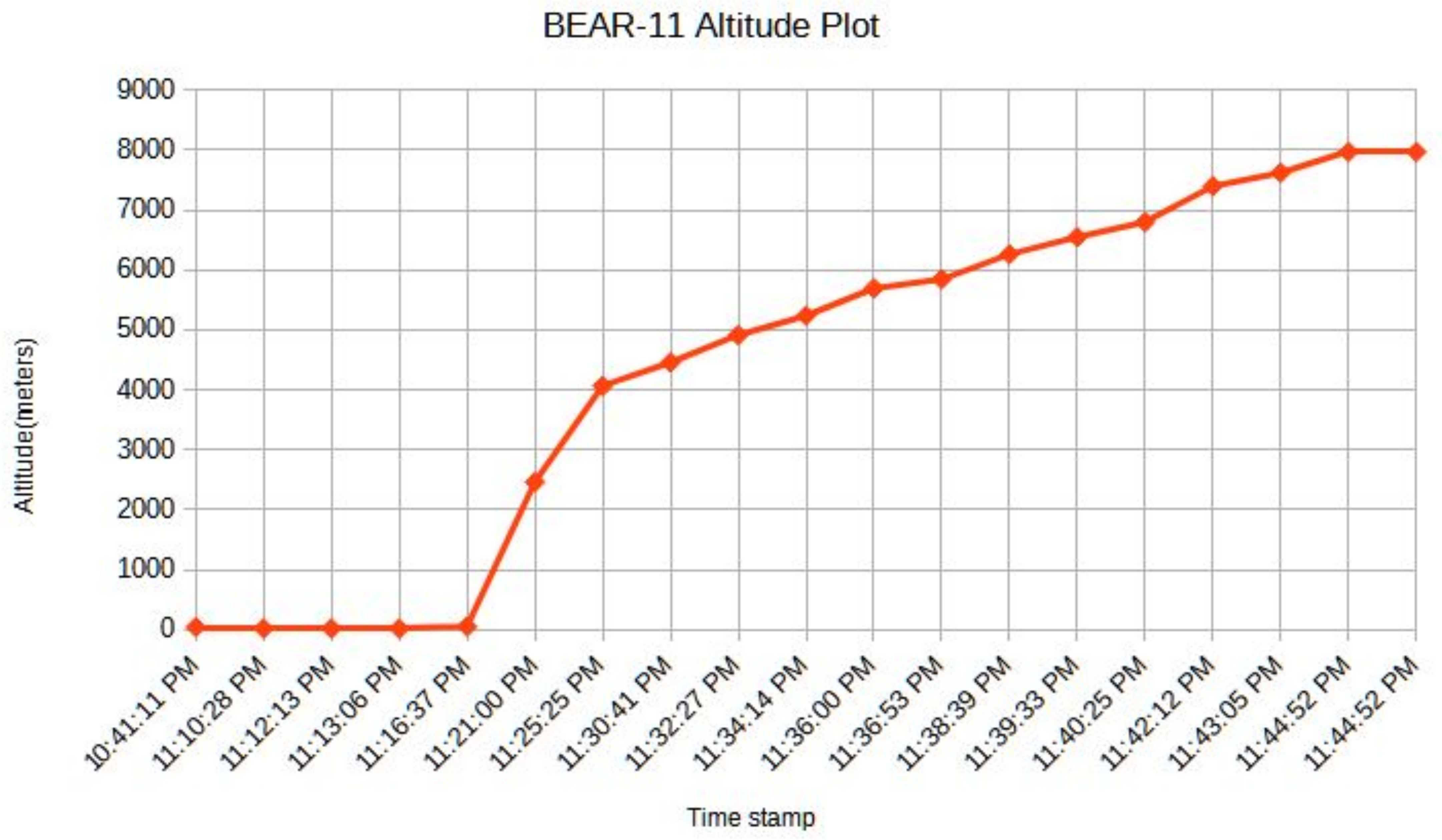
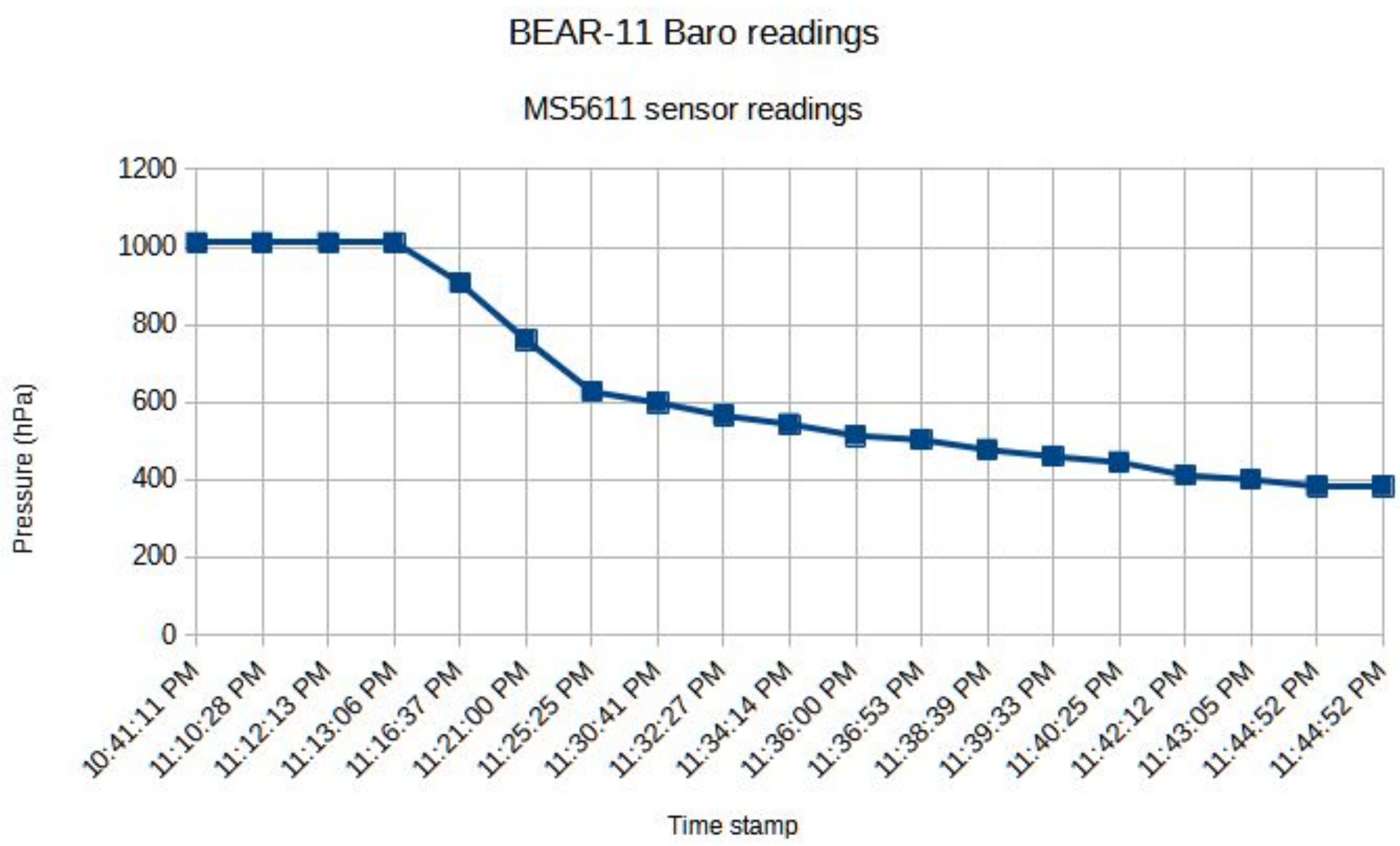
Balloon Experiments with Amateur Radio Flight 11 Post-Flight review

Payload lead: Wai Phyo 9V1WP
Resident-Rigging Expert: Fu Hang 9V1FH
Payload specialists and ground support: Liwei 9V1LW, Choong 9V1CV
Regulations,clearance: Chew 9V1YP

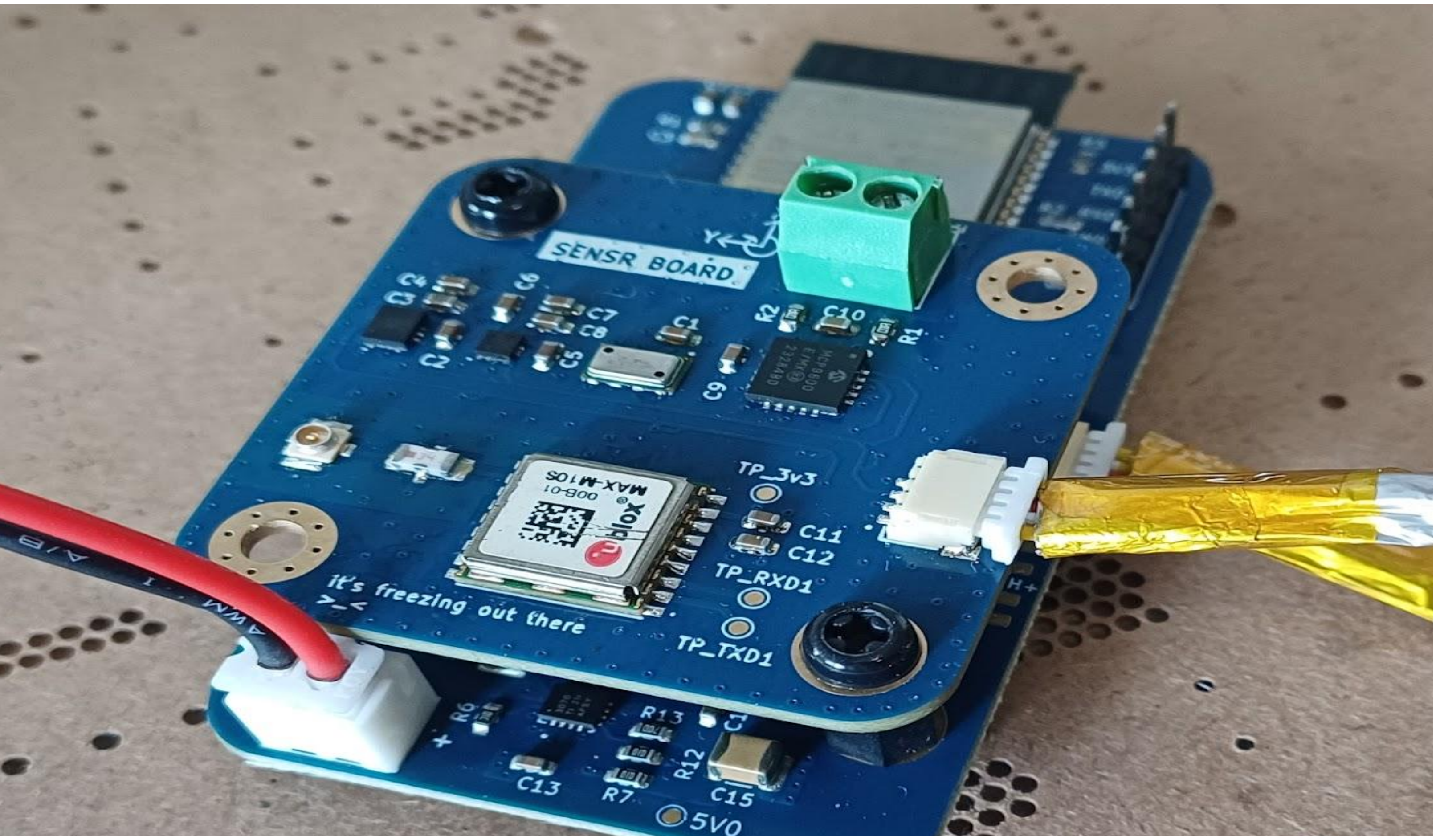


Loss of signal after Payload reached 7966m due to excessive
battery drain, causing battery to rapidly deplete



MS5611, rated to 30km altitude at low precision performed nominally until battery ran out

Flight Stack



Flight Program:
Launch->Payload cut from balloon at 30km->land

Sensor group:

- MS561101BA03-50
  - i2c
- ASM330LHHTR &
  - i2c
- MAX-M10s
  - i2c
- MCP9600
  - i2c

