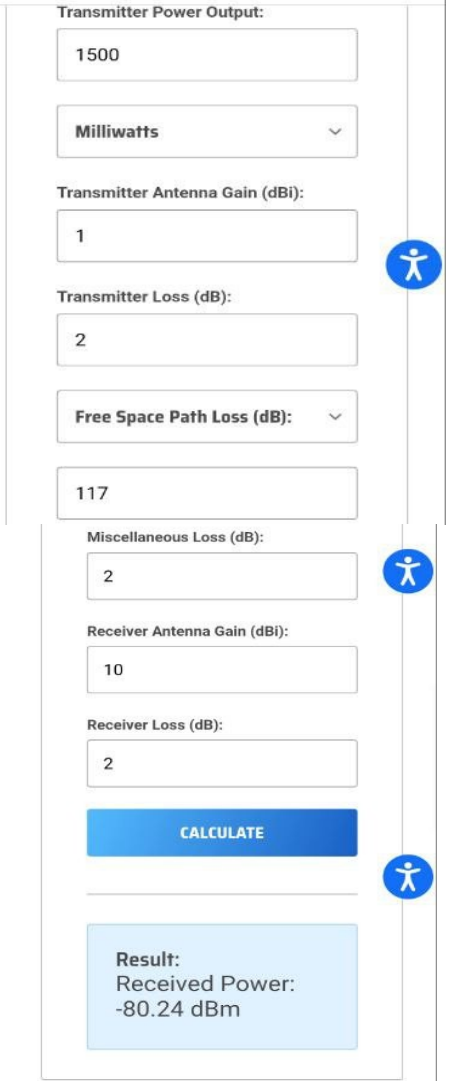
RF power meter and attenuator testing

FSPL approx for 50km: 117dB

Tx Antenna gain: 1dBi, Rx Antenna Gain: ~10dBi

Should have accounted for the Power Spectral Density as well as this assumes this is close to a narrowband transmission.(Ours is 1500mW over 20MHz)



