FORWARD SCATTER AIRCRAFT DETECTION WITH AMATEUR RADIO NETWORK WSPRNET

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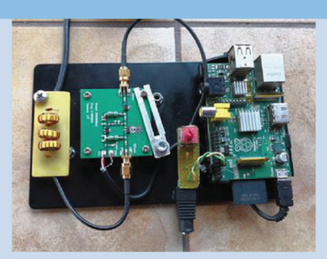
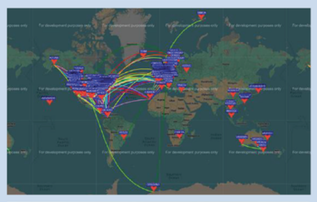
1. Introduction

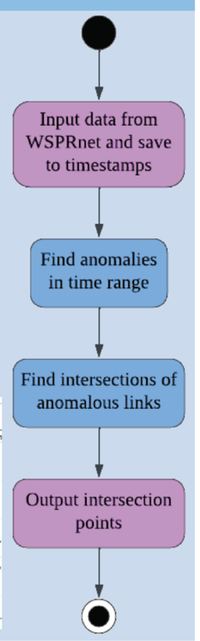
- WSPR protocol: used for long distance communications by amateur radio operators, records are uploaded to WSPRnet at www.wsprnet.org.
- Ionosphere: layer of electrons in the atmosphere that reflects HF signals, extends transmission distances beyond the horizon using skywave propagation.
- FSR: forward scatter radar, allows larger RCS and longer integration times.
- Anomalies in WSPR data could be caused by presence of aircraft [2, 5].
- This project aims to study the feasibility of using WSPRnet to detect and track aircraft.





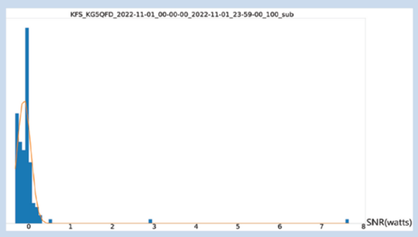
2. Existing Method

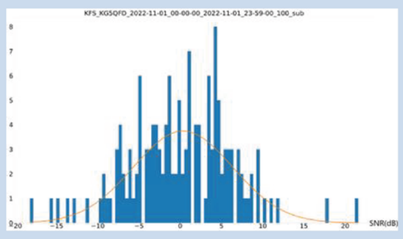
- Recreate and improve upon the existing algorithm GDTAAA [3].
- Calculate the mean and standard deviation across ±3h period.
- Find possible intersection points for links >1 standard deviation from mean.
- First used only short path intersections but later moved to all intersections with a calculated SNR of >-30dB as not enough intersection points were generated.

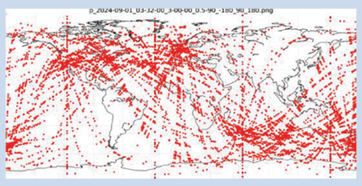


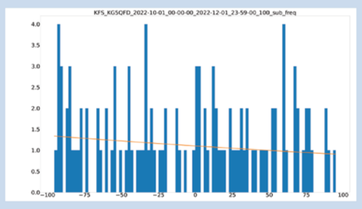
3. Empirical Study

- Verify the use of standard score to find anomalies, through verifying that the data is unimodal, with significant distance between the bulk of the distribution and the anomalies.
- Account for changes in ionospheric conditions by subtracting trend, then plot a histogram and curve fit on the data.



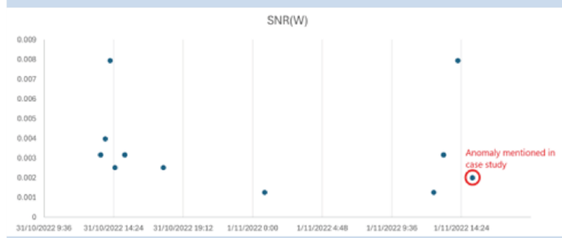






- SNR(dB) form a unimodal distribution, and anomalies are highlighted when represented in Watts.
- Frequency data is not unimodal, thus difficult to detect anomalies.
- Removing detections with calculated SNR < −30dB, reduces the number of intersections from 12324 to 11804 points [2, 3].