4 layer PCB w/coplanar Waveguide impedence matched trace for GNSS antenna

RF module: SX1268 based E22-M40030S 1W transmitter module
Tx freq: 432.600MHz

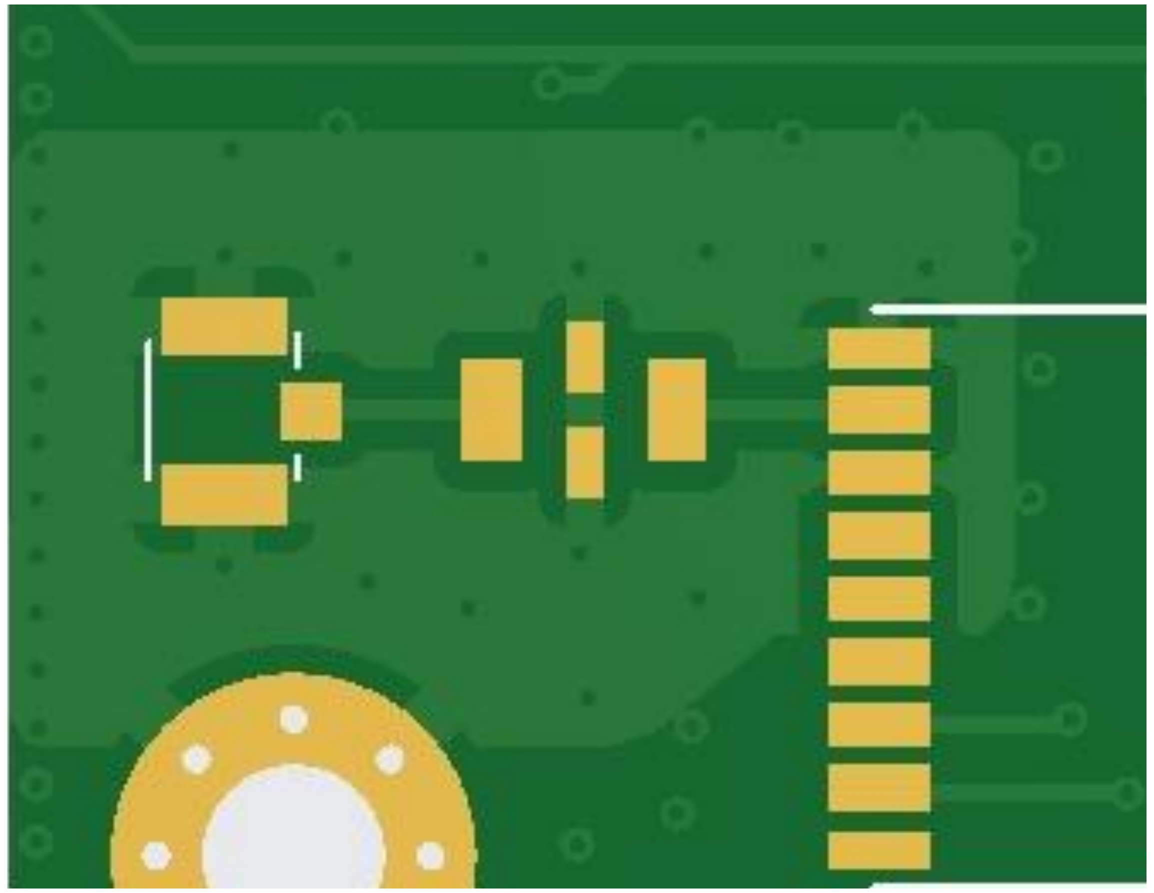
Control

- 1x GPIO for nichrome wire cutter(10 ohm,0.5A)
- 1x GPIO for controlling battery Heater

Power electronics:
TPS63070 Buck Boost Converter(Battery->5V0)
AMS1117-3.3(5V0->3V3)

ESP32-s2-mini-2
MCU

GNSS filtering



BFCN -1575+ Bandpass filter routed on CPW designed using KiCad CPW calculator and JLC stack up specifications.

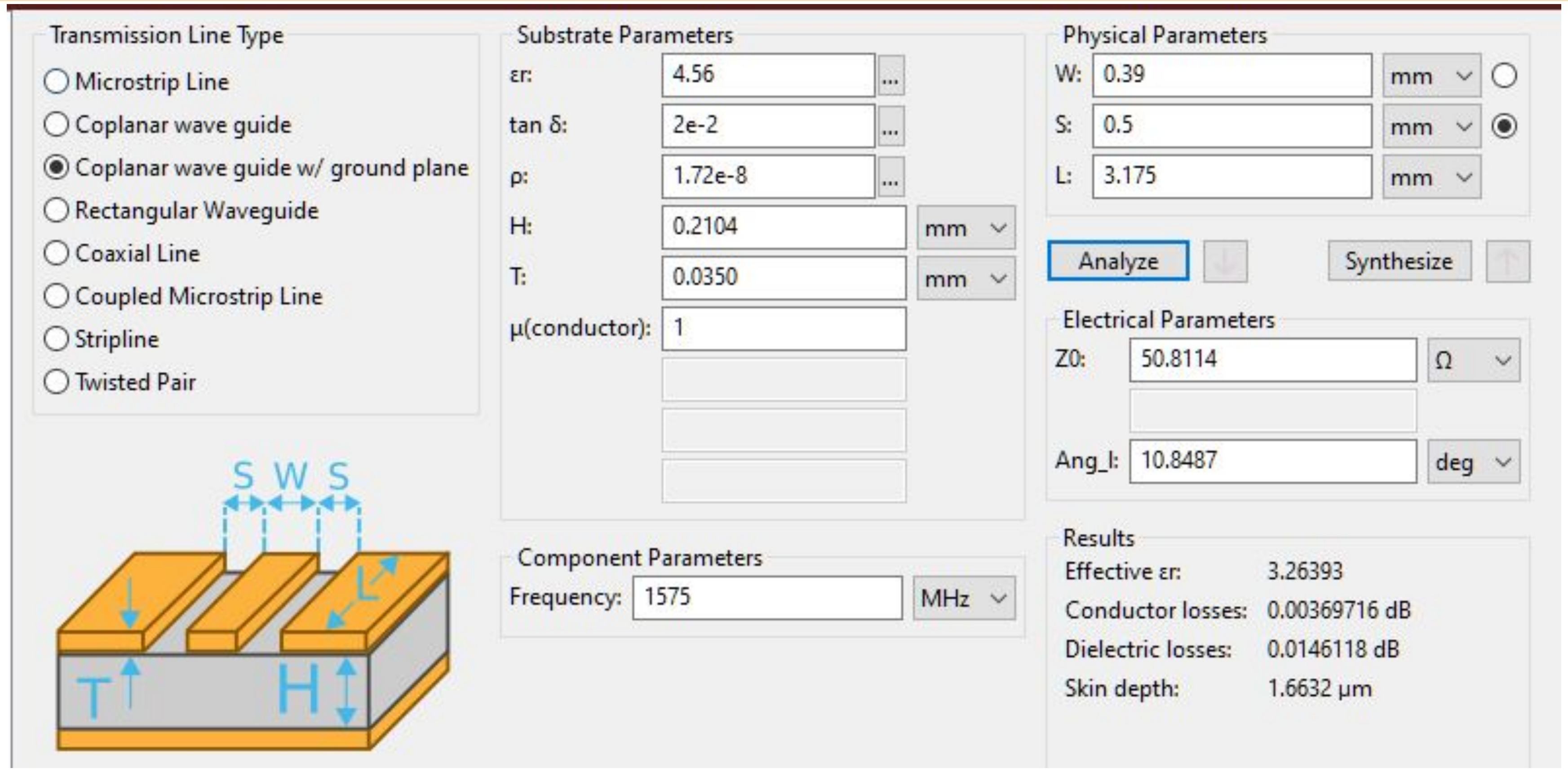
Via stitches used to produce low impedance return path to ground(improves EMI performance and decreases noise)

Impedance (Ω)	Type	Signal Layer	Top Ref	Bottom Ref	Trace Spacing (mm)	Impedance trace to copper (mm)
50	Coplanar Single Ended	L1	/	L2	/	0.50

JLC04161H-3313(成品板厚1.56mm±10%) | JLC04161H-3313A(特殊/成品板厚1.58mm±10%) | JLC04161H-7628(通用/成品板厚1.59mm±10%) | JLC04161H-7628B(特殊/成品

Impedance (Ω)	Type	Signal Layer	Top Ref	Bottom Ref	Trace Width	Trace Spacing	Impedance trace to copper
50	Coplanar Single Ended	L1	/	L2	0.3421	/	0.5000

Layer	Material	Thickness (mil)	Thickness (mm)
L1	Outer Copper Weight1oz	1.38	0.0350
Prepreg	7628, RC 49%, 8.6 mil	8.28	0.2104
L2	Inner Copper Weight	0.60	0.0152
Core	1.1mm H/HOZ with copper	41.93	1.0650
L3	Inner Copper Weight	0.60	0.0152
Prepreg	7628, RC 49%, 8.6 mil	8.28	0.2104
L4	Outer Copper Weight1oz	1.38	0.0350



Via fencing spacing calculations

Project | Journey SBC | Hackaday.io

Wavelength of /20 for board /8 for edges

Antenna Design and RF Layout Guidelines (infineon.com)

$$S(via) = \lambda/20 = c/(20f\sqrt{\varepsilon_r})$$

Why an additional BPF?

It’s mainly to test out GNSS lock functionality when there are heavy harmonics near a 1W transmitter, worked nominally, good GNSS lock during nominal flight.

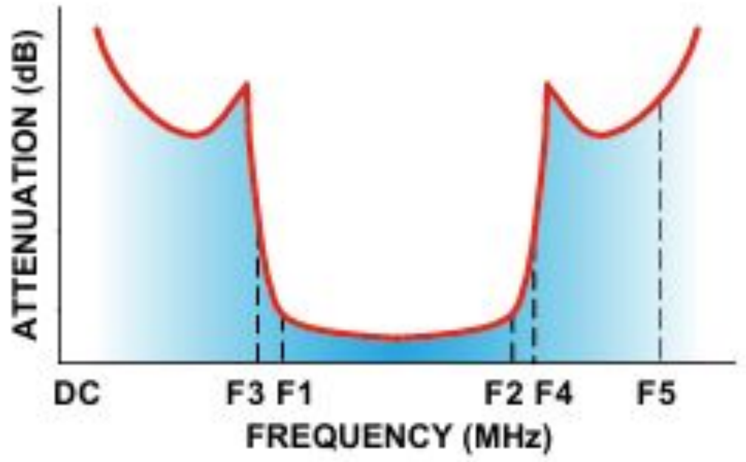
Useful for future flights where i plan to have a 1.5W Analog Video Transmitter

Electrical Specifications[1,2] at 25°C

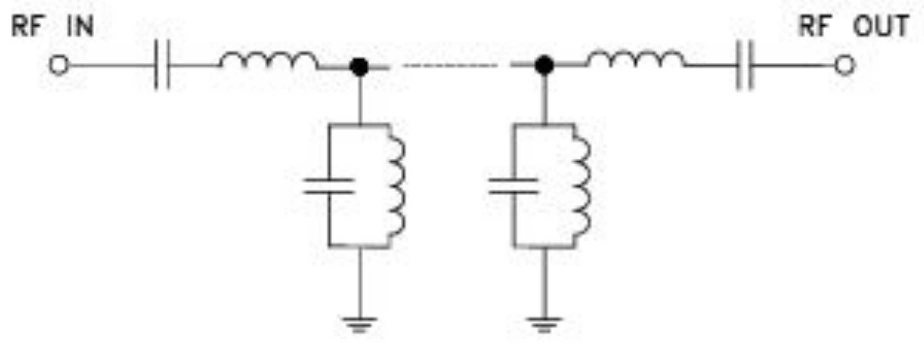
Parameter		F#	Frequency (MHz)	Min.	Typ.	Max.	Unit
Pass Band	Center Frequency	—	—	—	1575	—	MHz
	Insertion Loss	F1-F2	1530-1620	—	—	3.0	dB
	VSWR	F1-F2	1530-1620	—	—	2.5	:1
Stop Band, Lower	Insertion Loss	DC-F3	DC-1200	—	20	—	dB
	VSWR	DC-F3	DC-1200	—	25	—	:1
Stop Band, Upper	Insertion Loss	F4-F5	2800-5200	—	25	—	dB
	VSWR	F4-F5	2800-5200	—	20	—	:1

1. Measured on Mini-Circuits Characterization Test Board TB-270.
2. This filter is not intended for use as a DC Blocking circuit element. In Application where DC voltage is present at either input or output ports, blocking capacitors are required at the corresponding RF port.