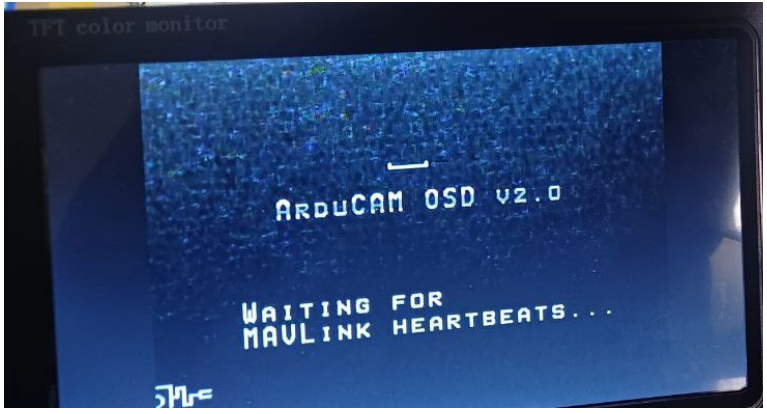


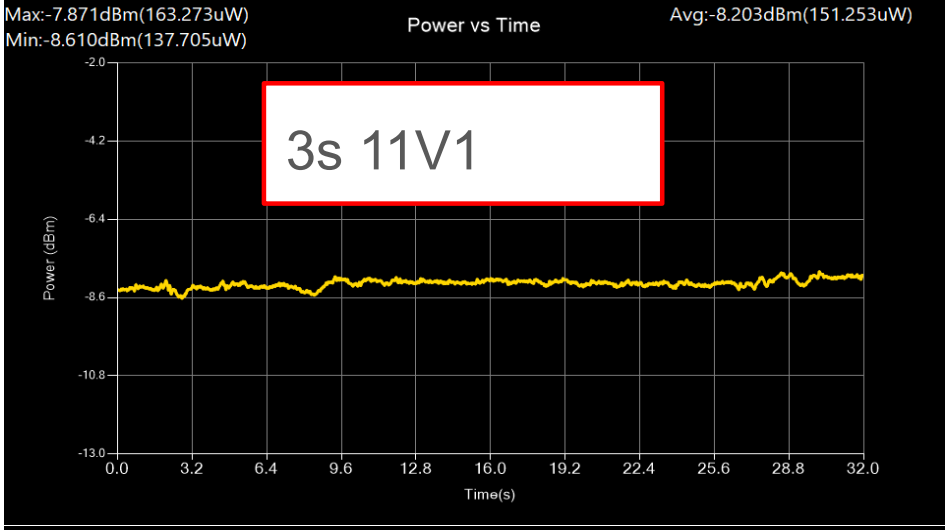
RF power meter results

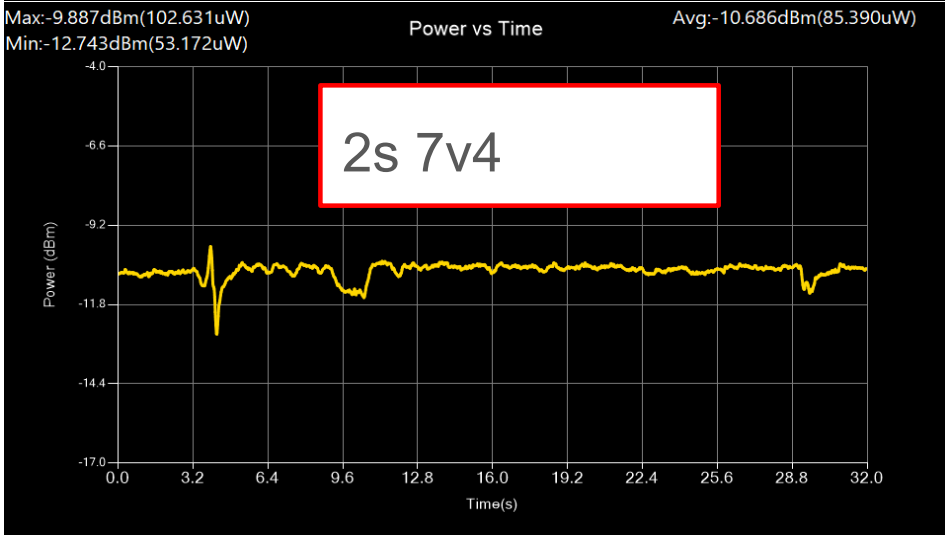
Undervoltage possible

Power loss of ~2dBm

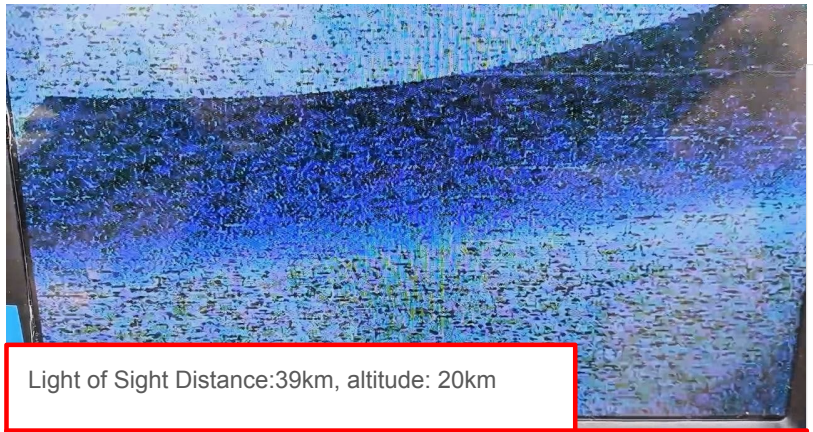
>Looked okay (Didn’t match in flight performance because RF is **black magic)**



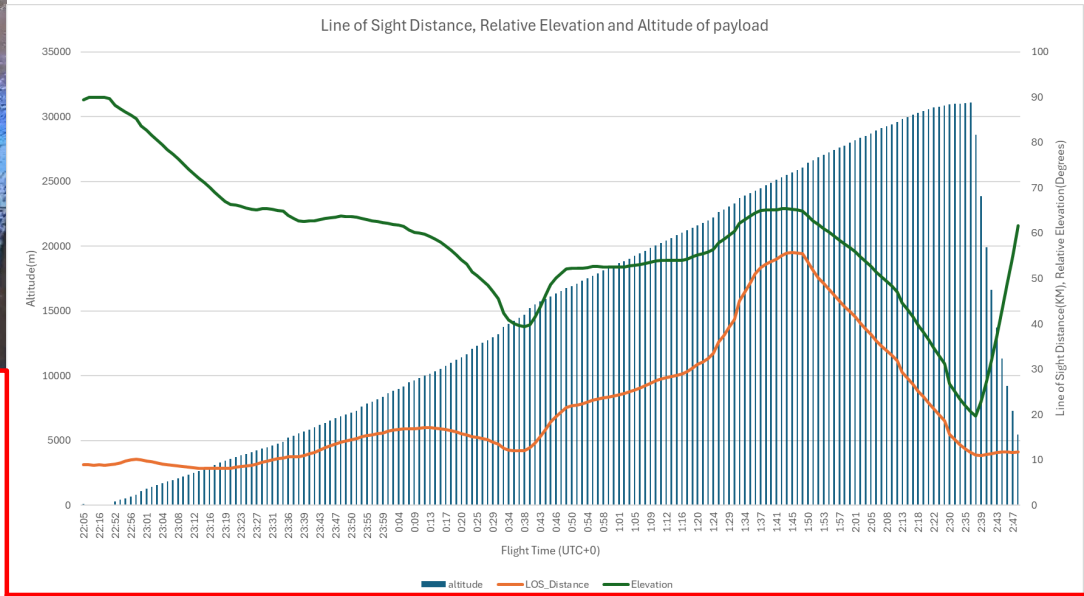




Real Flight Performance? **Very Far off**



Light of Sight Distance:39km, altitude: 20km



Total Loss of video;

LOS distance: 46km

Elevation: ~60 degrees w.r.t ground

Additional Notes: Interference from motor drivers on rotator?

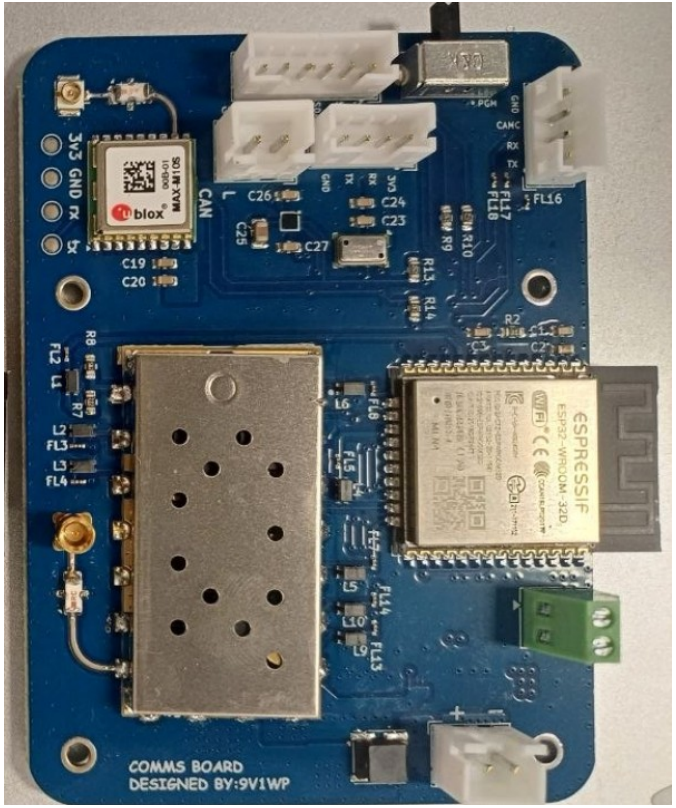
Telemetry board

Feature:

1. Impedance matched traces for RF transceiver and GNSS transceiver to reduce impact of 1280MHz VTx (Looks like it worked throughout the flight)
2. Audio decode with DC bias Circuit
3. Chip based band pass filter for GNSS (BFCN-1575+)
4. Chip based low pass filter for VHF (LCFN-160+)
5. Barometer (extended range to ~25km)
6. MCU used: ESP32-WROOM-32D
7. Custom Dipole Antenna using Coax cable
8. CAN bus for future use

One small issue: I stupidly routed an input only pin to a output purpose pin->BOTCH

