Monitoring trans North Sea propagation at 24 GHz: Project Phase 2 – Update

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RSGB Propagation Studies Committee

Pilot Study outputs

- Decision made to continue the project
- Need to tackle IF interference from on- site 70cm repeater
- UKuG funding approved
  - Improved SDR hardware
  - Further Software updates
- Poster paper at HamSci Workshop 2025 in the USA

Monitoring tropospheric propagation at 24 GHz: A pilot study

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[1]HamSci Community

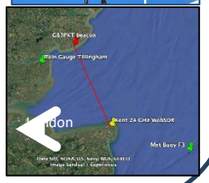
Abstract

HamSCI's upper atmosphere and space physics focus has drawn on ionospheric measurements by radio amateurs using protocols including WSPR, precision measurements of standard frequency transmitters WWV and CHU and systematic information gathering into accessible databases. Such techniques can be adapted to other amateur radio fields to advance understanding of propagation. As an example, we describe a UK pilot system for monitoring tropospheric propagation on 24 GHz. The transmitter (JO01mt22 12 m ASL) on 24.048945 GHz has a GPS disciplined oscillator and outputs 7 W ERP to an omnidirectional slot antenna. Transmissions alternate each minute between WSJT-X's JT4G sub-mode and a carrier with CW identification. A 53 km test path from the GB3PKT beacon over the Thames Estuary glances the sea surface to a receiver (JO01qj81 80 m ASL). At the receiver a masthead down-converter to 400 MHz IF connects to a Raspberry Pi controlled SDR running OpenWebRX [1]. The pilot SDR, an RTL-dongle, is to be replaced by an Airspy R2 [2]. The data monitoring software, based on early WsprDaemon, uses WSJT-X wav files. It logs the basic data of callsign, SNR and frequency from JT4G and signal and noise levels from carrier-only transmissions. SNR derived from carrier measurements shows greater resolution and dynamic range than from JT4G. Measurements of frequency with lower scatter are obtained from cross-correlating the JT4G signal with its sync vector, finding the peaks via continuous wavelet transform, then interpolation. Marine environmental data that may influence propagation is collected from a moored Lightship, including air and sea temperature, relative and absolute humidity and wave height. Rain rate is from a shore station near the transmitter. Radio and environmental data go to a Timescale database with a Grafana dashboard for visualisation.

Equipment

Indoor unit

- IF WebSDR at 400 MHz 1 MHz wide using OpenWebRX Software on a Raspberry Pi3B with an RTLSDR at 400 MHz
- Wired LAN connection to site Internet
- Leo Bodnar GPSDO at 123.16667 MHz
- Single coaxial feed to outdoor unit carrying 123.16667 MHz LO plus 400 MHz IF and 12 V DC

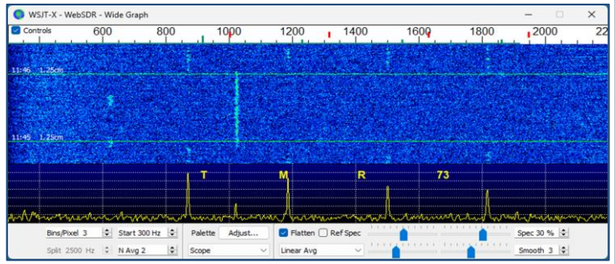


Outdoor 24 GHz Downconverter

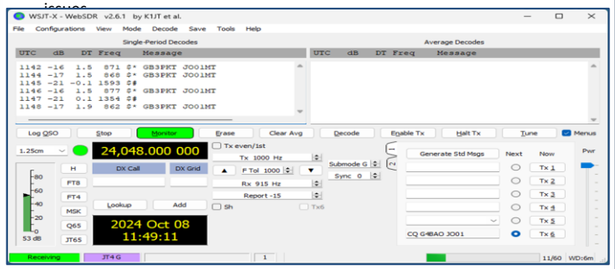
- 1.6 dB Waveguide LNA
- OE9PMJ design waveguide image filter
- Commercial waveguide harmonic mixer
- Kuhne 12 GHz Multiplier to 11824 MHz
- 15 dBi 90-degree waveguide sector antenna

Results

GB3PKT beacon at Clacton was receivable 24/7 over a 53 km sea path.

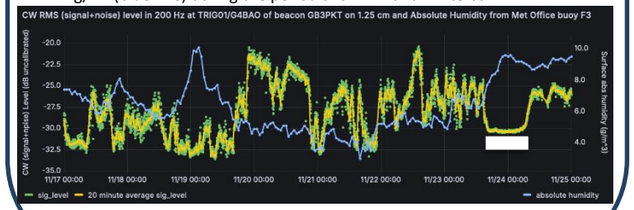


The standard WSJT-X screen allowed us to monitor for RF hardware issues.

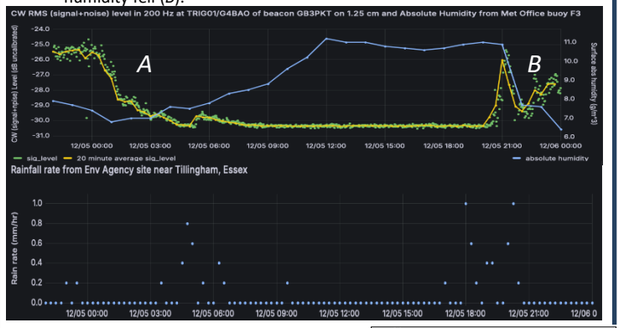


In relation to weather related phenomena, although the distance (48 km) separating environment and radio measurements preclude accurate assessments, encouraging semi-quantitative effects on propagation have been observed. These include:

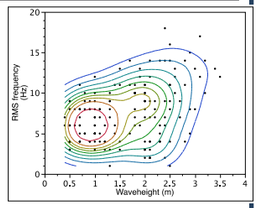
- Signal drop out (Yellow line below) at absolute humidity above 8 g/m^3 (blue line) during the period shown with a white bar.