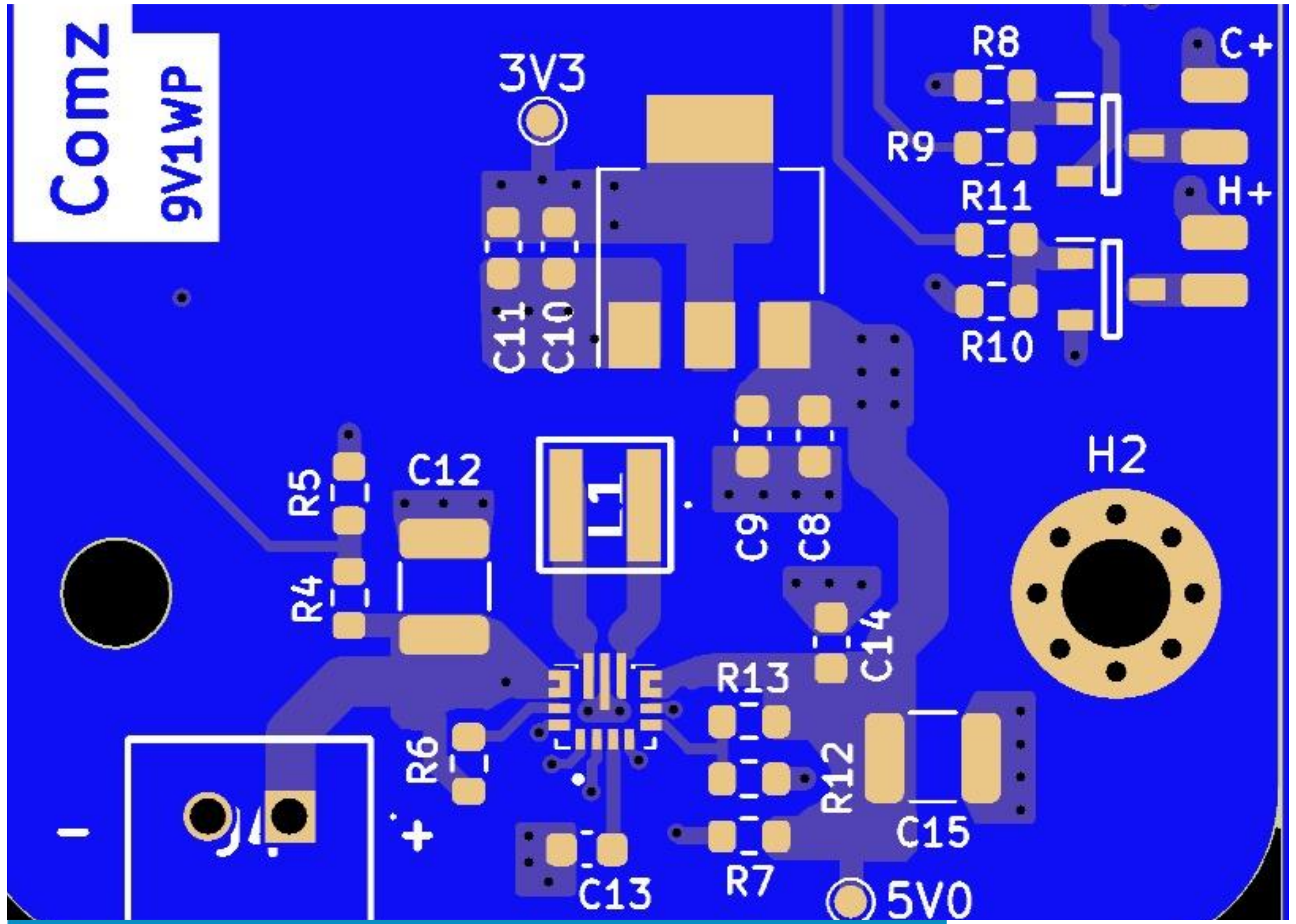
Typical Frequency Response

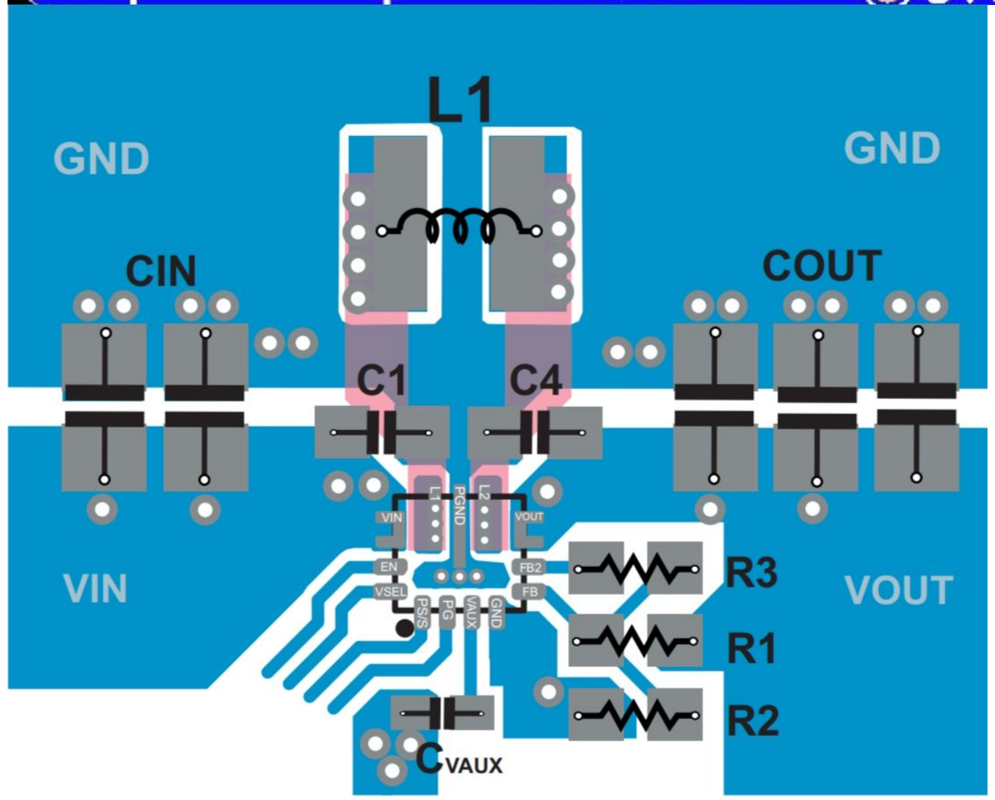


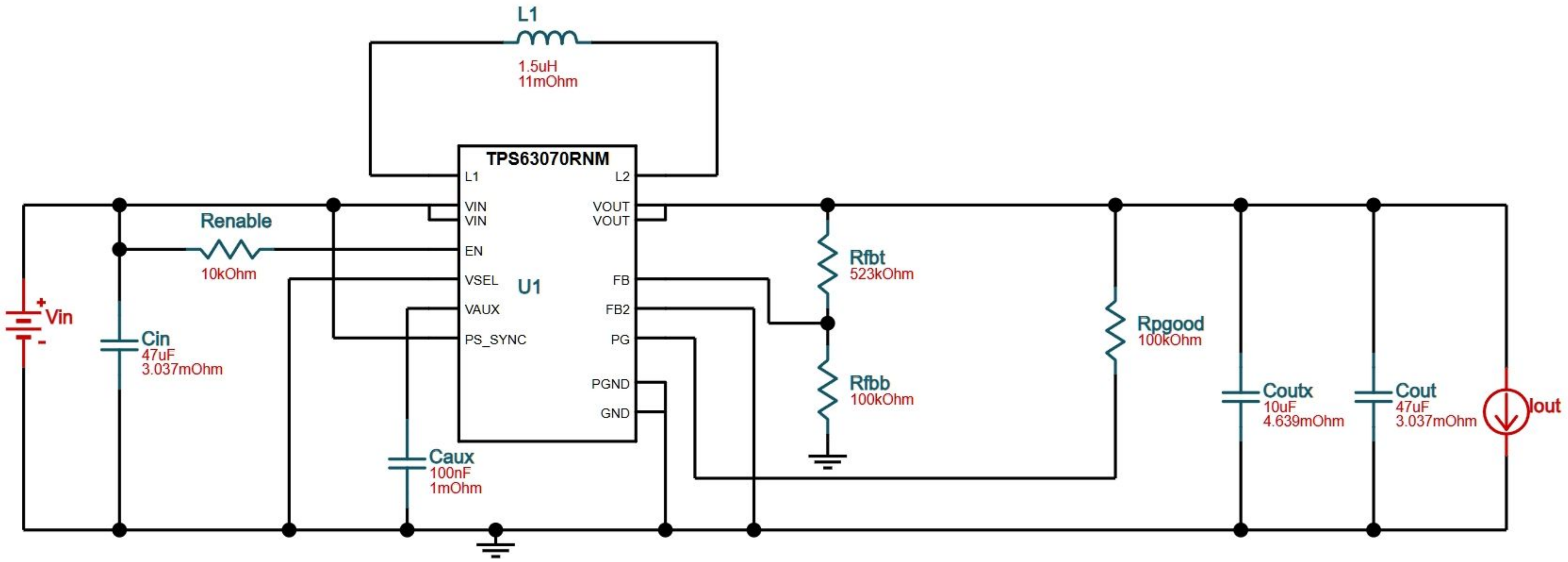
Functional Schematic



Power electronics





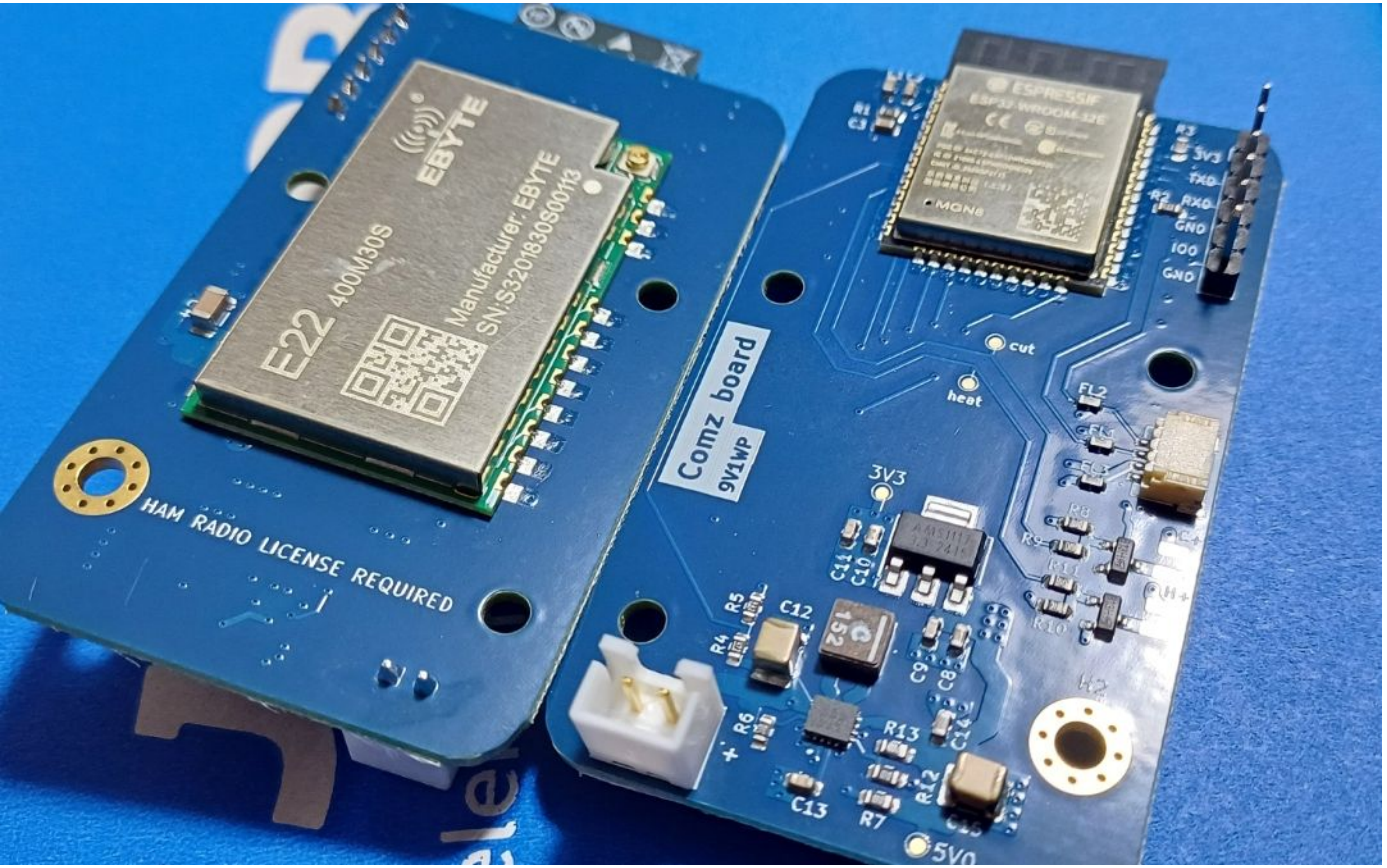


Used Ti Power Designer tool to get a layout with inputs Vin and Vout, ripple voltage was also a concern for the transmitter.(There are internal LDO and DC-DC converter in the SX1268 and on the Ebyte module)

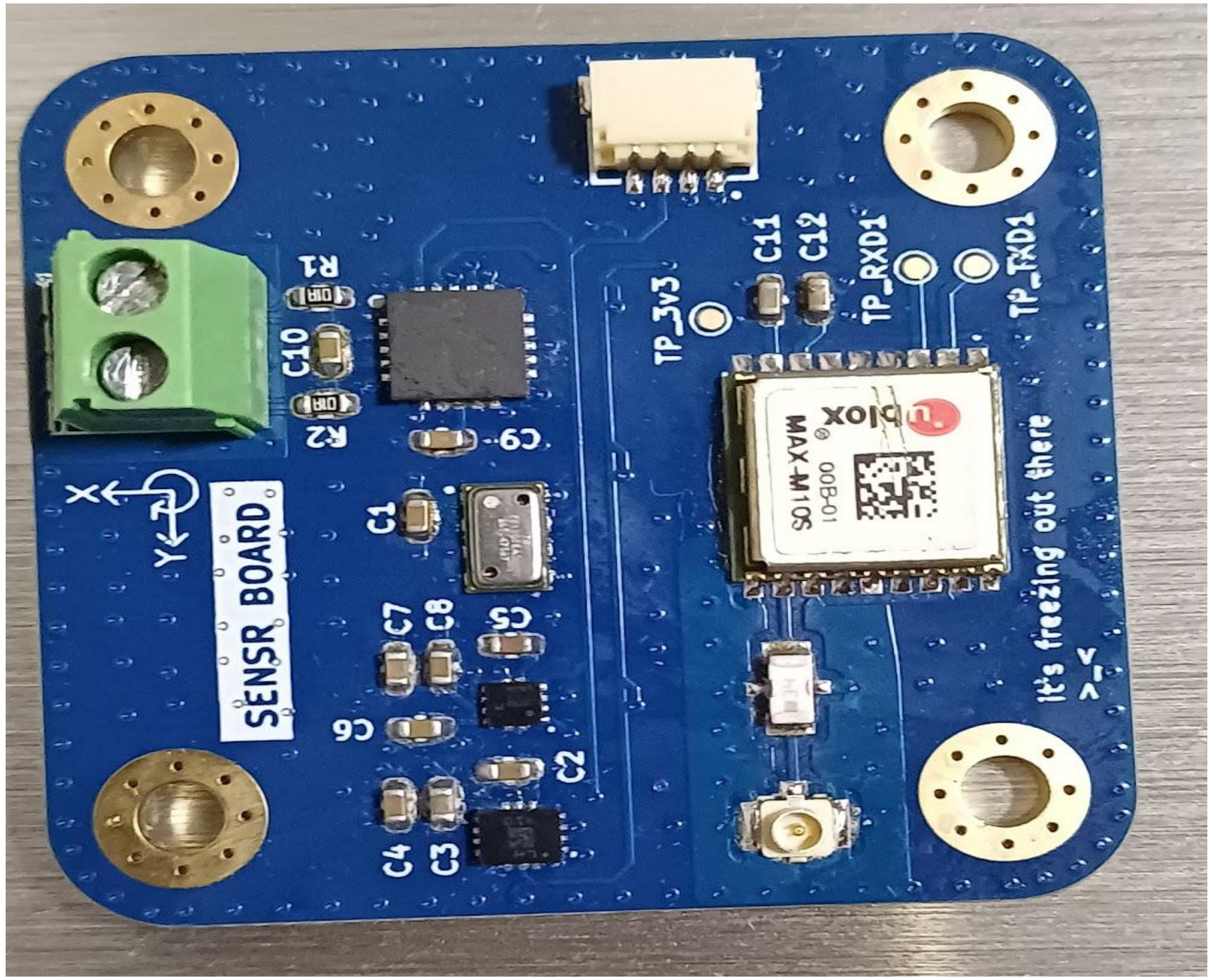
Voltage sense done by a voltage divider

Liberal use of ground pours and vias to have low impedance return path for currents, decrease voltage drops, ensure low voltage ripple and improve EMI (inductor!)