- Analyse case study of QTR901[4]. Only WSPR link between S77HQ and VK6WR, was short path propagation.



row	id	time	tx_sign	tx_loc	rx_sign	rx_loc	frequency	power	snr	drift	distance	azimuth	band	version	code
1	4900907653	2022-10-31 13:30:00	S77HQ	LI75	VK6WR	OF77wx	14097099	23	-25	0	7015	124	14	2.3.0	1
2	4900994847	2022-10-31 13:50:00	S77HQ	LI75	VK6WR	OF77wx	14097062	23	-24	-1	7015	124	14	2.3.0	1
3	4901078804	2022-10-31 14:10:00	S77HQ	LI75	VK6WR	OF77wx	14097057	23	-21	0	7015	124	14	2.3.0	1
4	4901167030	2022-10-31 14:30:00	S77HQ	LI75	VK6WR	OF77wx	14097193	23	-26	0	7015	124	14	2.3.0	1
5	4901358200	2022-10-31 15:10:00	S77HQ	LI75	VK6WR	OF77wx	14097092	23	-25	0	7015	124	14	2.3.0	1
6	4902020332	2022-10-31 17:50:00	S77HQ	LI75	VK6WR	OF77wx	14097168	23	-26	0	7015	124	14	2.3.0	1
7	4905492456	2022-11-01 12:30:00	S77HQ	LI75	VK6WR	OF77wx	14097000	23	-29	-1	7015	124	14	2.3.0	1
8	4905648969	2022-11-01 13:10:00	S77HQ	LI75	VK6WR	OF77wx	14097034	23	-25	-1	7015	124	14	2.3.0	1
9	4905885847	2022-11-01 14:10:00	S77HQ	LI75	VK6WR	OF77wx	14097116	23	-21	-1	7015	124	14	2.3.0	1
10	4906174732	2022-11-01 15:10:00	S77HQ	LI75	VK6WR	OF77wx	14097191	23	-27	-1	7015	124	14	2.3.0	1
									Mean	-24.9000					
									SD	2.4838					
									AD	2.1906					
									AD%	85					

Table 43: SNR Anomalous WSPRnet link S77HQ to VK6WR at position 15:10 UTC.

- Last record at 15:10, right as the aircraft takes off.
- Last record is flagged as an anomaly in the study. However, from a plot of the data, it does not appear to be anomalous.

4. Theoretical Study

- The Doppler shift can be calculated for HF band to be within ±25 Hz using the equation,

$$f_d = 2f_c\frac{v}{c}$$

- Signal-to-Noise Ratio (SNR) from FSR can be calculated to be,

$$SNR = \frac{P_{tx}\lambda^2\sigma 30}{(4\pi)^3 R_{tx}^2 R_{rx}^2 K T_0 B}$$

- Verify RCS of 45dBm2 for a Boeing 777 at 14MHz used in existing method by comparing a Boeing 777 to a Cessna-172 [1] using the ratio of lengths and frequencies. FSRCS equation is

$$\sigma = \frac{4\pi A^2}{\lambda^2}$$

- Ratio of 93MHz to 14MHz, and ratio of length 8.28m, and height 2.72m, to length 73.9m, and height 18.5m -> 83 times bigger.
- RCS of a Boeing 777 is 41dBm2 at 14MHz, so 45dBm2 is plausible.
- Distance increase due to the signal hopping between the ionosphere and the earth can be calculated using

$$d_h = 2n\sqrt{2R\left(R+h\right)\left(1-\cos\left(\frac{d}{2Rn}\right)\right)+h^2}$$

- The max. propagation distance is calculated to be 19,600km and the great-circle distance is then calculated to be 19,500km.
- Long path propagation and detection is thus possible under ideal circumstances.
- Note that WSPR signal will only spend around 10% of its propagation time in the same altitude as cruising aircraft.

5. Summary

- Current GDTAAA model cannot be used to reliably track aircraft
- Unable to conclusively verify that data from WSPRnet can/cannot be used to detect and localise aircraft.
- Anomalies in SNR can be detected, highlighted in linear scale.
- Long path propagation has to be considered to increase datapoints, but not all can be decoded by WSPR.

6. References

[1] Contu et al. Passive Multi-Freq FSR Meas of Airborne Targets Using Broadcasting Signals, IEEE TAES, 2017. URL https://ieeexplore.ieee.org/document/7835708
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[3] Richard Godfrey et al. MH370 flight path analysis. Case study, 2023. URL https://www.mh370search.com/2023/08/31/mh370-case-study/
[4] Richard Godfrey et al. Flight QTR901 GDTAAA WSPRnet analysis, Case study, 2023. URL https://www.mh370search.com/2023/06/09/qtr901-case-study/
[5] Robert Westphal. “Geocaching” in the ionosphere, 2021. URL https://hamsci.org/publications/geocaching-ionosphere.