- Signal level reducing gradually by 8 dB during the passage of a cold front (*A*) followed by a band of rain up to 1 mm/hour and the associated rise in absolute humidity. Signal recovered as absolute humidity fell (*B*).



- Increased standard deviation of the difference between the received and transmitted frequencies with wave height is suggested in the scatterplot at right. The coefficient of regression R^2 of 0.15 implies that 15% of the variance was related to variation in wave height.
- The caveat to this is that the SDR is currently not GPS locked



Conclusion

24GHz is one of the few areas of amateur propagation investigation still left open to us. Contacts within UK's Ofcom (UK equivalent of the FCC) tell us that they still seem to think there is much to learn about 24 GHz and above.

This pilot study shows the feasibility of automatic 24/7 monitoring of 24 GHz Amateur beacons with simple equipment and has thrown up some interesting observations to follow up with the upgraded, GPS locked SDR equipment. Stations living near the coast or at least within the maritime influence, could contribute quite a lot to this research. For example, the effect of offshore wind generators on 24 GHz is worthy of investigation and Nick G4OGI has made a good start on this.

References

[1] OpenWebRX Software Source code at https://github.com/jketterl/openwebrx

[2] Web SDR URL: - http://trig01.ddns.net:8073

Acknowledgements

We thank the Thanet Radio Infrastructure Group https://www.trig.org.uk/ , the UK Met Office for F3 buoy data sourced via the NOAA National Data Buoy Centre and the UK Environment Agency for rain gauge data.

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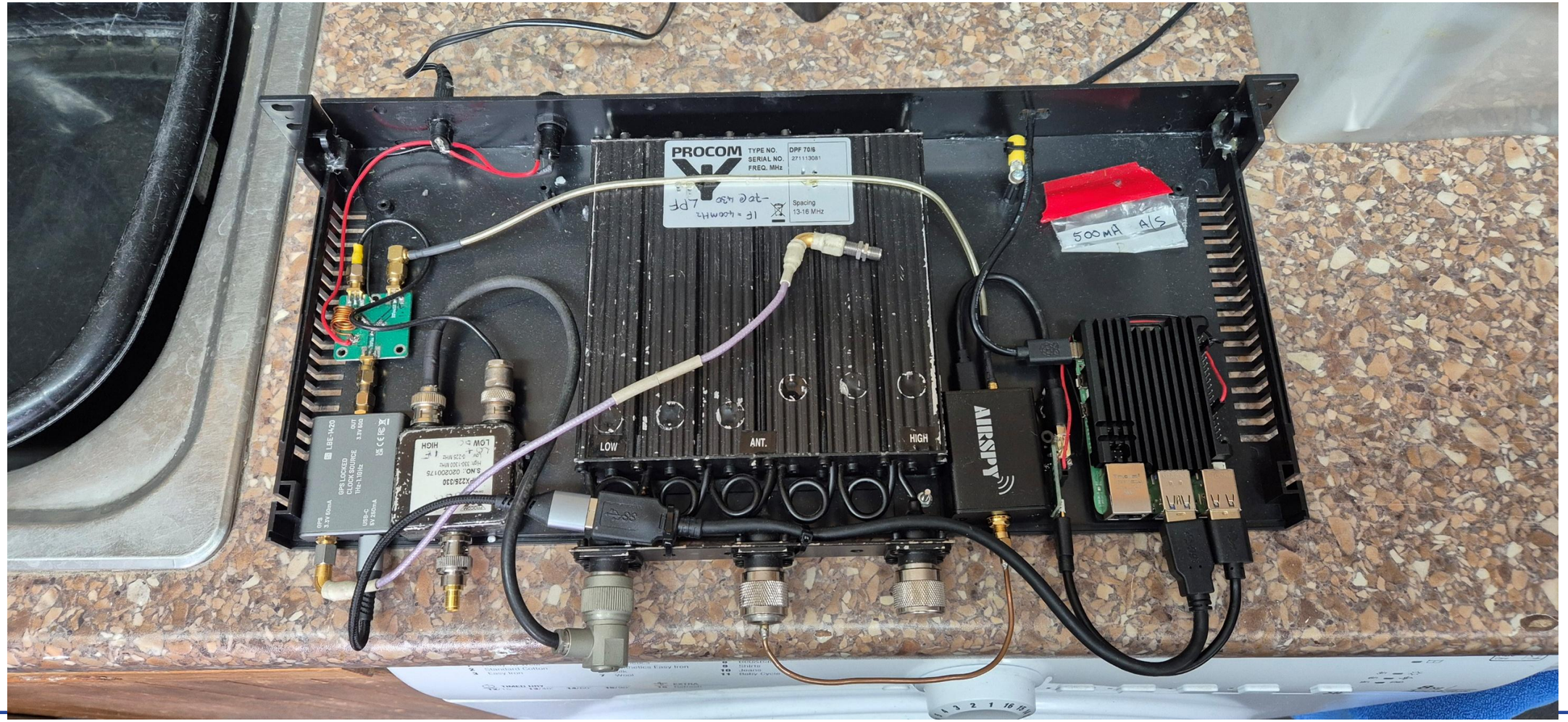
Phase 2 – Hardware update
New Indoor unit

- Upgraded processor to Raspberry Pi 5
- Reference locked Airspy R2 SDR
- Custom firmware in Airspy to allow:
  - Common “Leo Bodnar” GPSDO reference for 24GHz downconverter and Airspy SDR at 123.16667MHz
- SDR front end low pass filtering at 400MHz
  - >70dB rejection of 70cm band to remove interference from on site repeater

Phase 2 – Hardware update
New Indoor unit



Phase 2 – Hardware update

- Phase 2 hardware update completed in 2 stages
- May 2025 – new indoor unit installed as per previous slide
  - Discovered serious Rain damage to outdoor unit
- Complete rebuild of Outdoor unit done between May and July 2025