Link:https://github.com/RandomAerospace/COMMS-BOARD



PCB Stackup information

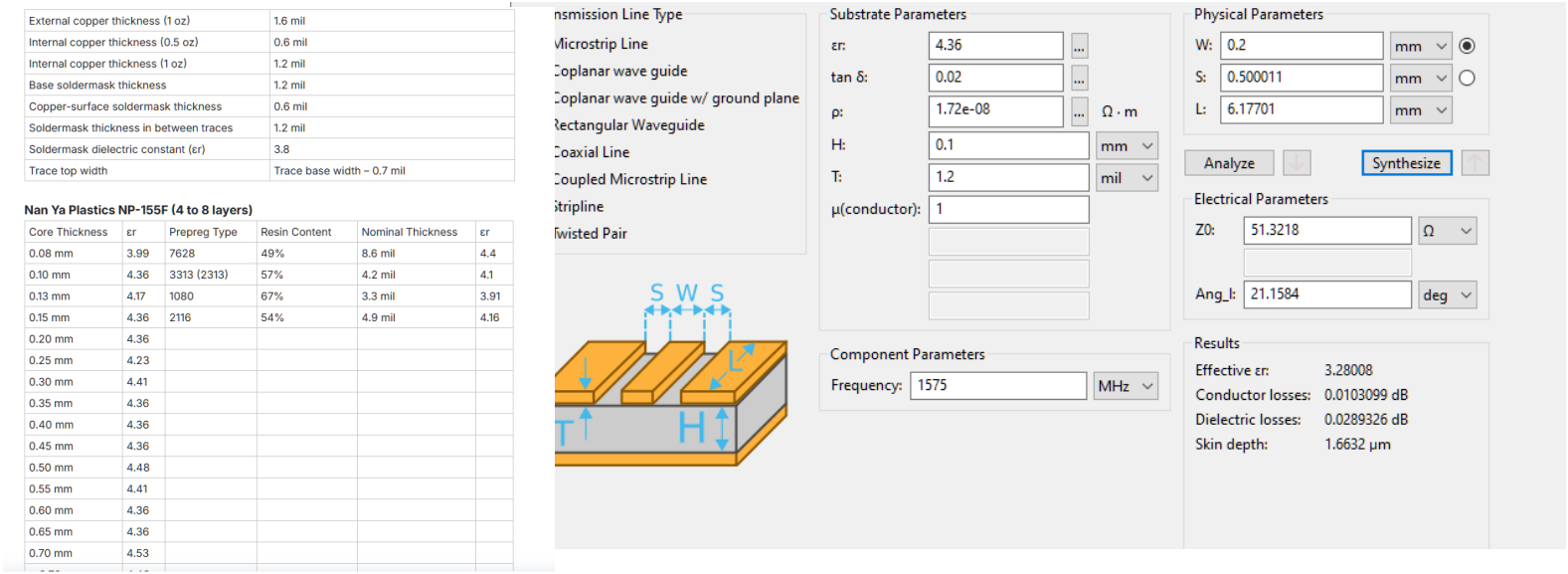
Used stackup: NP-155F, 7628 stack up

Process: Get electrical properties from JLC->tune for impedance with length on KiCAD.

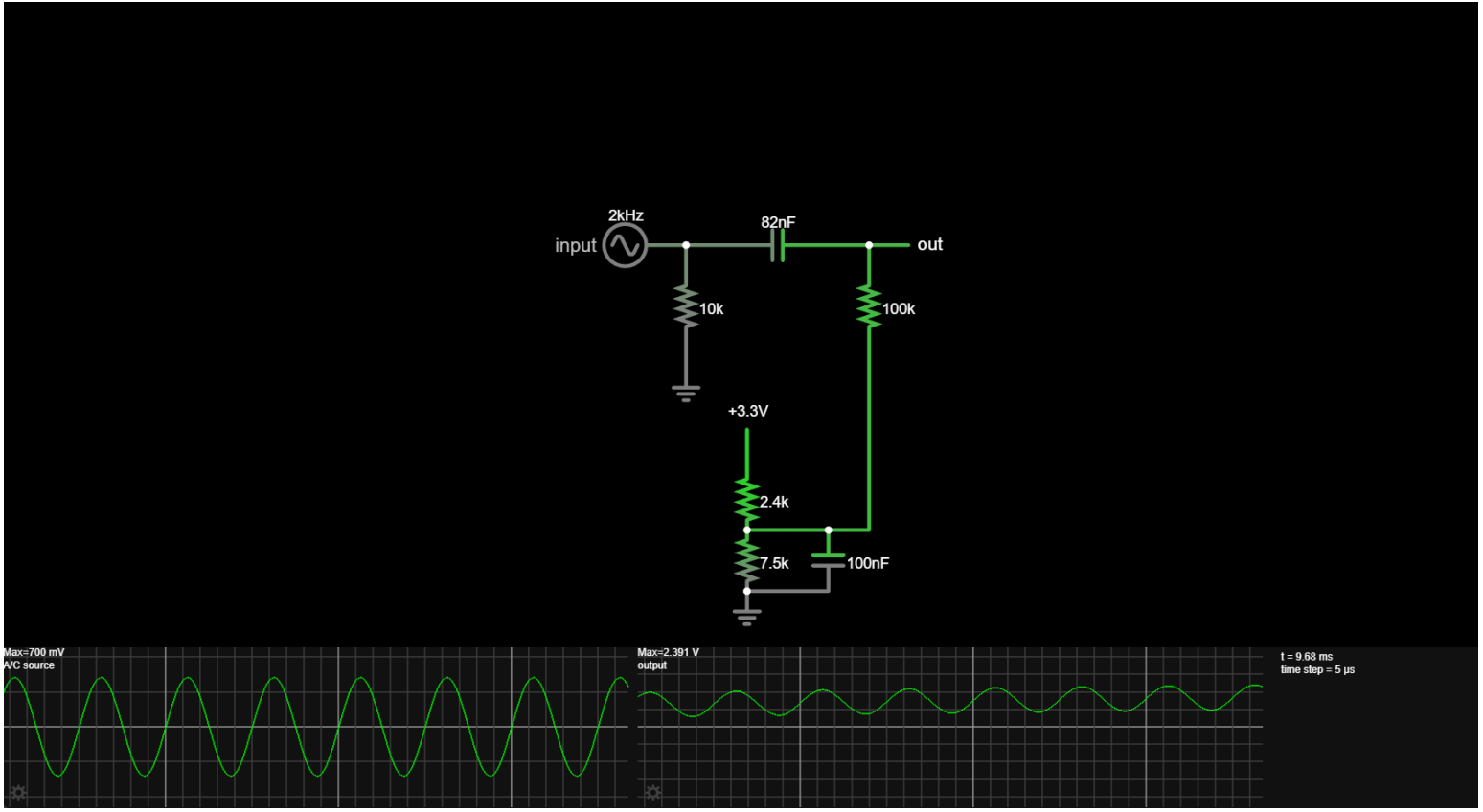
External copper thickness (1 oz)	1.6 mil
Internal copper thickness (0.5 oz)	0.6 mil
Internal copper thickness (1 oz)	1.2 mil
Base soldermask thickness	1.2 mil
Copper-surface soldermask thickness	0.6 mil
Soldermask thickness in between traces	1.2 mil
Soldermask dielectric constant (εr)	3.8
Trace top width	Trace base width – 0.7 mil