Jlc soldered



Diy soldered

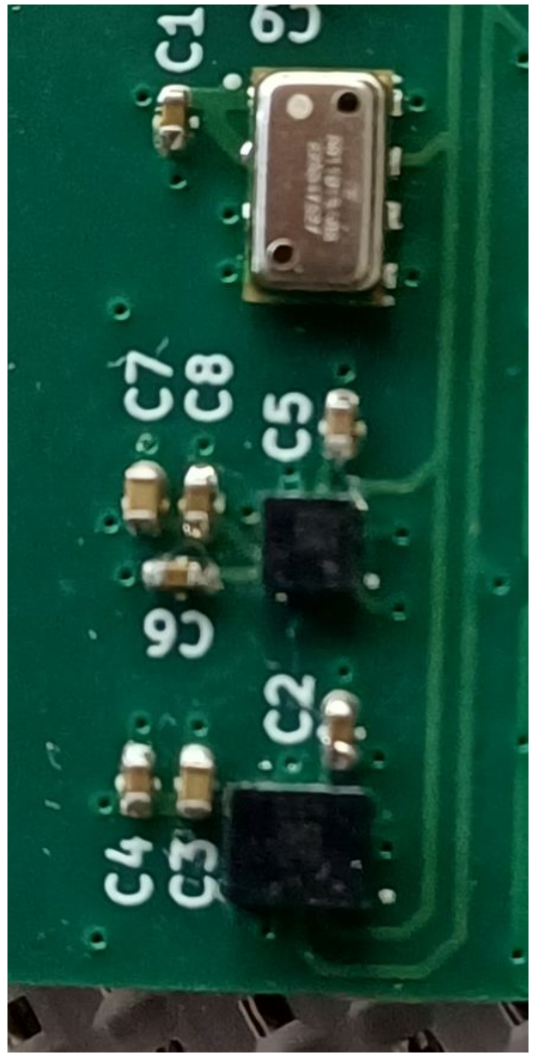


Lessons learnt from SMD soldering

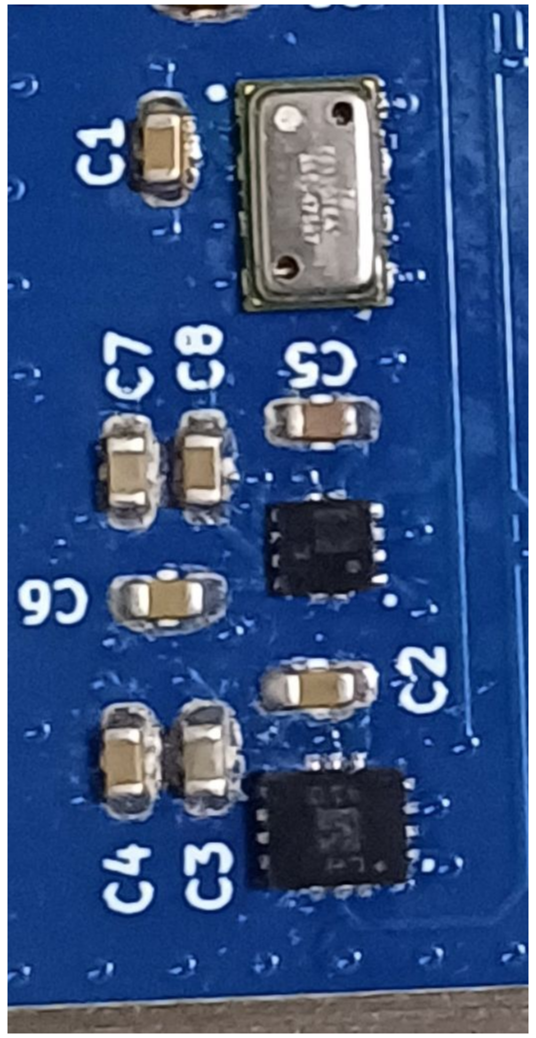
Do not use footprints imported from the IC libraries especially for LGA/QFN ICs.

Extend the solder pads out so that there is an indication of a good solder point(unless you have an x ray)

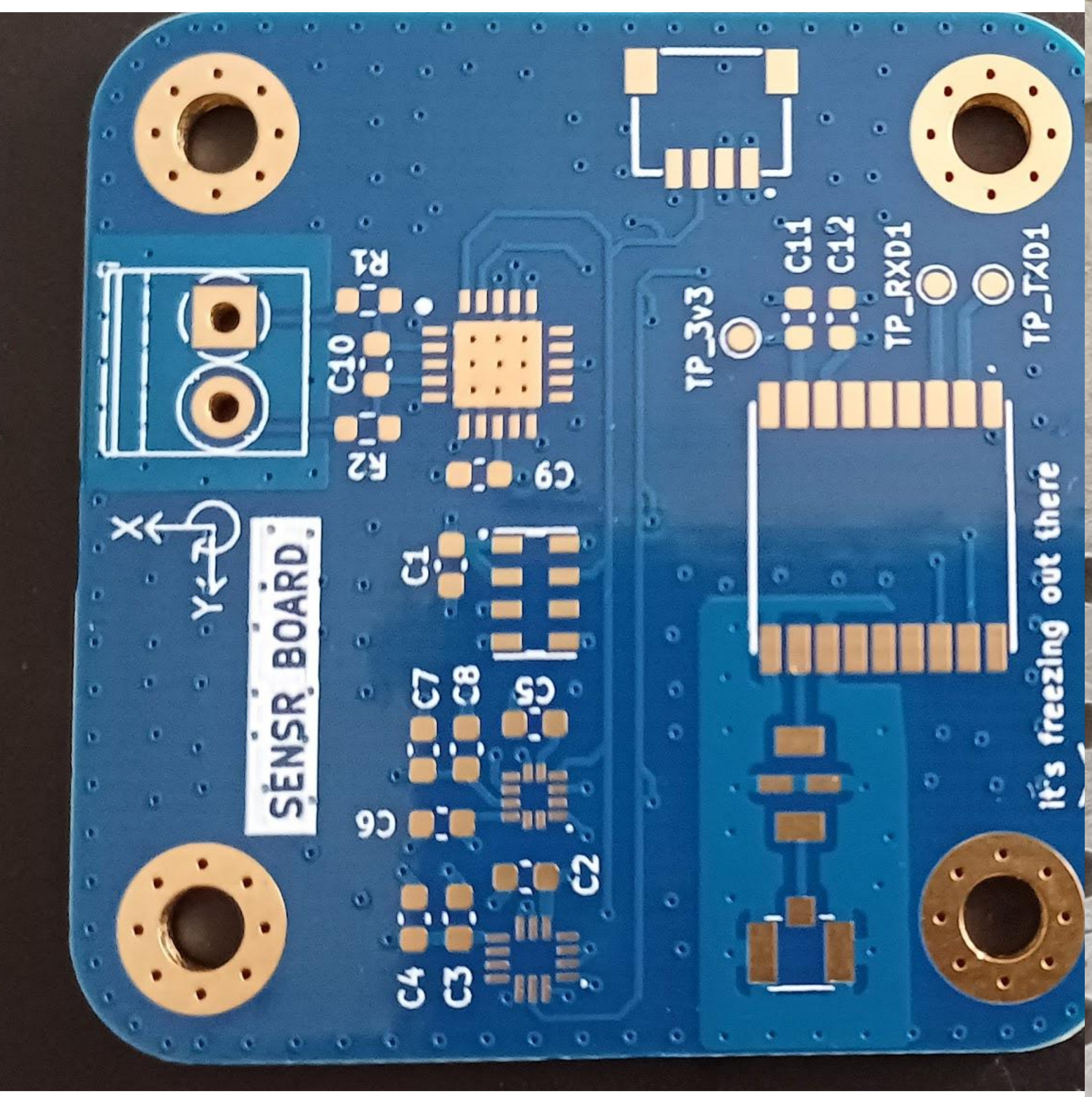
No indication->I2c device not detected)