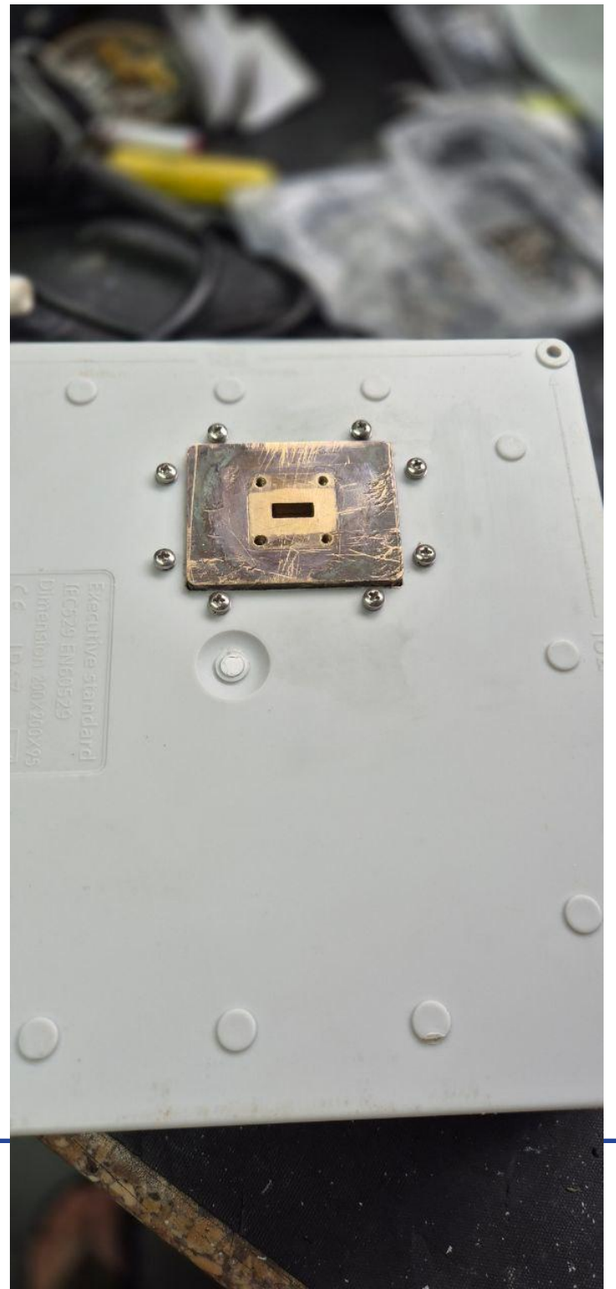
Phase 2 – Hardware update

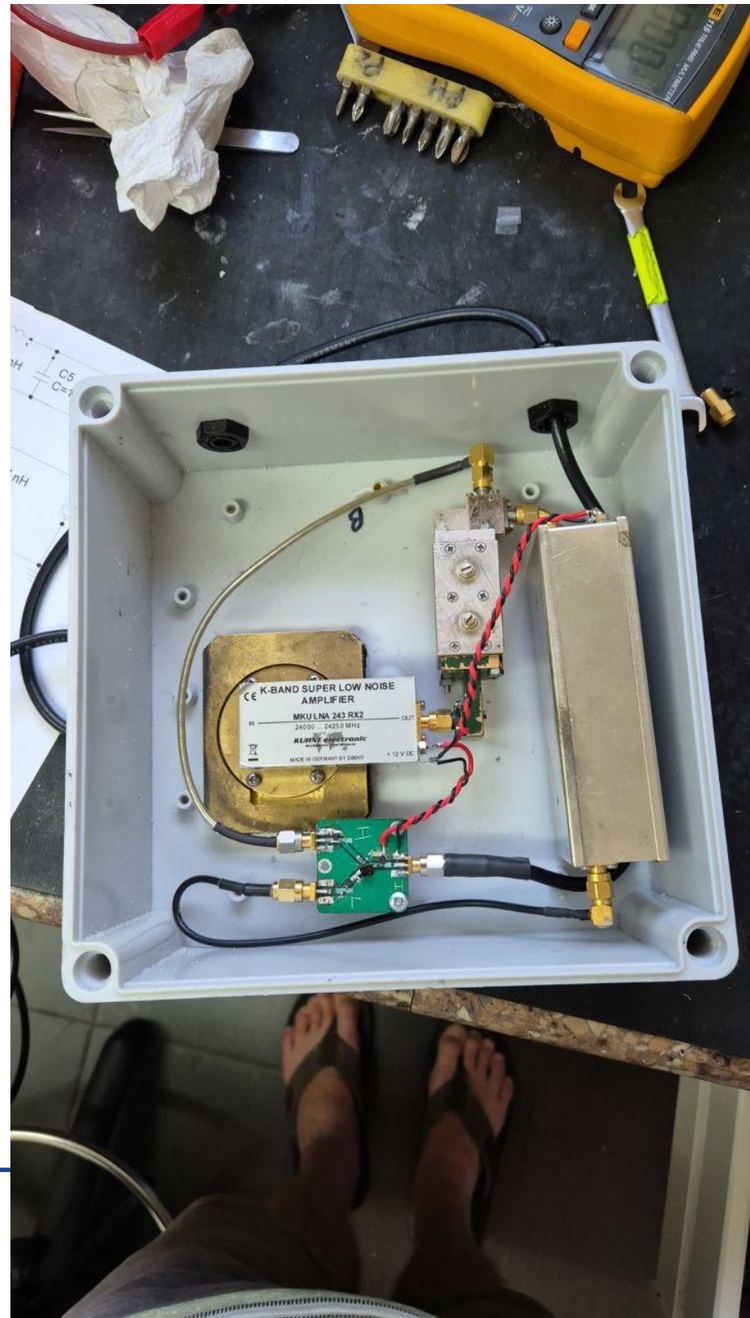
- Rebuild of Outdoor unit

  - Existing 12GHz LO multiplier and harmonic mixer
  - Existing Antenna
  - Better waterproof box
  - New IF + DC + LO cable run
  - Proper “waveguide through box” transition to antenna
  - New super low noise Waveguide LNA
  - Hardware improvements funded by the UKuG