Nan Ya Plastics NP-155F (4 to 8 layers)

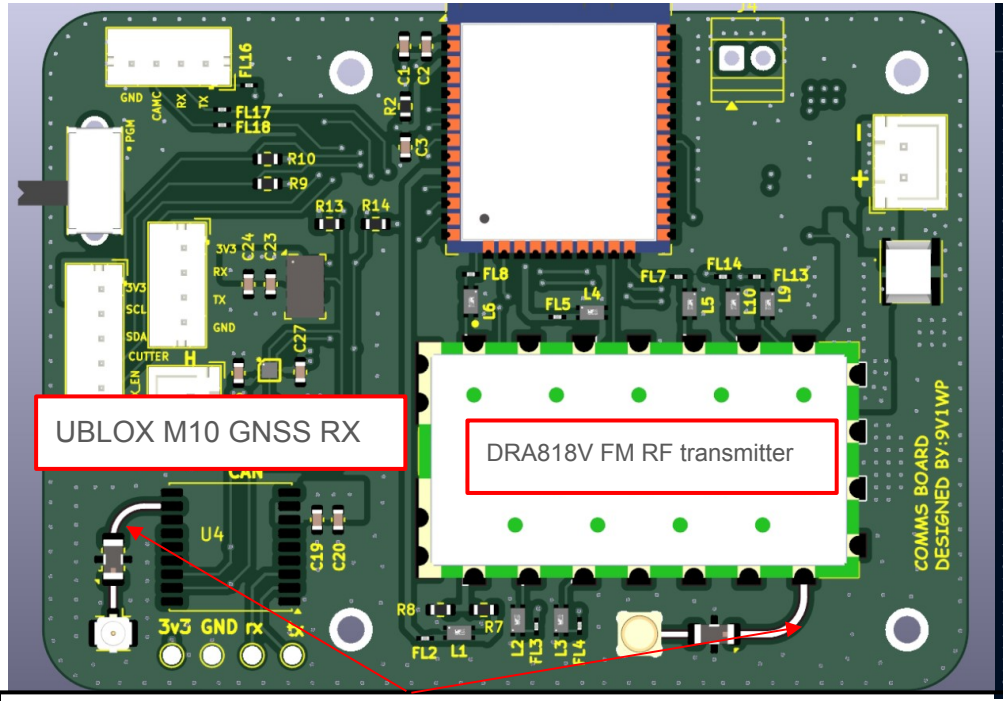
Core Thickness	εr	Prepreg Type	Resin Content	Nominal Thickness	εr
0.08 mm	3.99	7628	49%	8.6 mil	4.4
0.10 mm	4.36	3313 (2313)	57%	4.2 mil	4.1
0.13 mm	4.17	1080	67%	3.3 mil	3.91
0.15 mm	4.36	2116	54%	4.9 mil	4.16
0.20 mm	4.36				
0.25 mm	4.23				
0.30 mm	4.41				
0.35 mm	4.36				
0.40 mm	4.36				
0.45 mm	4.36				
0.50 mm	4.48				
0.55 mm	4.41				
0.60 mm	4.36				
0.65 mm	4.36				
0.70 mm	4.53				