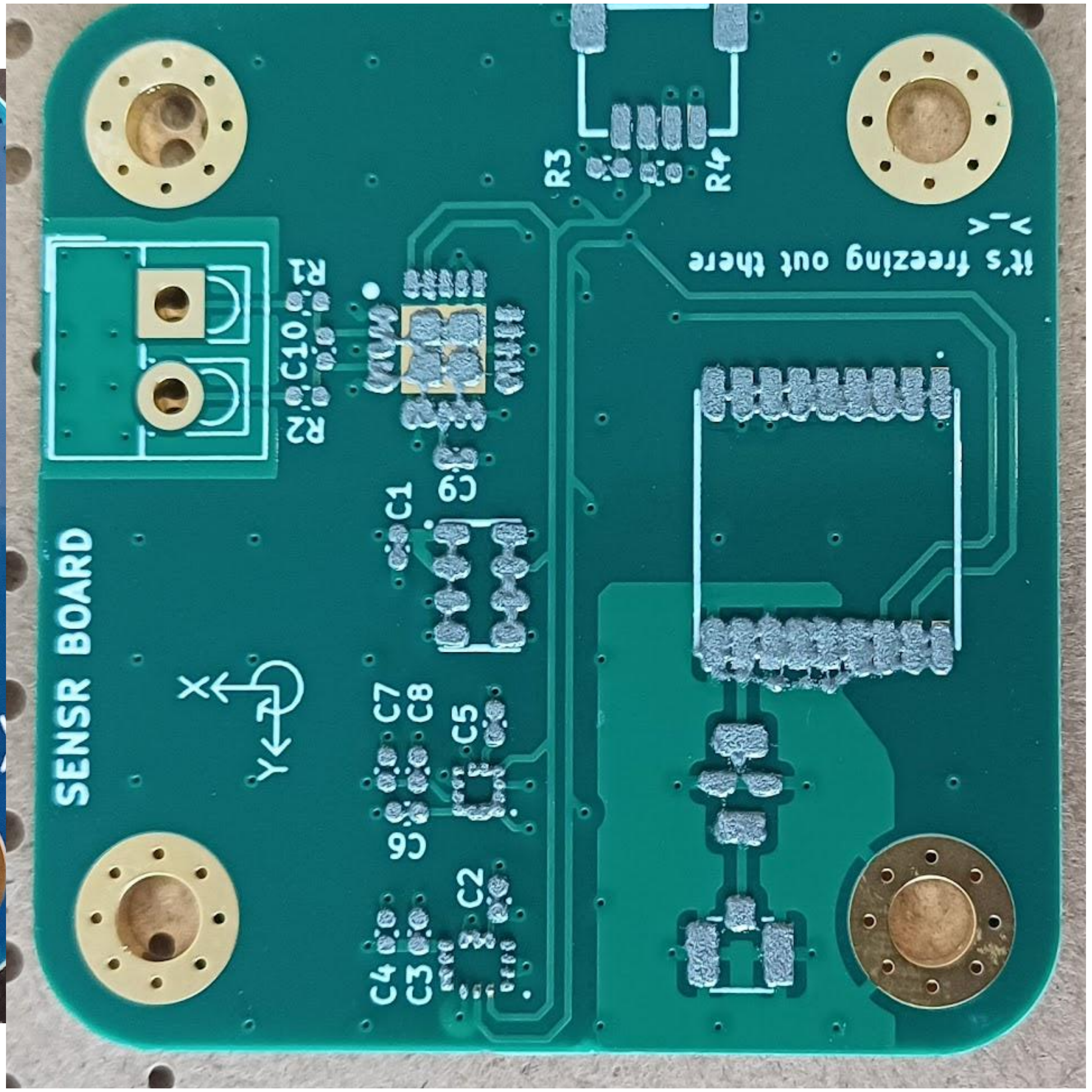


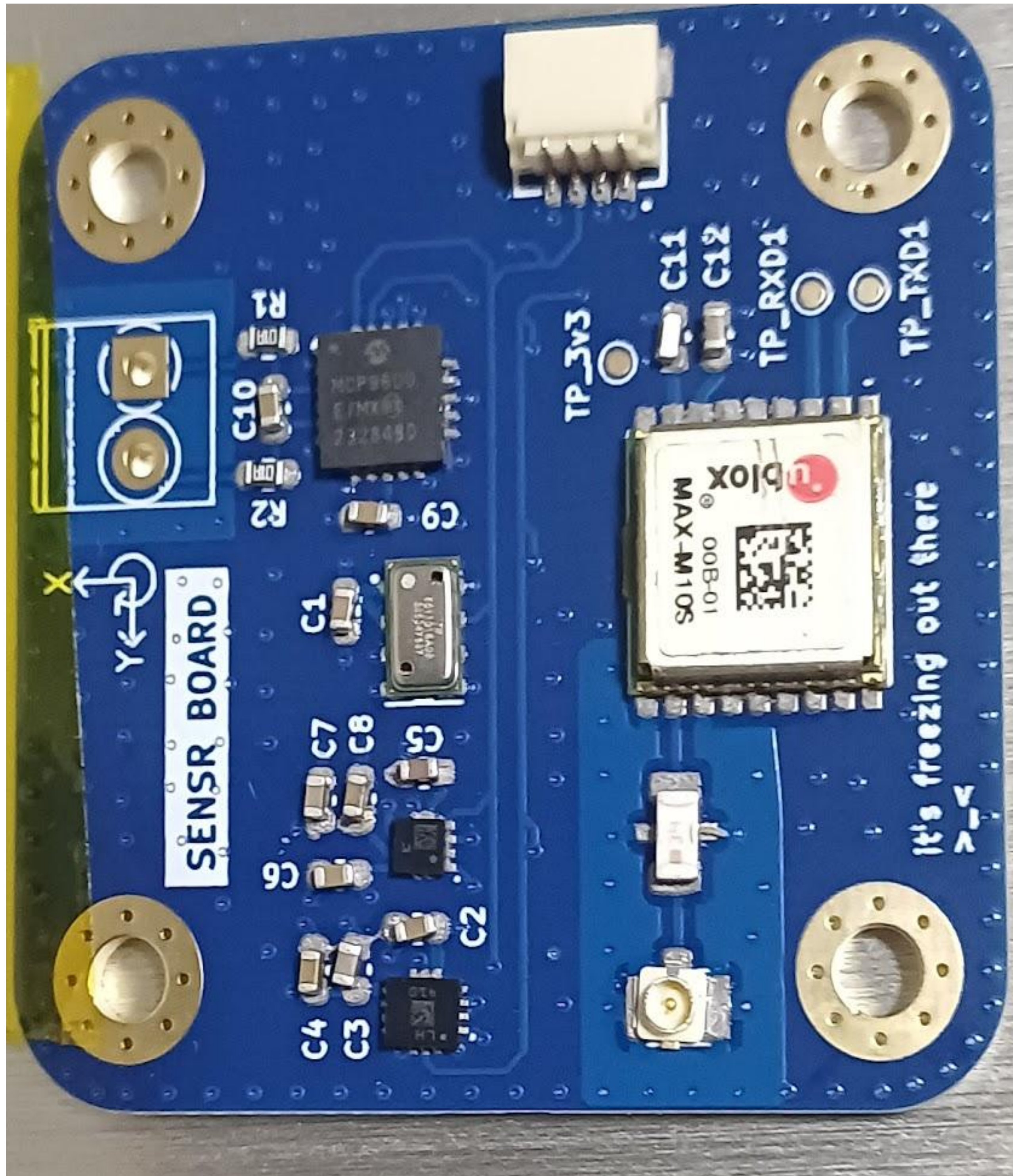
Solder pad extension ->good indication



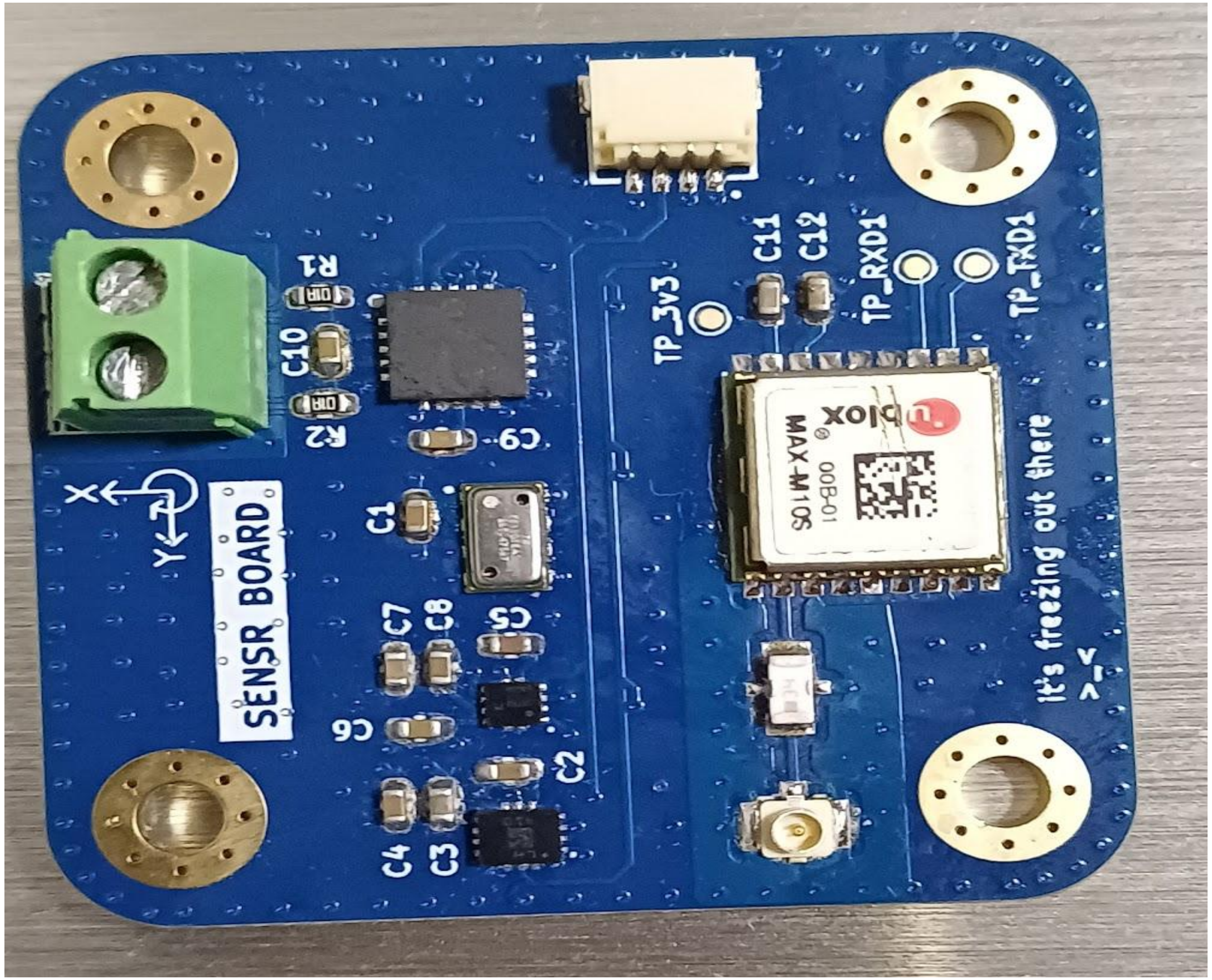
Hot plate soldering







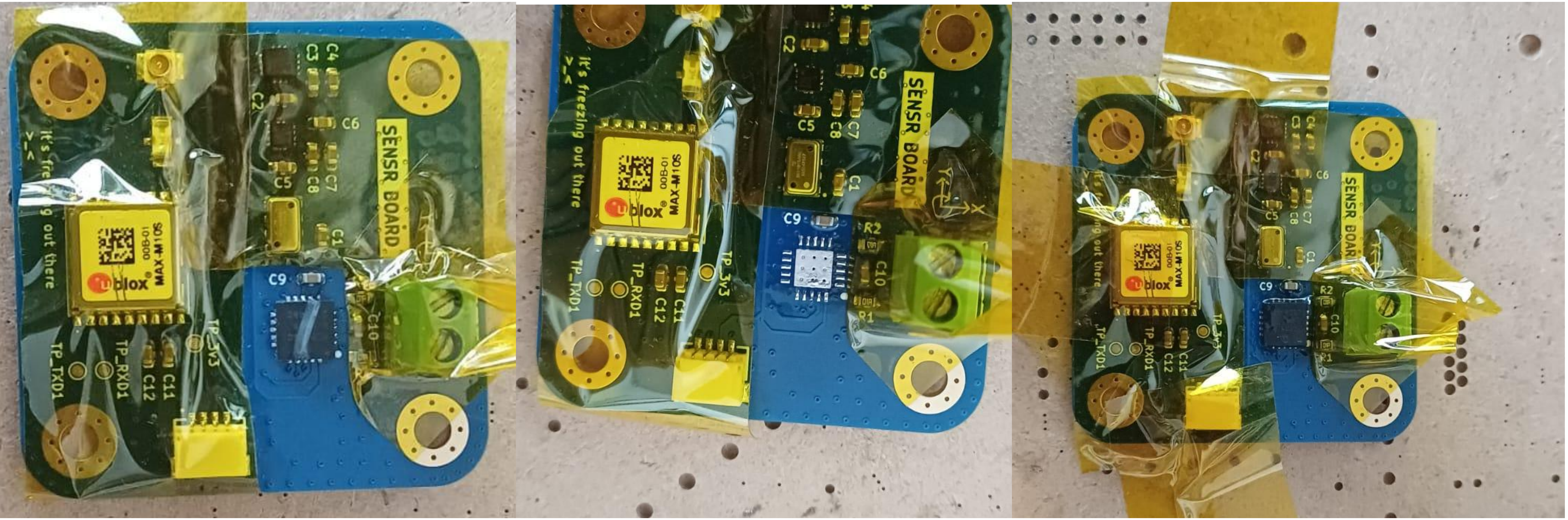
Finished product….or is it?



Open heart surgery: nothing a pint of Flux, heat gun, solder wick and a can do spirit can't solve

Solder did not reach some pins after hot plate soldering

Open heart surgery: nothing a pint of Flux, heat gun, solder wick and a can do spirit can't solve



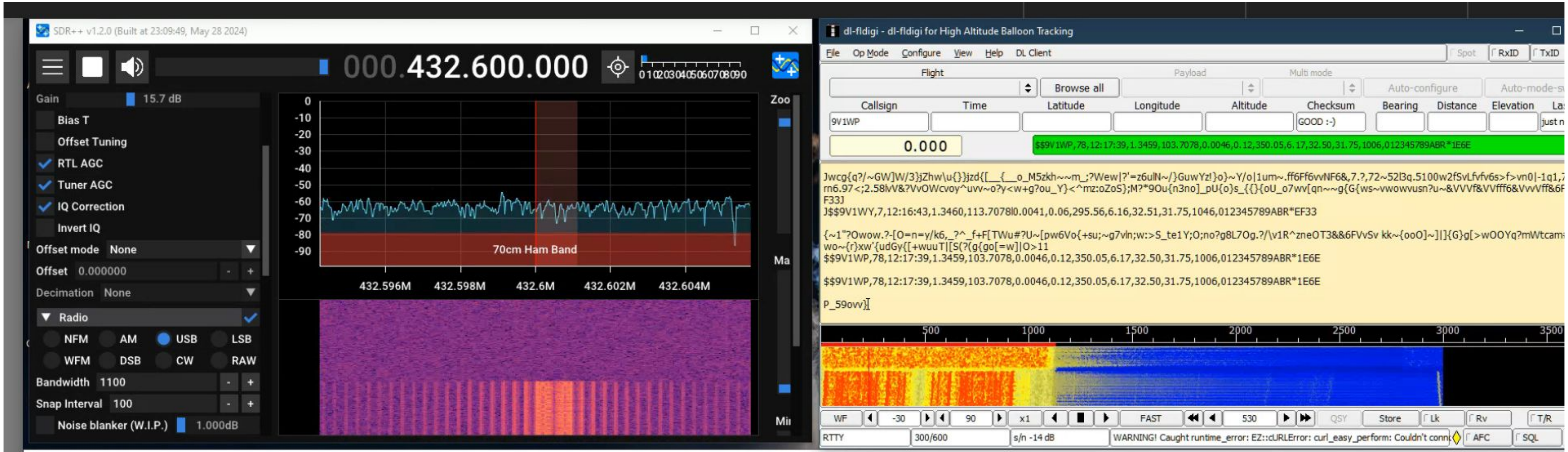
Telemetry

80 Baud RTTY was used, where 2 frequencies with a shift of 170Hz are switched, to represent binary coding at 80 times a second(10 bytes/Second)

$$CALLSIGN,frame_counter,HH:MM:SS,latitude,longitude,altitude,other,fields,here*CRC16\n

$$<callsign>,<count>,<UTC>,<lat>,<lon>,<alt>[,<optional_field1>....]*CRC<LF>

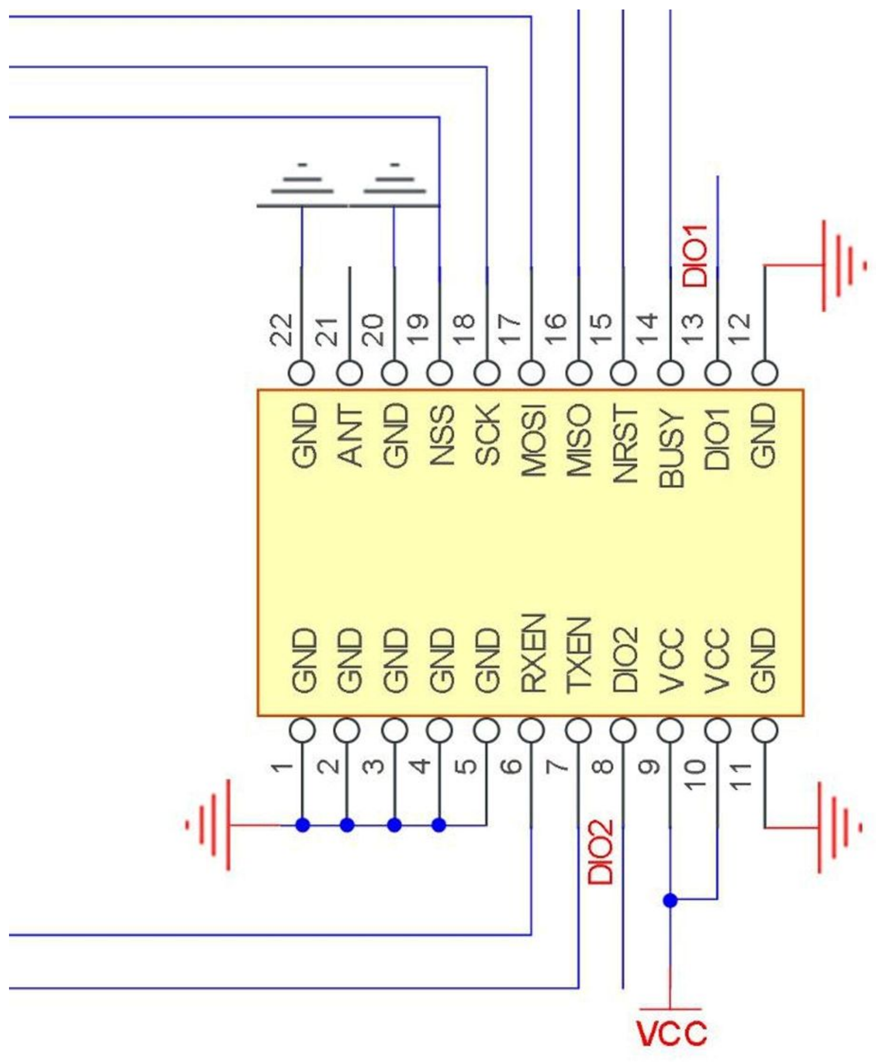
$$9V1WP,6,22:41:11,1.2974,103.7617,43.8630,1.79,161.84,6.24,47.6,42.5,1011,012345789ABR,0*FC09



Using these 1W transmitter modules(E22 M40030S)

THE TX EN PIN IS TO BE TRIGGERED BY A 3.3V LOGIC HIGH SIGNAL FOR THE 1W PA TO WORK!!!