Phase 2 – Hardware update

- Rebuild of Outdoor unit



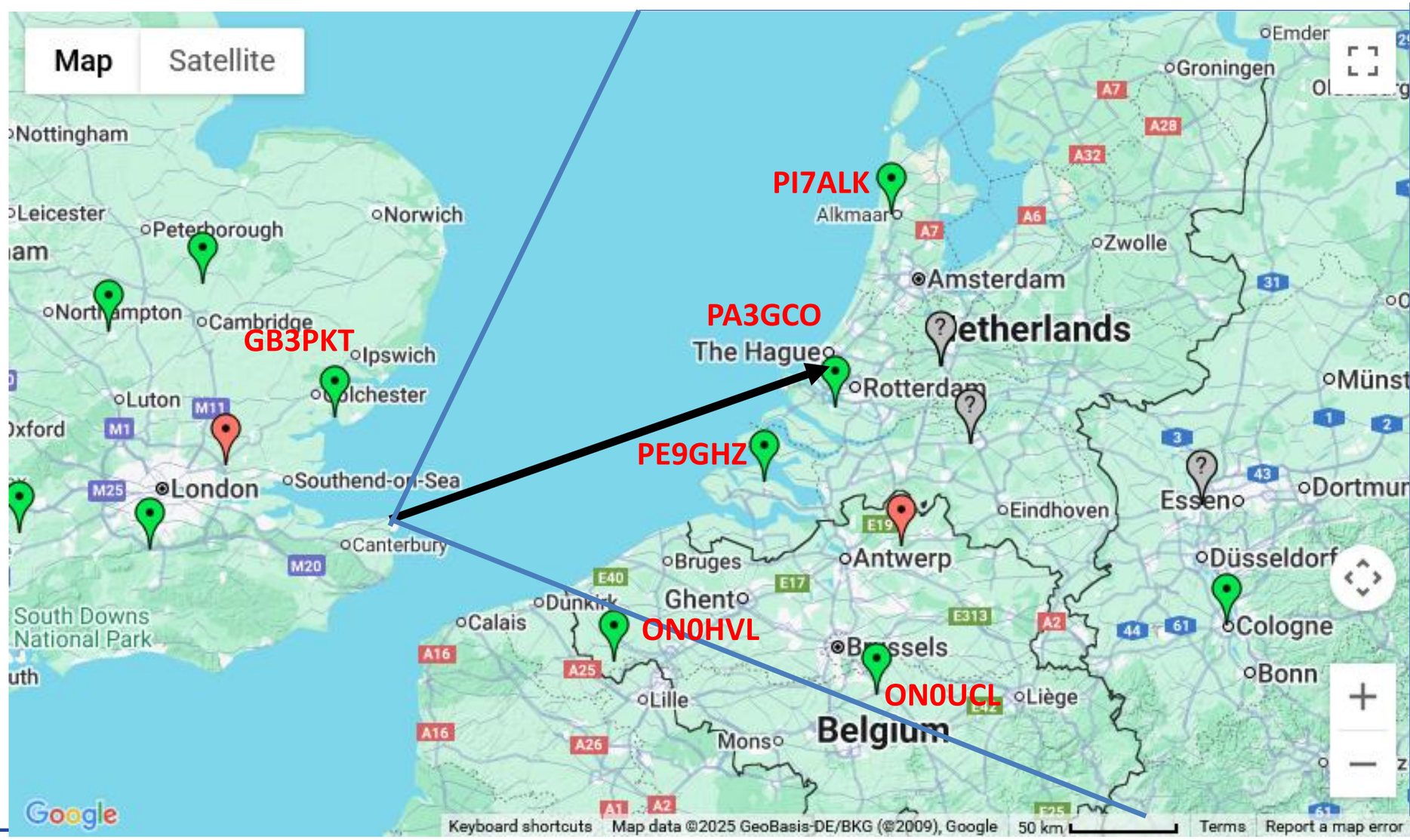


Phase 2 - Software

- Automatic logging of GB3PKT JT4G beacon now running.
  - “reference point”
- PI4 beacon logging implemented and in beta test
  - Currently watching PA3GCO Rotterdam
- Future plans to investigate use of “KA9Q radio” Linux software to allow simultaneous monitoring of multiple beacons