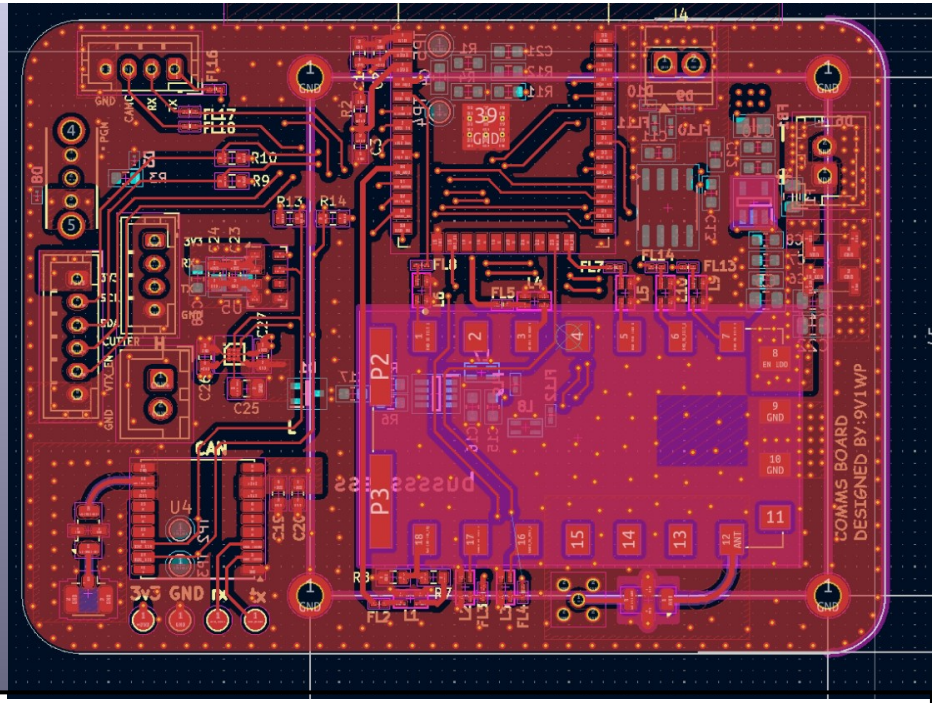


AC coupling to DC coupling circuit



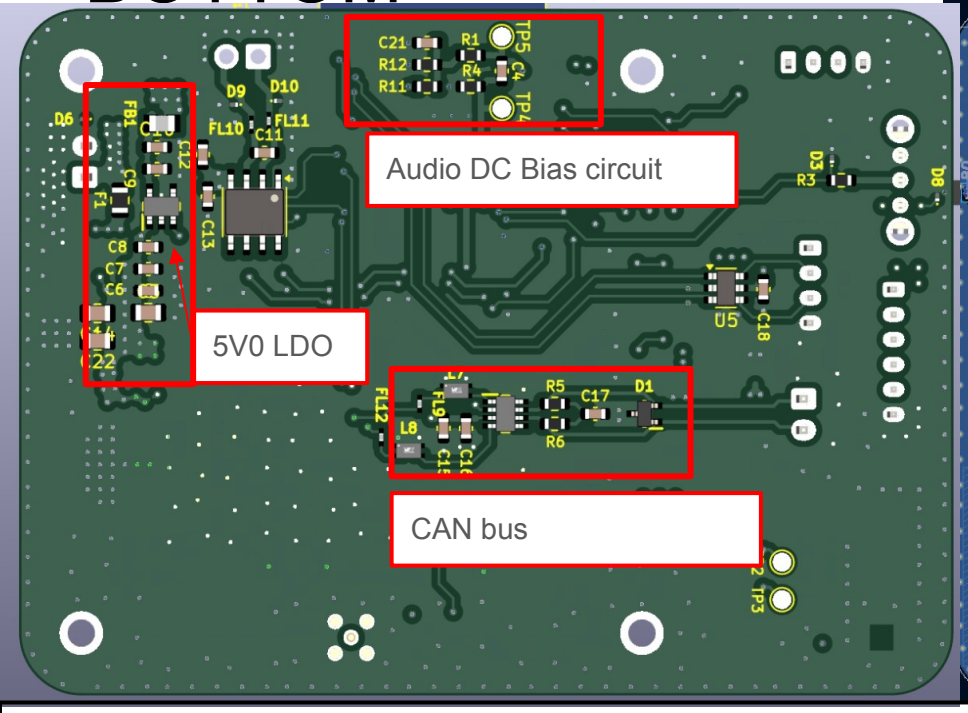
TOP

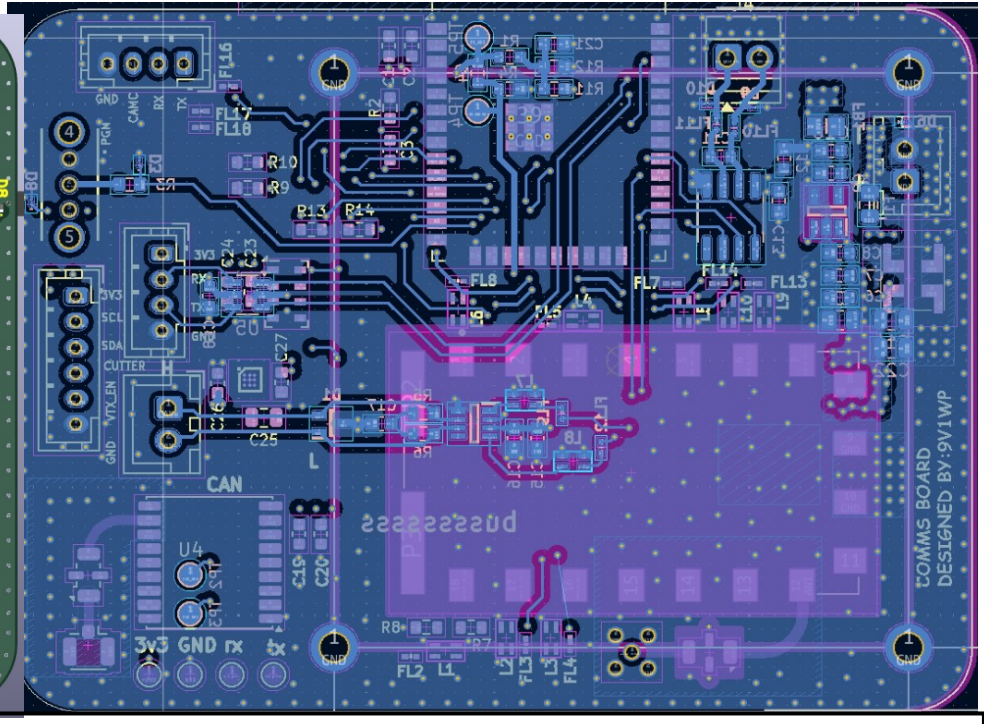




Soldermaskless RF traces for GNSS and VHF APRS, Coplanar Waveguide, added via stitching to groundplane at spaced at ⅛ wavelength of VTx

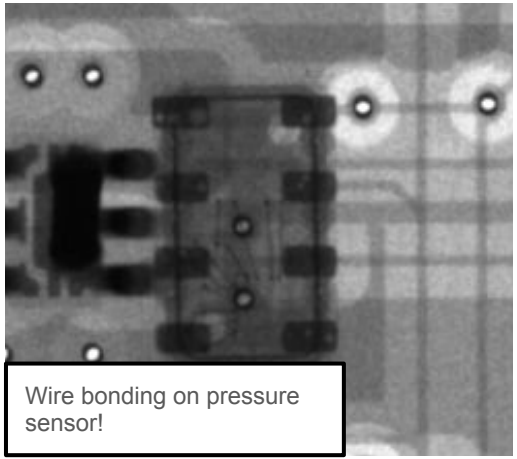
BOTTOM



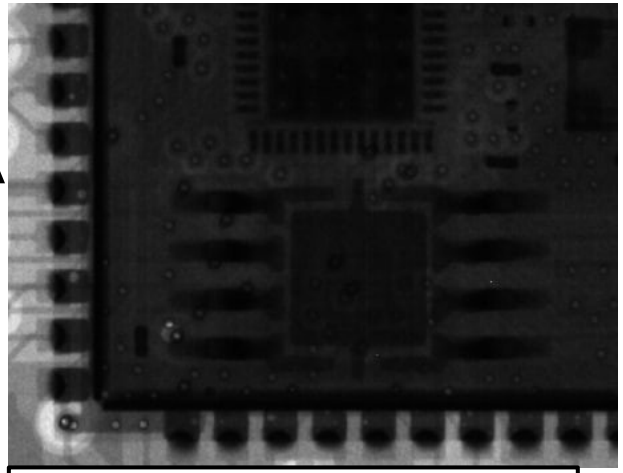


5V0 LDO, CAN Bus, used inductor filter beads with a 100MHz peak impedance to act as low pass filter with a Passband below 100MHz(no coupling with VHF 144.390MHz VHF transmit)

JLC X-Ray(FOC if you have BGA

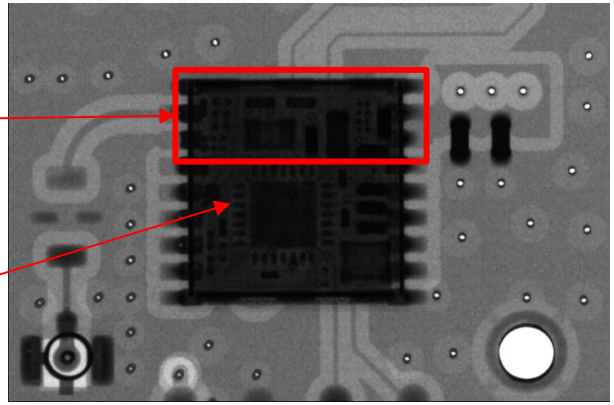


Wire bonding on pressure sensor!