I made a mistake and did not set the TX EN pin high in the module, which resulted in abysmal range in our range tests where we go behind 4-6 walls for the test propagation instead of doing an actual end to end test.



RTTY, Not so optimal

Pros:

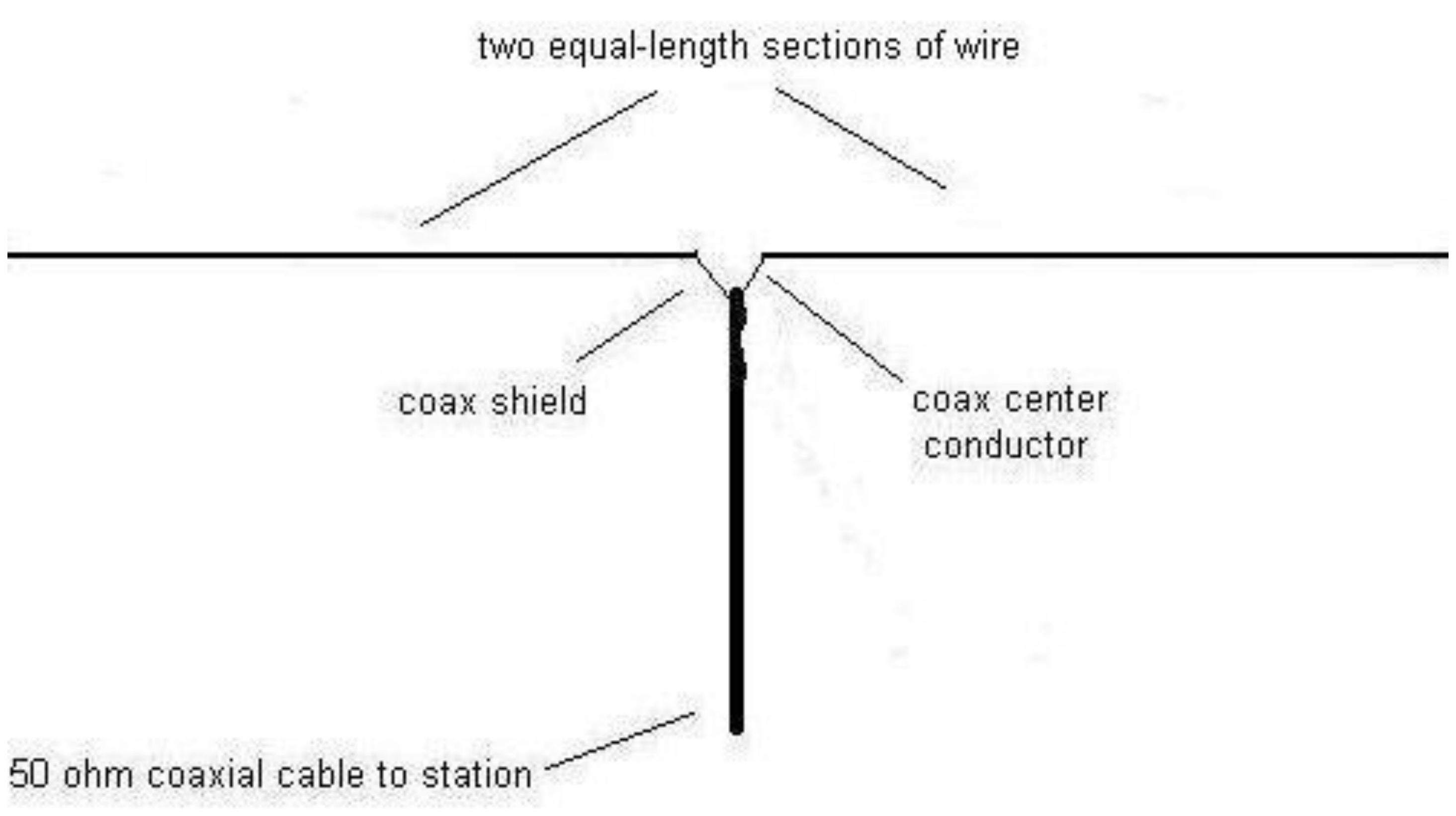
- Very bandwidth efficient, 170 hz frequency shift, a BW of 750 Hz is enough.
- Simple code, you are encoding a string in ASCII that is then turned into Bits.

Cons:

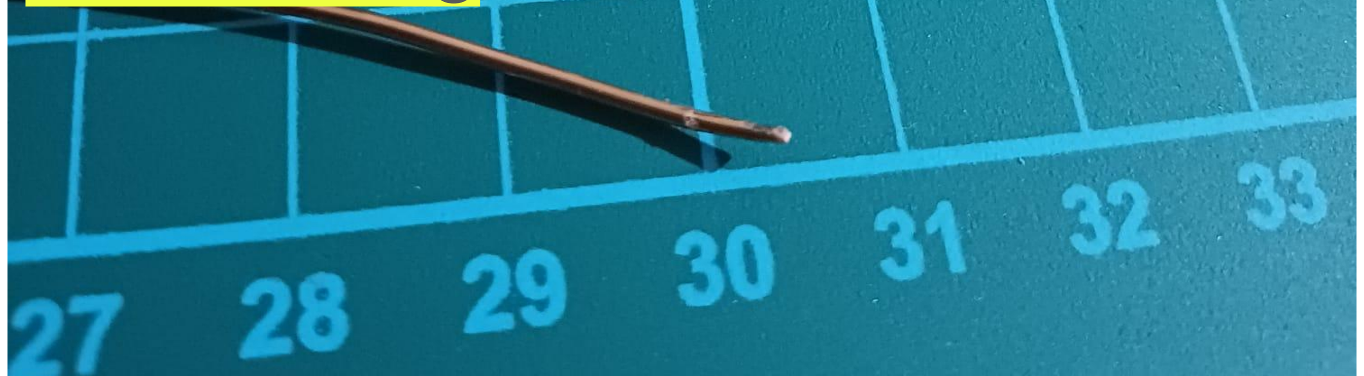
- Very slow bit rate, long transmissions can mean Very high power usage
- Manual data sorting after flight.
- If using Hab hub for uploads to sondehub, even a slight error In the data string can fail the CRC16 CCITT check (best to DIY a dashboard)

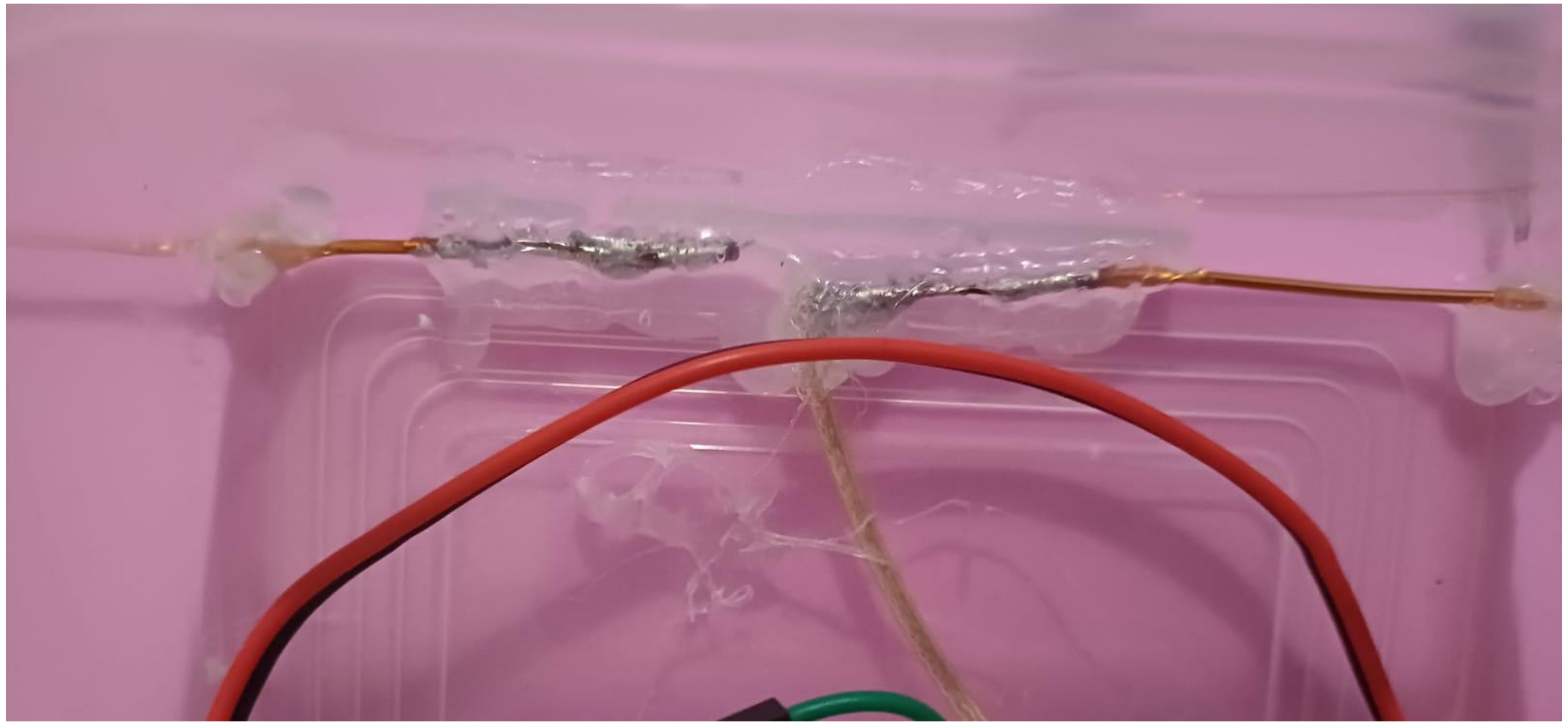
Will switch back to 1k2 baud AFSK or even custom 9k6 baud GMSK for future flights. The goal is to get high rate telemetry of 1Hz-10Hz optimally.

Antenna construction(Hot Glue Spam)



Remember to burn off the enamel on copper wire to ensure an electrical connection and ease of soldering





Significantly lighter than a SMA ended monopole commonly found on walkie talkies

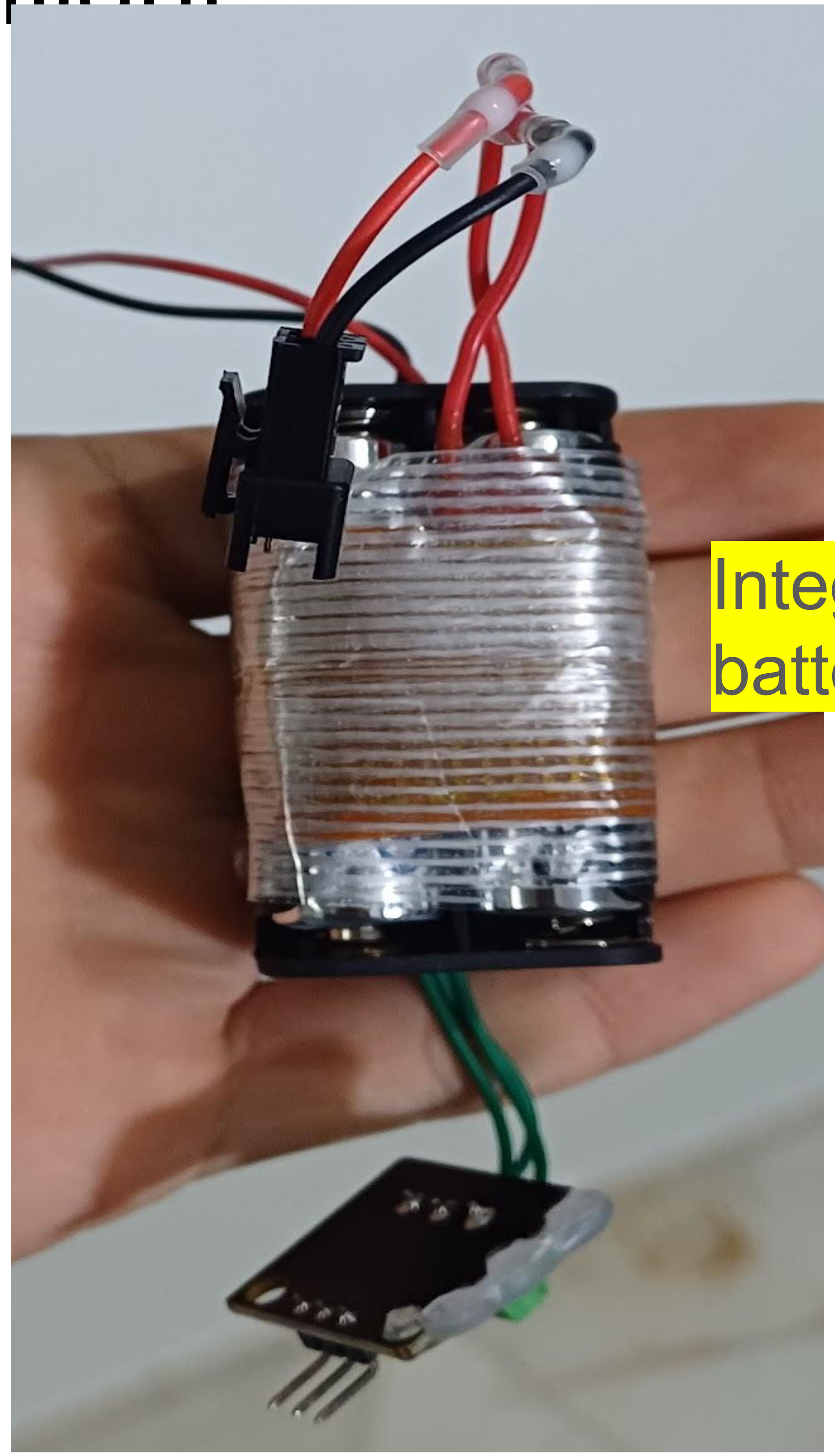
The battery choice that doomed the flight

Typically, radiosondes use energizer AAs for powering the 100mW Si4xxx transmitter. Can be received within the range of 20-30 km.