Phase 2 – Antenna coverage

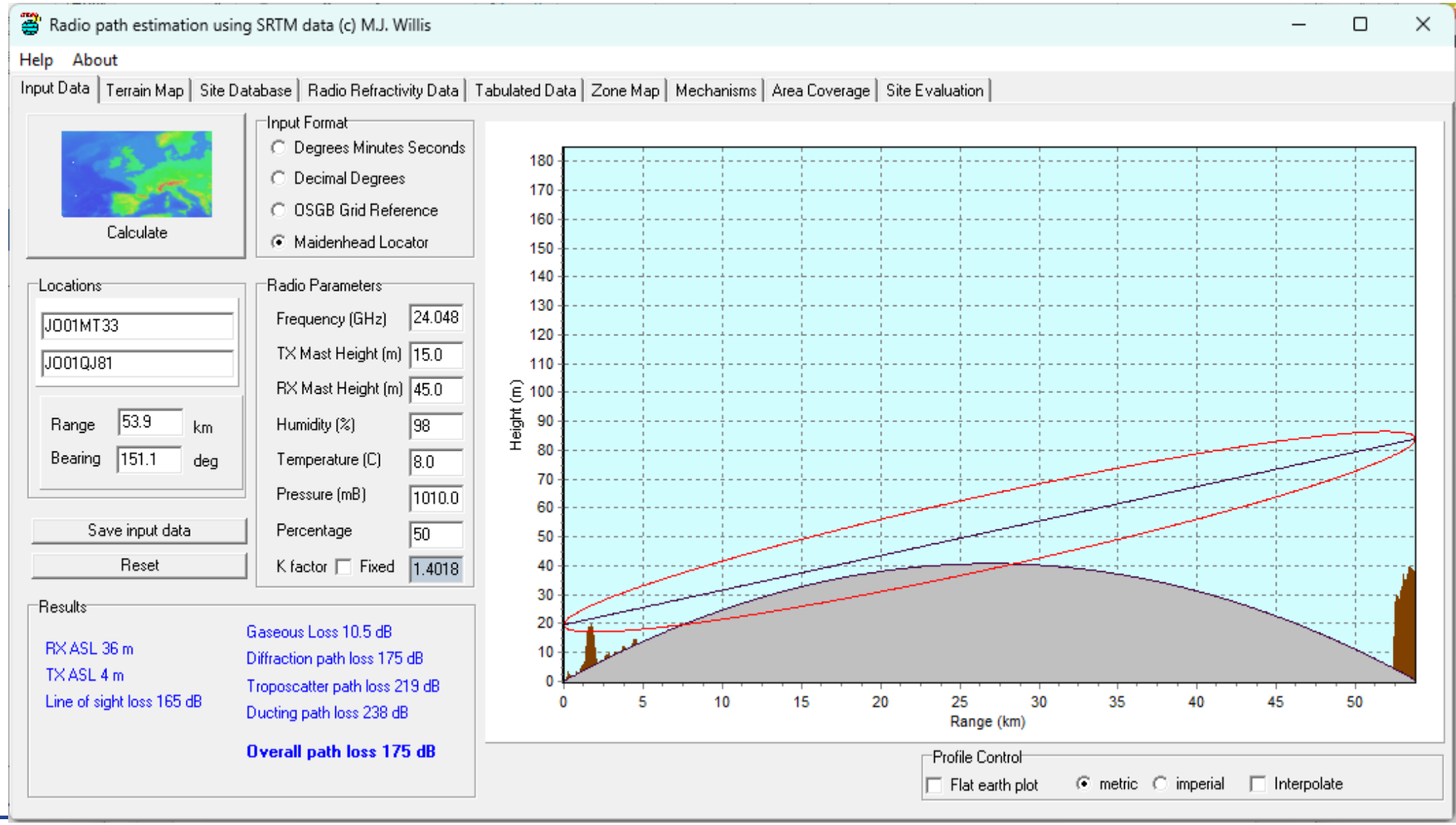
- 90-degree sector antenna aimed at PA3GCO Rotterdam



Map courtesy of beaconspot.uk

Phase 2 – GB3PKT reception

- 54km off the side of the antenna
- Much stronger and more reliable signal than before
  - Typically, -12 to -7 dBJT with dropouts