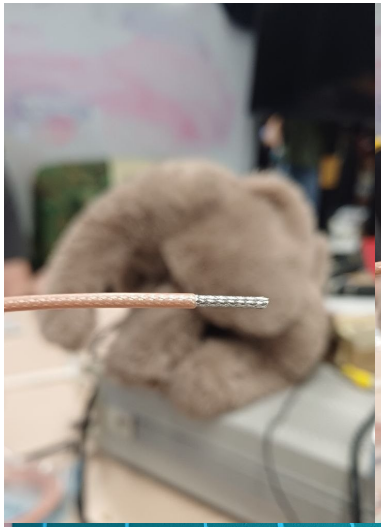
ESP32 module

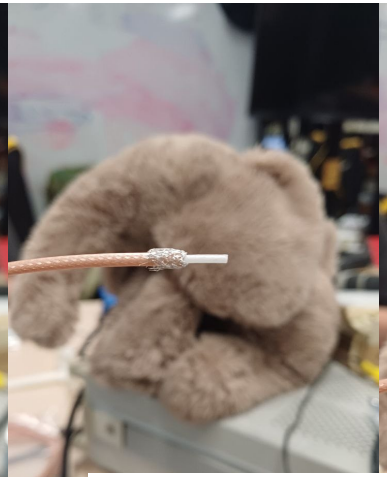
RF front end?

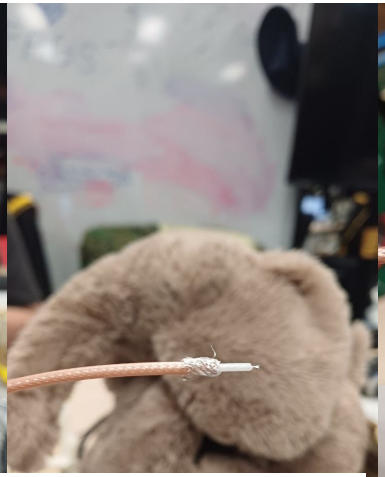


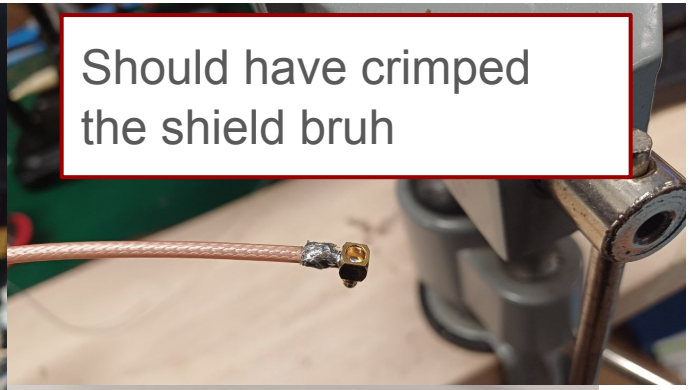
UBlox probably uses an ASIC?(my next project is to make a COCOM limit breaker using a FPGA and custom RF front end)