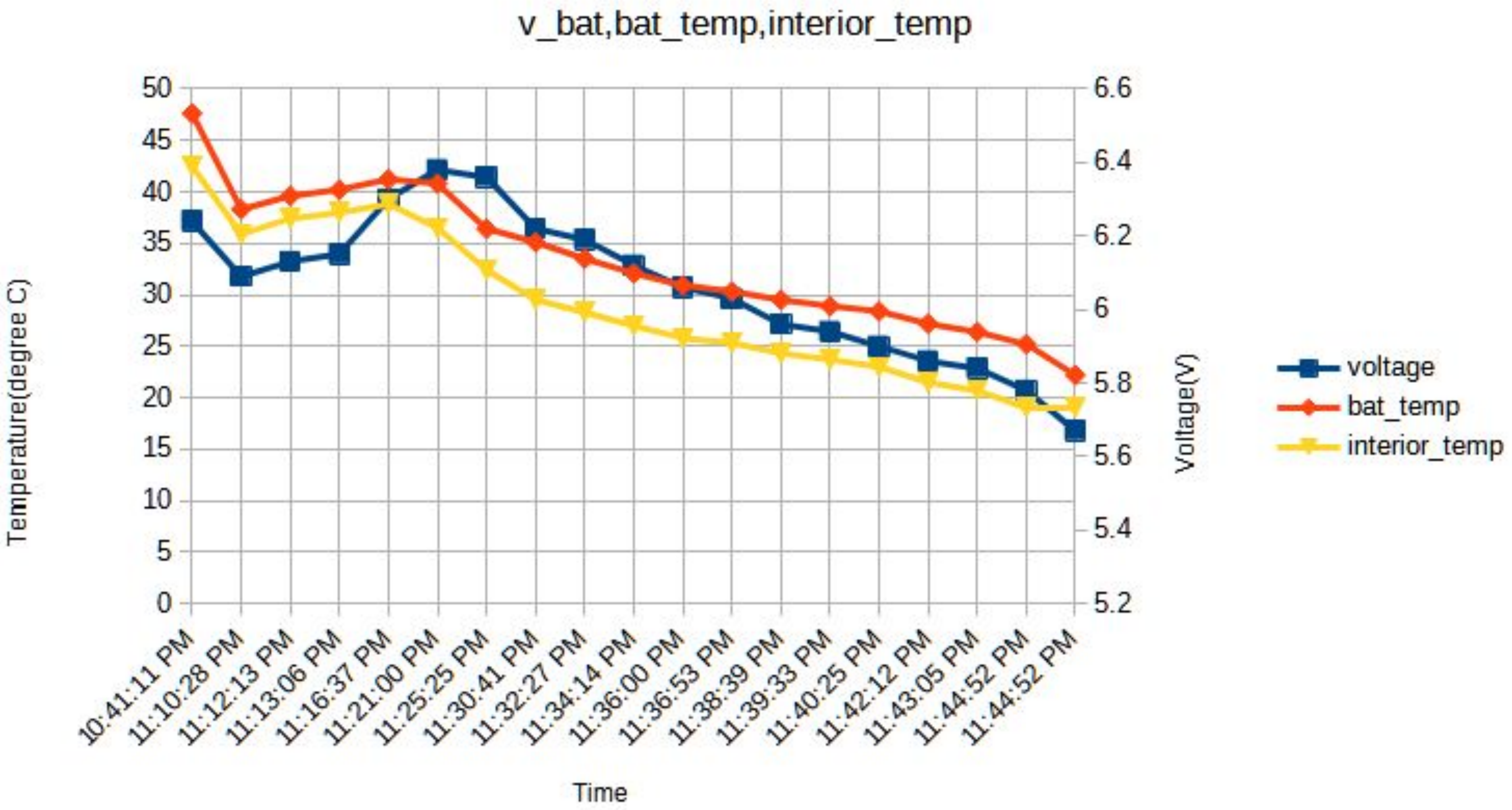
Decided to use Energizer Lithium AAs for this flight.

Battery temp sensor is a one wire DS18B20 Onewire sensor(it only requires 3 wires, SIG,GND and VCC)

Battery heating done by a flexible 1W heating pad bought off aliexpress



Integrated battery pack



1.1W transmitter Drained the battery too fast, due to high discharge, bat_temp is high due to the drain and internal resistance, rapidly draining the battery.(Bat_Temp)
2.Acted as a secondary heater until battery was drained.

I2c woes

The MCP9600 is an I2c thermocouple Sense IC with cold junction compensation. This is to read the accurate external temperatures that goes down to as low as -80 degrees C at 20-25 km altitude

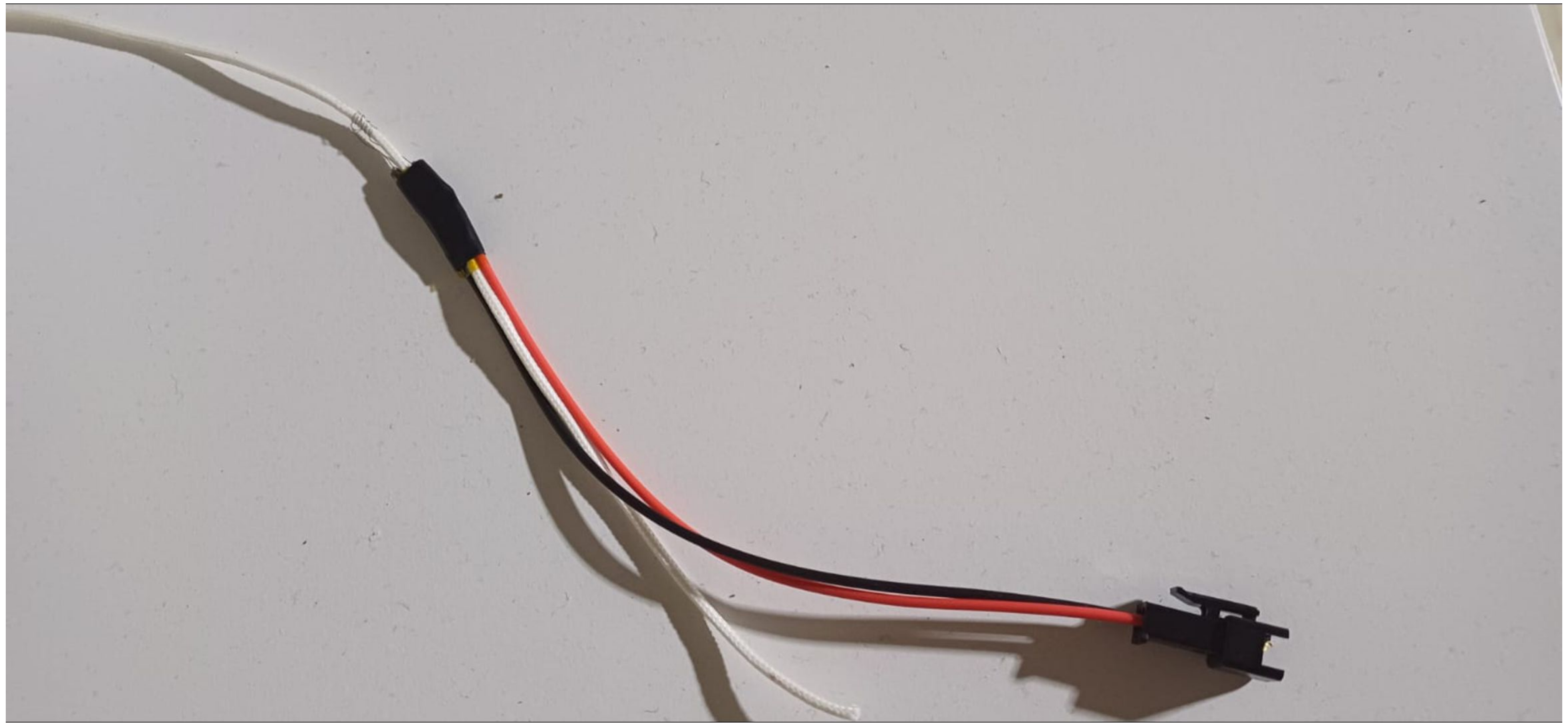
I ran through an I2c device checker that pings all i2c sensors and at above a i2c speed of 10kHz, the MCP9600 did not work.

I2c speed could have affected sensor read rates which could have been a significant problem if this was an actual flight controller.

I’d caution future users to have a separate I2c bus for this sensor.

Nichrome wire payload cutter

I decided to use JST-SM connectors for external connections. Connector has a securing latch that can be weight bearing for whole ~220g flight box.

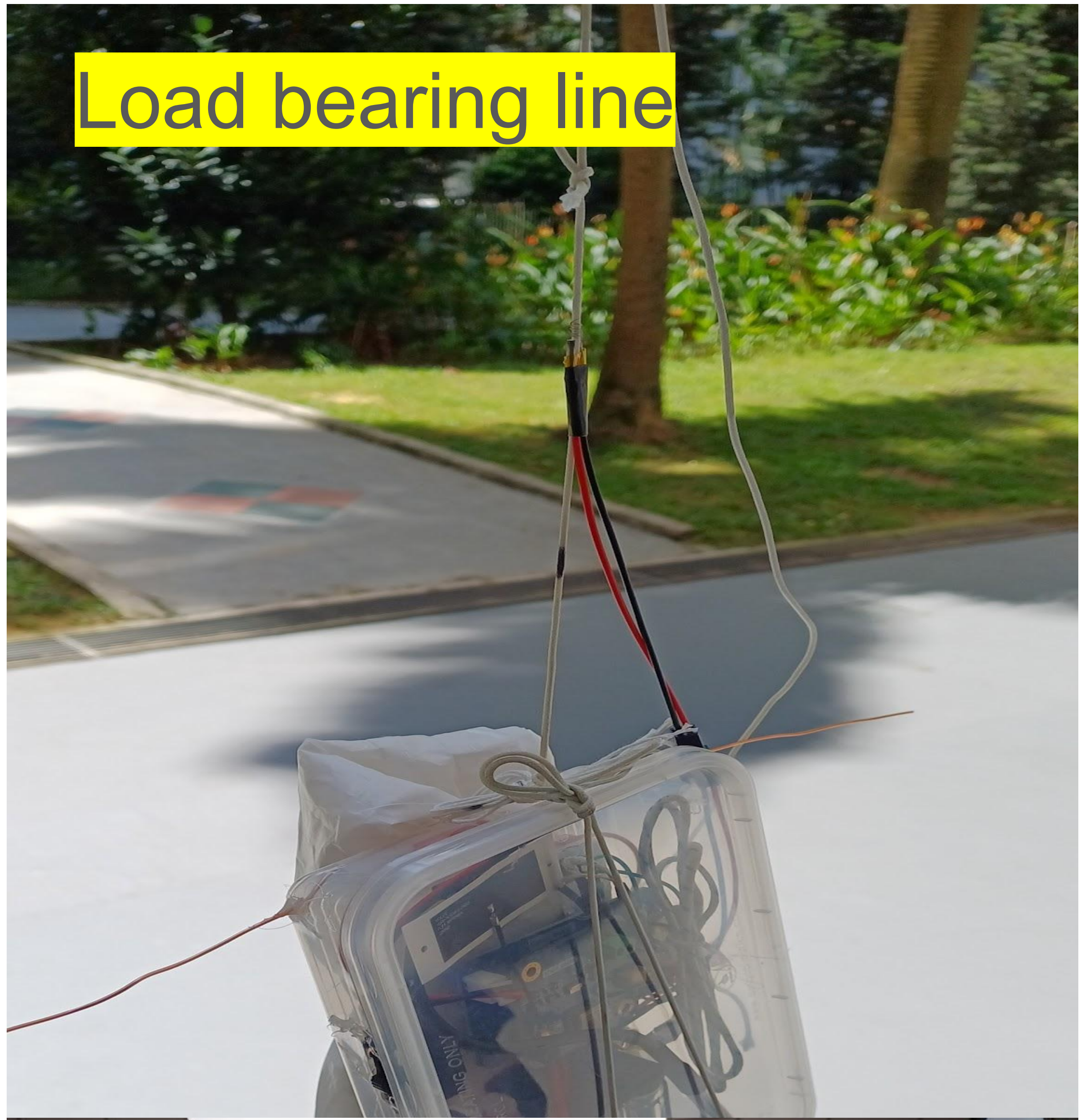


The magic knot

Recovery system developed by the BEAR team to address reliable parachute deployment while keeping to 2m dimension limits due to regulations.