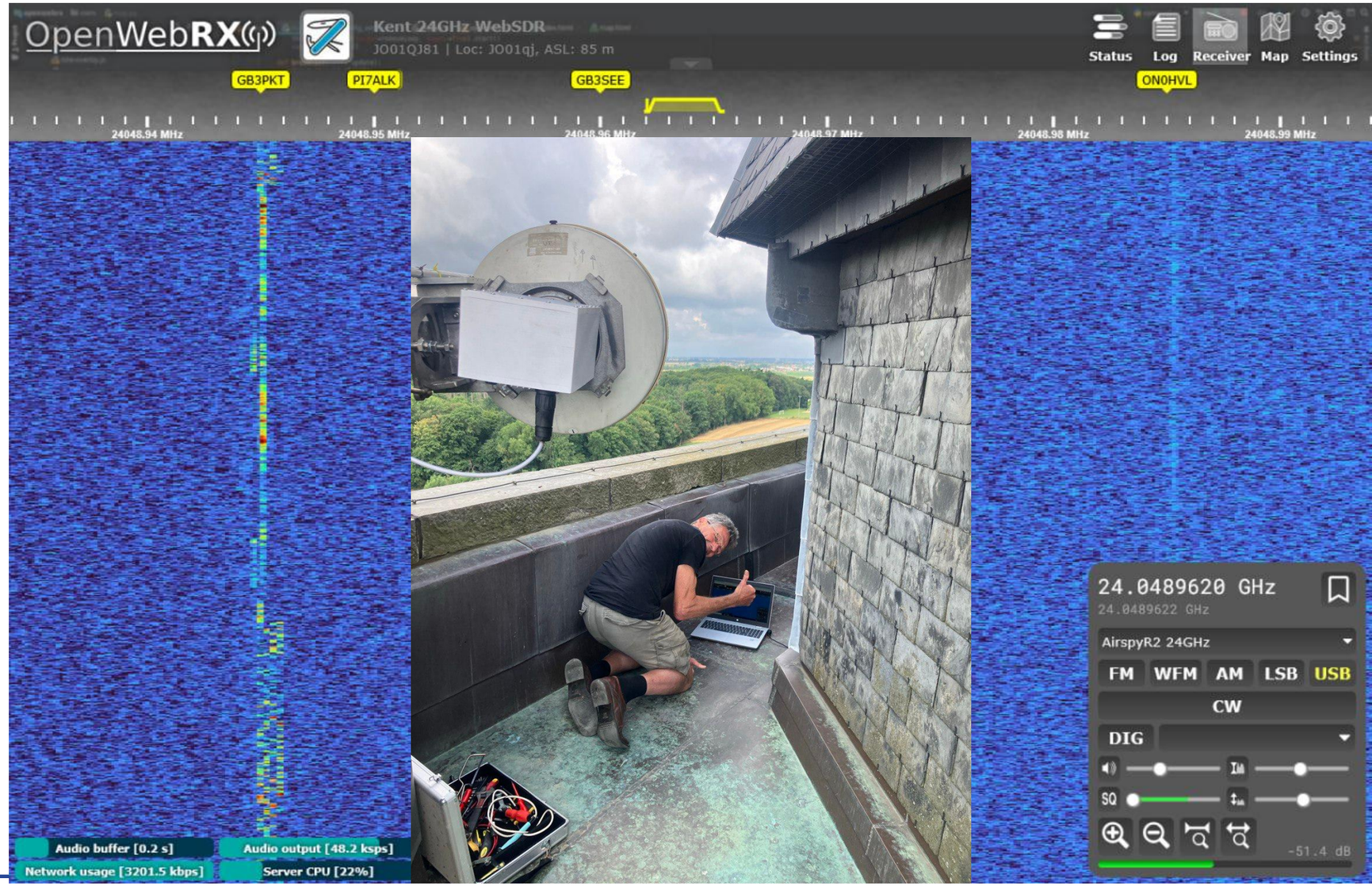


Phase 2 – Some results

ON0HVL beacon Reception at 122km out of main beam

Beacon currently on a small dish pointing at Margate

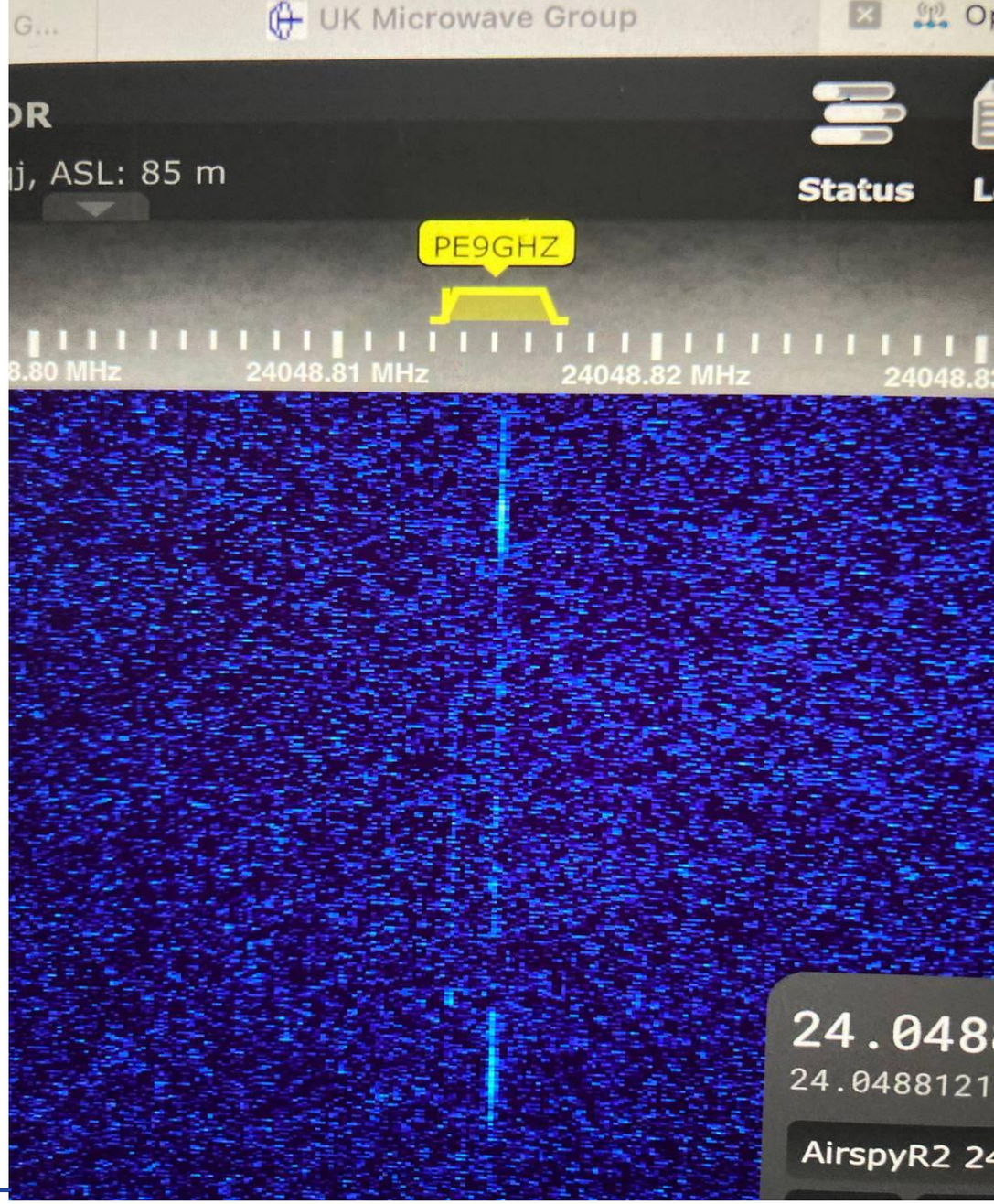
Plans underway to add PI4 mode