Half wave dipole Antenna construction

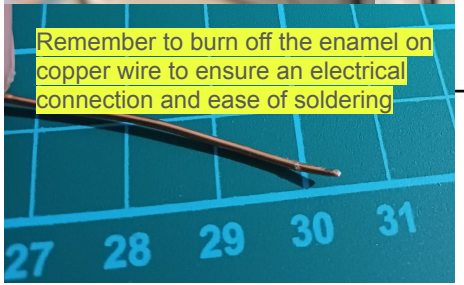


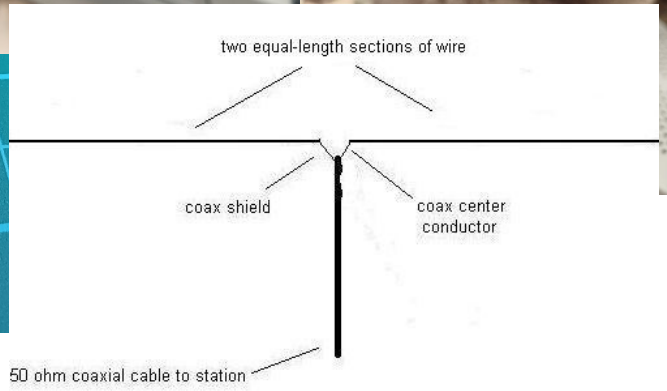


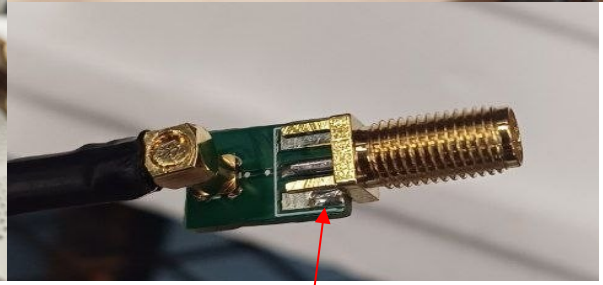




Should have crimped the shield bruh

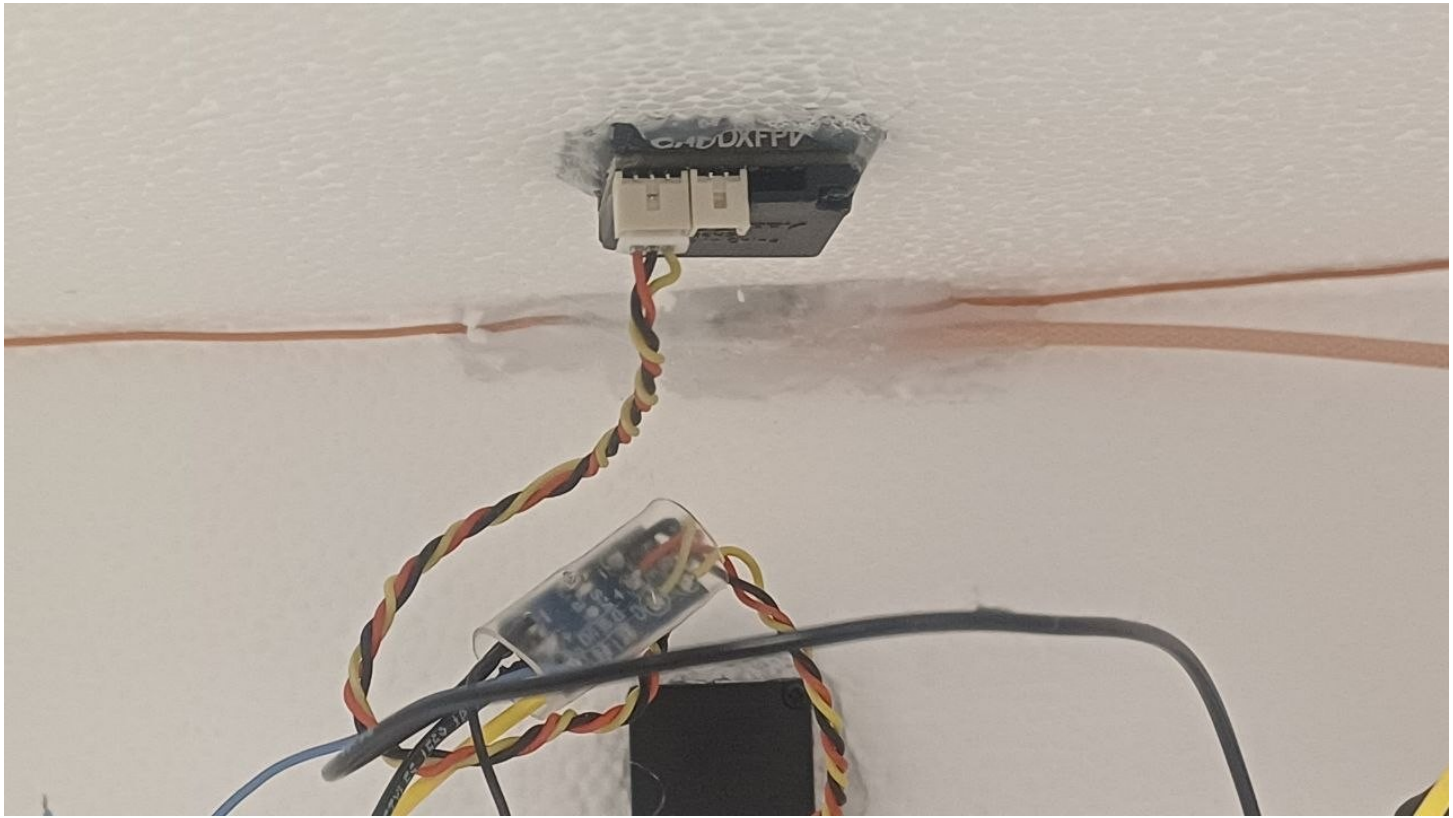






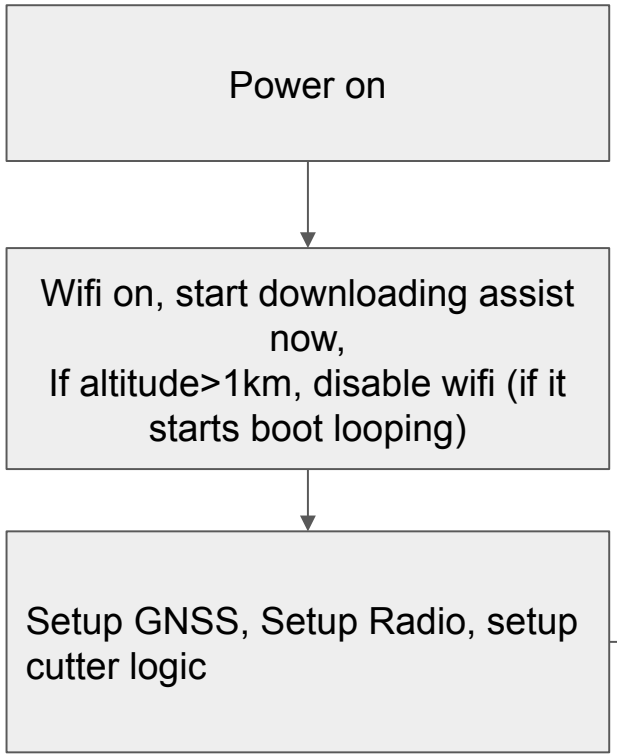
MMCX to SMA adaptor for VNA testing

Integrated Antenna(Hot Glue Spam!)



VNA measurement. not bad VSWR~1.67

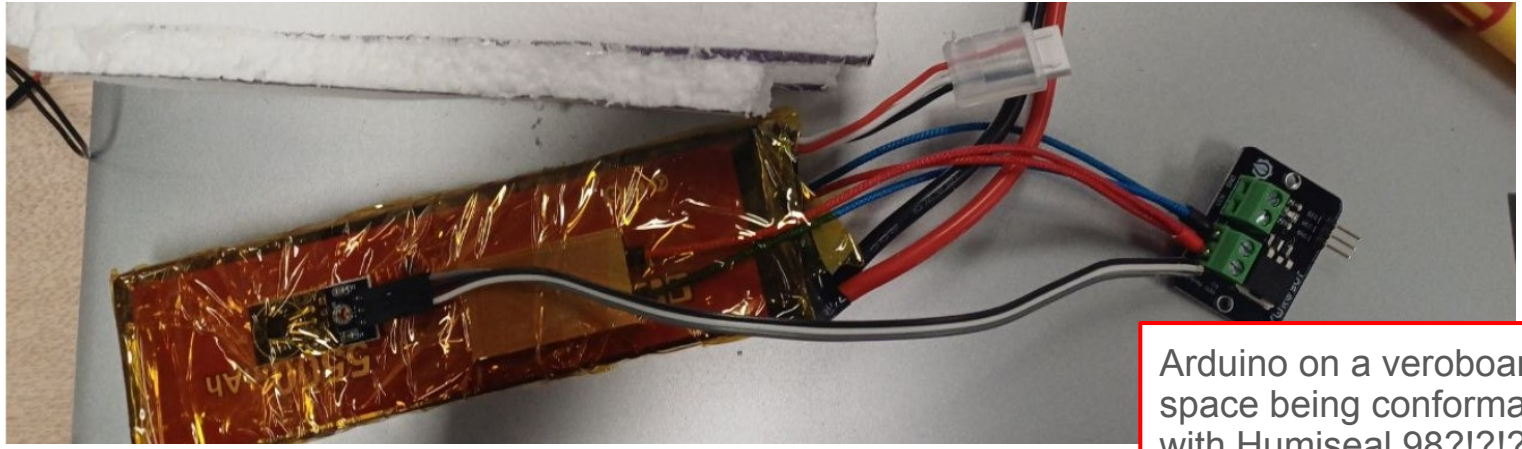
Flight software review



[Void loop]
Transmitter state machine:
2s to warm up Tx->Give 6s to give time for APRS message to fully transmit->2s warm down Tx->wait 30s for next transmission
<Possibly some limitations like turning off high power draw devices like heater during transmission>