Local meteo office packs the parachutes inside the balloon, which be unreliable where the parachute lines get tangled, increasing decent rate.

Nichrome burns off load bearing line that undos a knot to release the parachute and payload.



Weather Balloon launching into weather

Mostly mid to low level cumulus cloud cover, payload loss of signal will be attributed to battery voltage dropping.

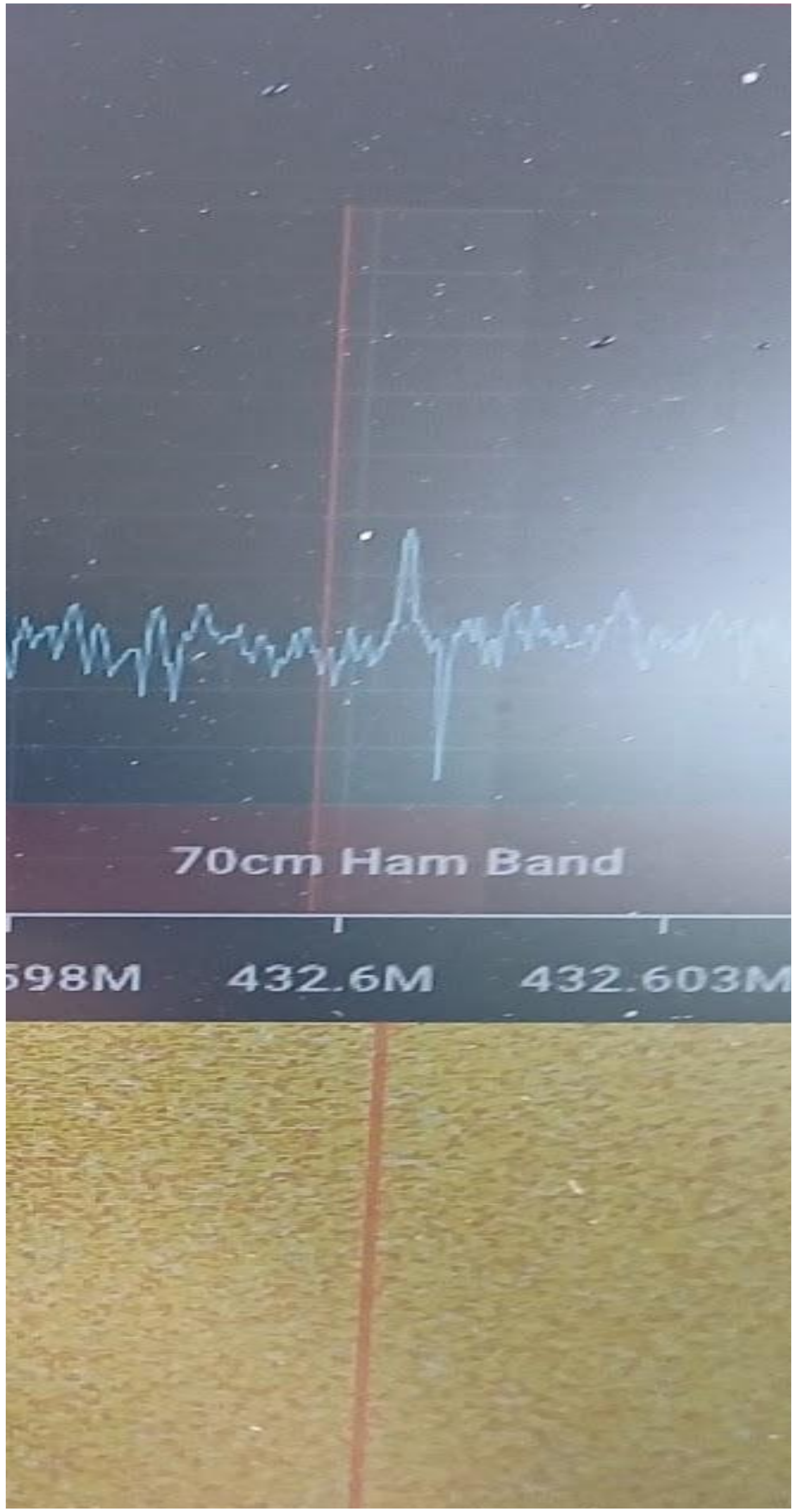
+Payload box was good enough to keep moisture out

The death tone

Once the battery runs out of voltage, the ESP32 is driven into a boot loop state.

Somehow a very narrow band tone is still being sent through the power amplifier of the RF module. Which consumes power and continues to do so, leading do a death cycle, death cycle continued until end of flight, T+1hr after launch before LOS.

A software fix can be implemented for all future flights where Tx lockout can be initiated to stop transmitting to ensure there is enough power for at least a GNSS lock and battery voltage recovery.

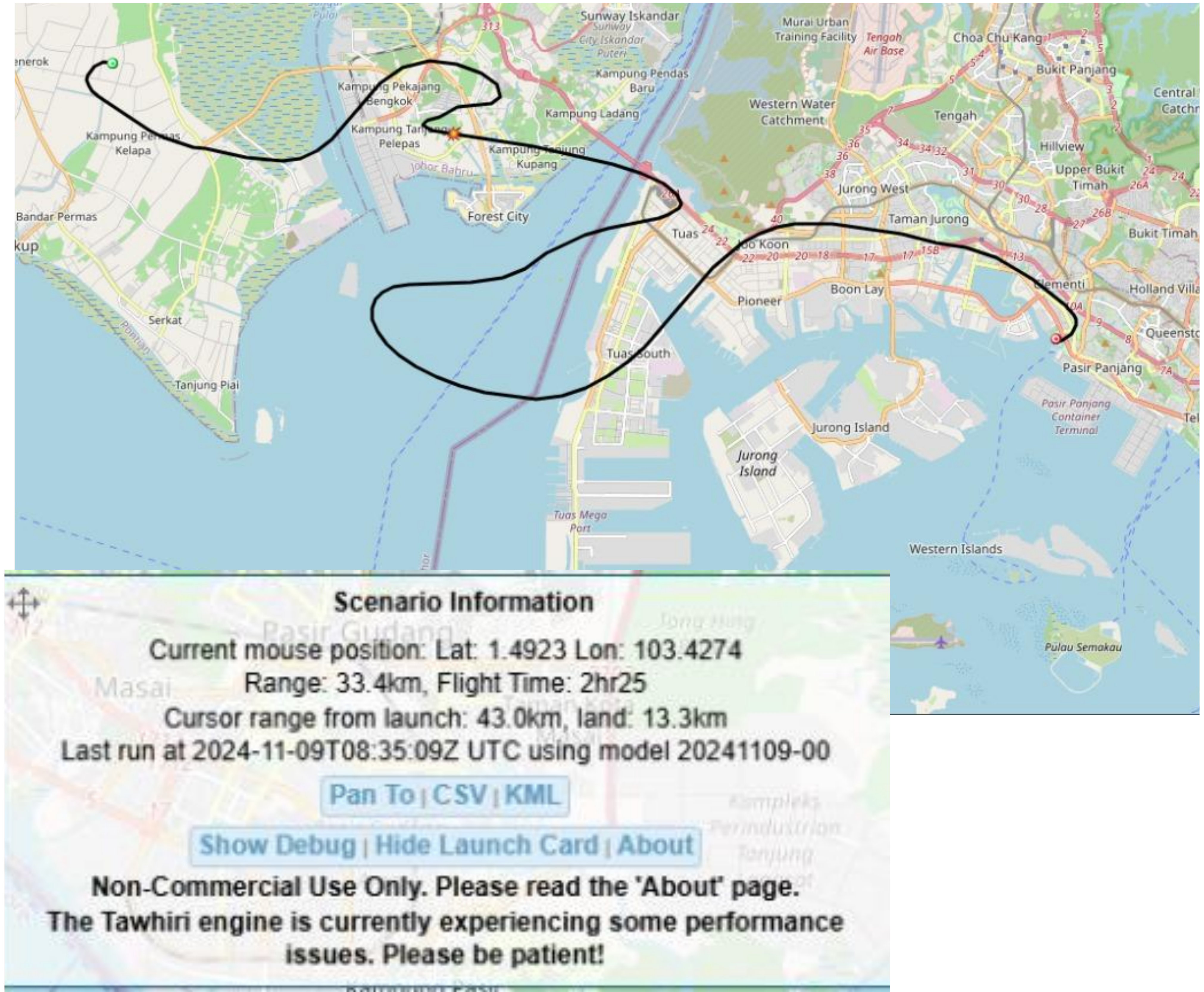


death tone was RX'ed until end of flight, T+2.5hr after launch before LOS.

Flight was modelled to last 2hr30 mins at a cut altitude of 30km

Two possibilities:

- Balloon Burst at 30km
- MCU and GNSS was still working, to initiate cut at a set altitude of 30km



Learning points from this flight and to dos

1.Change to 18650, 21700 or lipo batteries for transmitters beyond 100mW.

2. Solar powered with battery power management and charging circuits akin to satellite electrical power systems w/current sense.

2.Look into more elegant ways to stack pcbs such as Samtec connectors and design PCB such that there is clearance for screws and standoffs.

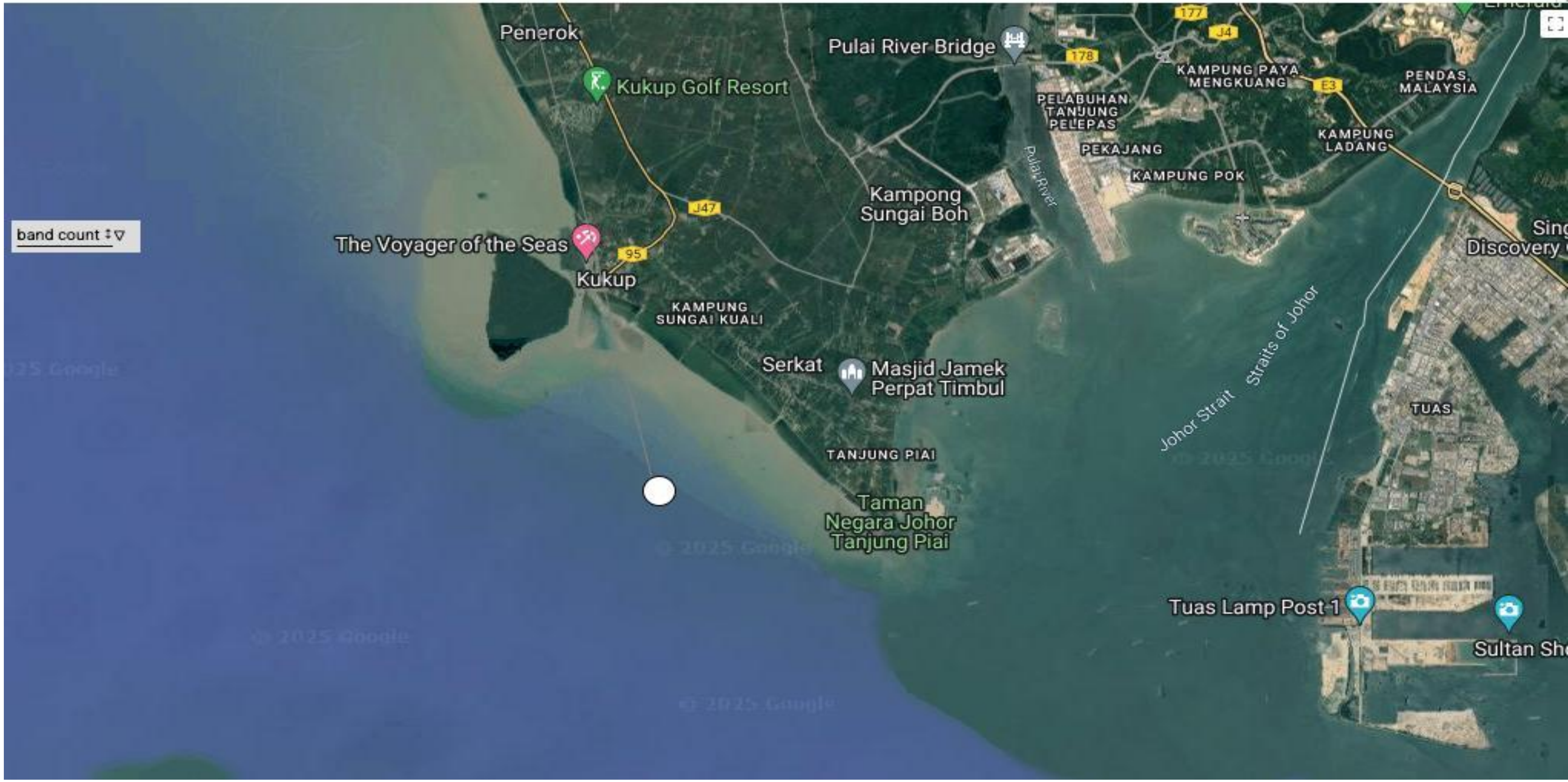
3.Look into 9k6 GMSK or even BPSK/QPSK next.

4.Software mitigations to avoid the death tone.

5. Have a dedicated sensor fusion board with a MCU next flight. IMU shall be SPI for high read rates. If the MCP9600 is to be used again, it must have it’s own i2c bus.

y-m-d UTC	txCall	txGrid	rxCall	rxGrid	MHz	W	SNR	drift	k	txAz°	mode	k/W	spotQ	version
2025-01-26 05:52	9V1WP	OJ11rg	HS0ZQS	OK03fu	14.097211	0.01	-28	0	1438	347	WSPR2	143800	28760	1.4A Kiwi

BEAR-12



Flew to 4-5km altitude based on power level measurements.


26 Jan 2025 09:35:41
71 W Coast Hwy, Singapore 126844

Rx from Australia!