Phase 2 – Some results

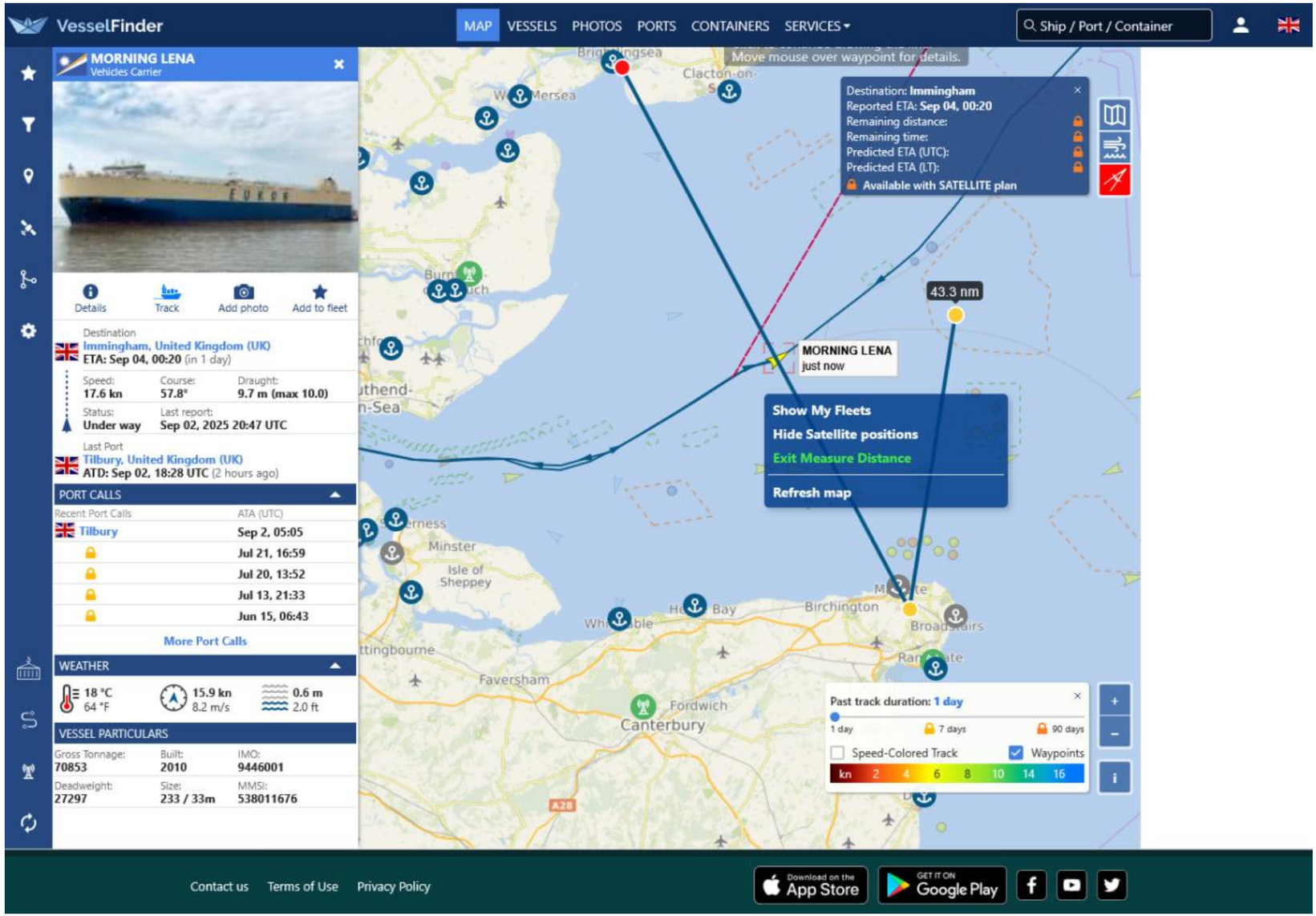
PE9GHZ CW beacon reception at 172km.

In main beam



Phase 2 – Some results

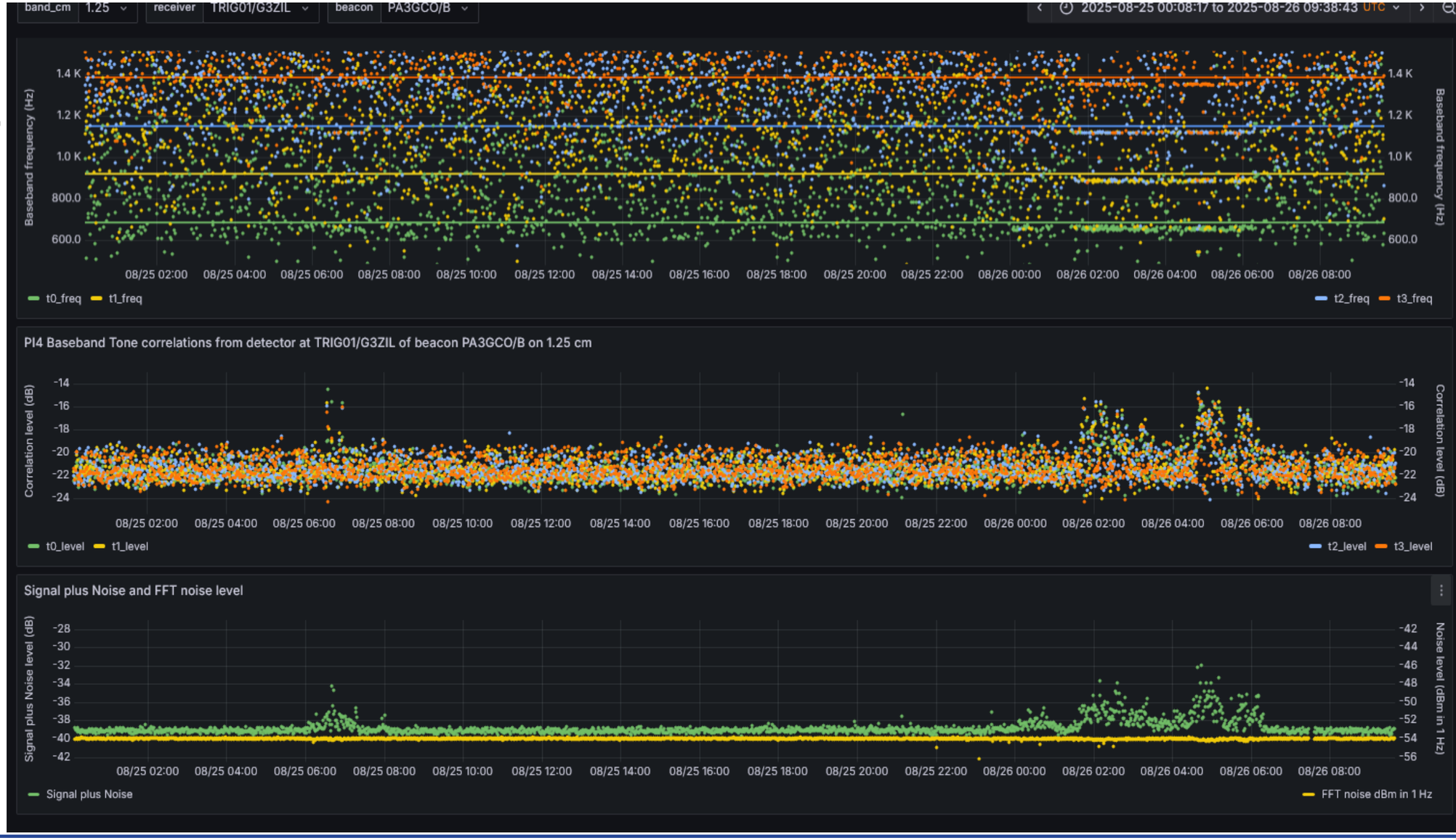
Dropout of GB3PKT due to ship blocking the path.