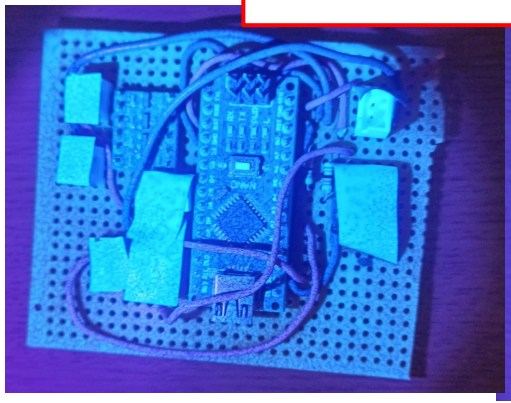
Read Sensors
Cut altitude detector
<Timing done by typical millis code blocks to avoid using blocking delays, no RTOS used>

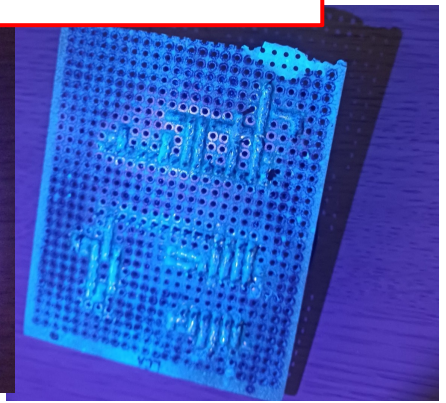
Battery Pack & Management board(Done by Alvin Tan)



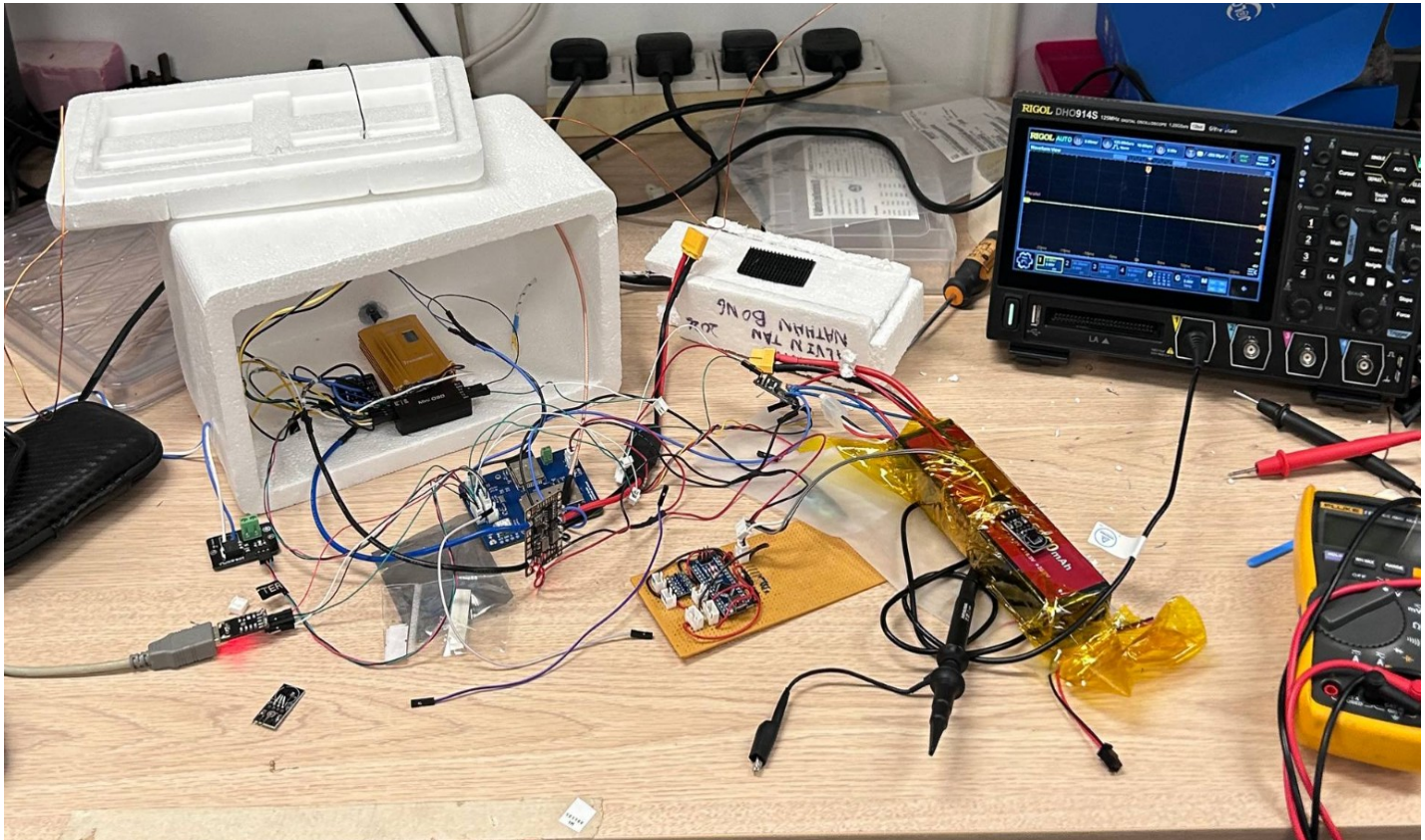
Arduino on a veroboard to near space being conformal coated with Humiseal 98?!?!?!

2x PTC Heaters
1x One Wire temperature sensor
1x 5200mAh LiPo battery
1x Current Sensing and comms to Comms board
Kick in temperature: 15C (To maintain capacity)





Flight Payload



Rotator (Done by Nathan Bong)

- Track weather balloon using APRS data (Longitude, Latitude, Altitude) using API call from APRS.fi
- This ensures continuous video reception due wideband nature of signal (Lower Power Spectral Density)
- Repurposed Celestron Telescope rotator with custom software to enable us to use it for a weather balloon purpose using Hamlib to communicate with the proprietary protocol used.

Thank you!

Hardware:

RandomAerospace/COMMS-BOARD: APRS+GNSS board with hotwire, FPV camera control capability, to be paired with a power board with load switches

Firmware

RandomAerospace/BEAR13_FIRMWARE: Weather Balloon APRS Telemetry board using the SA818V, MS5611 barometer that works to 25km and a BMM350 magnetometer.

Public Repo of Flight Videos:

https://drive.google.com/drive/folders/1_X3jxc-5LpaSDKGHUICmf7610ZXz4bj3?usp=drive_link

Organisations:

Bumblebee Autonomous Systems, National University of Singapore(NUS), NUS Satellite Technology and Research Centre