Phase 2 – Some results

1st Confirmed reception of PI4 tones from PA3GCO Rotterdam 210km

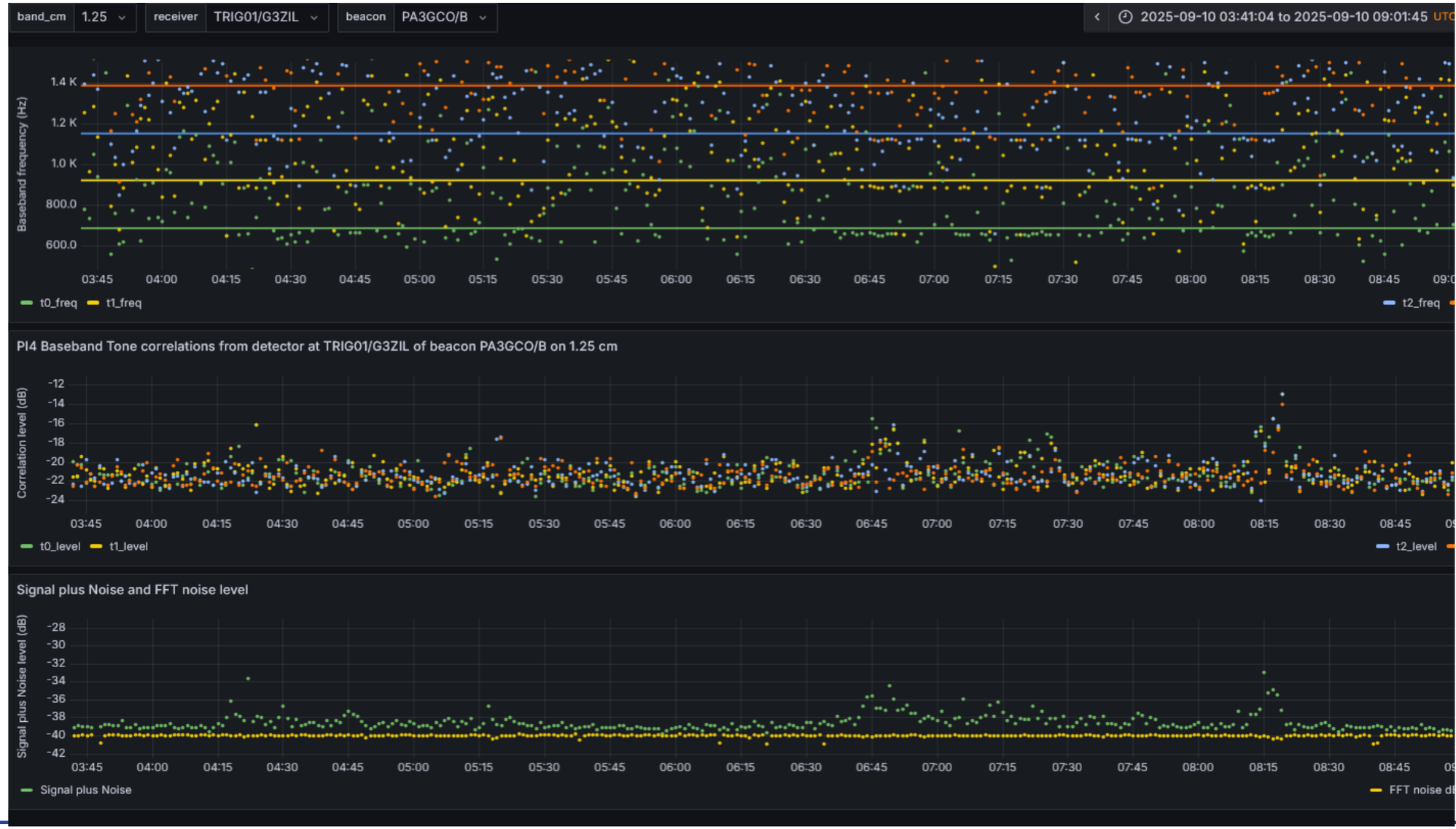
25th August 2025



Phase 2 – Some results

2nd Confirmed reception of PI4 tones from PA3GCO Rotterdam 210km

7th & **10th** Sept 2025



Summary

- 24GHz and above is one of the few areas of amateur propagation investigation still left open to us.
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- Contacts within Ofcom tell me that they still seem to think there is much to learn about 24GHz and above.
- Phase 2 study producing interesting results.

Find out more…

http://trig01.ddns.net:8073

Installation team
L-R G0JBA, G4BAO, M0LMK,
M5AAD (took the photo)