WHY IT IS NOT POSSIBLE TO TRACK JET AIRCRAFT USING THE WSPR HISTORICAL DATABASE

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What is WSPR

WSPR stands for 'Weak Signal Propagation Reporter'.

Amateur radio operators attached to the WSPR system via the internet will record various information in the system's database.

For example a radio operator say in Australia when his system is transmitting the location and details of the signal strength and frequency will be recorded in the database.

Another Radio Operator say in the U.K. when his ham radio picks up the signal from the radio operator from Australia will record into the database his location and some details about the received signal e.g. the drift and SNR (Signal to noise ratio).

See example of fields captured in the WSPR system.

spot	datetime	Tx	Rx	Link	TxG	RxG	SNR	MHz	dBm	drift	km	°T	Band	sw	code
186139232	07/03/2014 18:20:00	HS0ZKM	KI7CI	HS0ZKMKI7CI	OK03gr	DM09ch	-16	14.097148	37	1	12787	34	14	2.11_r2263	0
186142456	07/03/2014 18:36:00	HB9CZF	VK3DXE	HB9CZFVK3DXE	JN47ch	QF21nv	-10	14.097090	30	-1	16400	90	14	2.11_r2263	0
186143007	07/03/2014 18:38:00	DH5RAE	VK7DIK	DH5RAEVK7DIK	JN68qv	QE48cq	-17	7.040134	37	-1	16428	94	7	2.20_r2283	0
186165782	07/03/2014 20:34:00	AC7SM	CX2ABP	AC7SMCX2ABP	DM26ie	GF15wc	-12	28.126030	37	-1	9998	135	28	2.21_r2286	0
186182893	07/03/2014 21:52:00	CX2ABP	KB4RG	CX2ABPKB4RG	GF15wc	EL09wn	-11	28.126111	37	1	8411	323	28	2.12_r3617	0
186192709	07/03/2014 22:52:00	VK3DXE	W4AC	VK3DXEW4AC	QF21nv	EL86	-12	14.097044	37	-2	15362	92	14	2.21_r2286	0
186199506	07/03/2014 23:36:00	YO3ITD	K4RCG	YO3ITDK4RCG	KN34cj	FM08xl	-10	7.040094	37	-1	8082	307	7	0.8_r3058	0
186201515	07/03/2014 23:48:00	YO3ITD	K4EH	YO3ITDK4EH	KN34cj	EM73	-17	7.040102	37	-1	8920	308	7	2.21_r2286	0

What fields in the above table are used to detect an aircraft

The main fields that are used to tell if an aircraft has flown through the radio signal for example a radio transmitter based in Australia and a radio receiver based in the U.K are:

(1) SNR

(2) Drift

Why these fields are not suitable to detect an aircraft in flight

The Doppler affect of an aircraft (hitting the signal) is much smaller than natural fluctuations of the carrier signal.

Therefore the effect of the aircraft flying through the radio waves will be totally masked by the large natural fluctuations with the signal.

It is like being at a noisy rock concert and expecting to pick up a person whispering a hundred metres away.

Technical articles

Here are some technical articles that explain why using the WSPR historical database is not suitable for tracking jet passenger aircraft.

Please view this Youtube video from Ham Radio Dx.

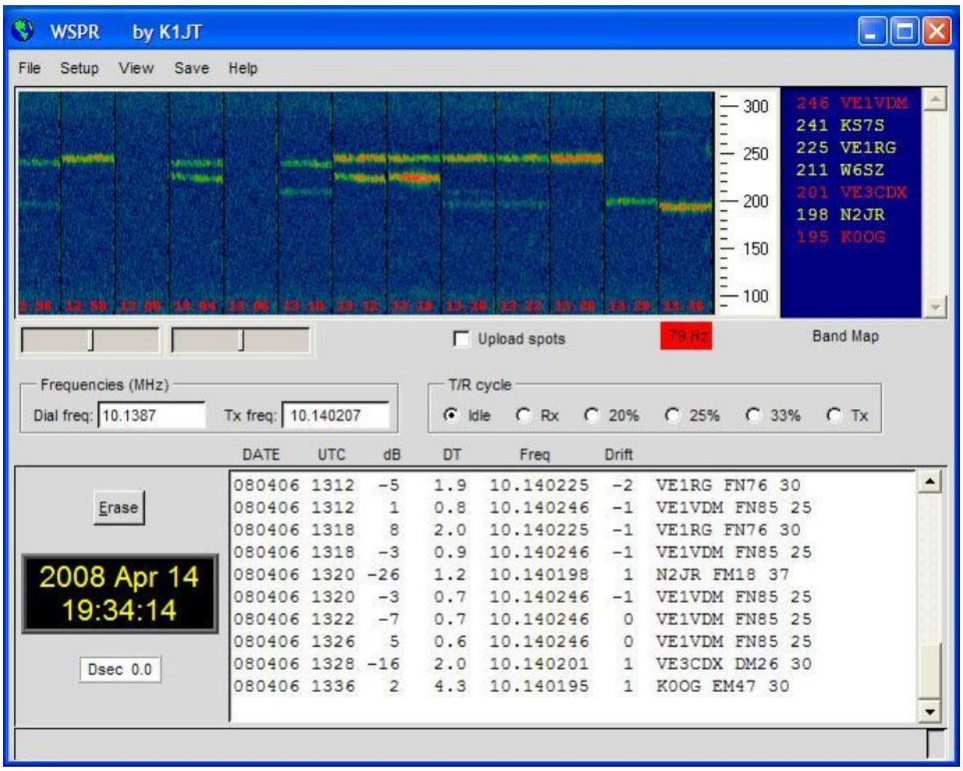
https://youtu.be/KefDzzDAeew

Also please see the following appendices.

Appendix A - Rebuttal by IG (Independent Group)

WSPR Can't Find MH370

by Victor Iannello
POSTED: SUNDAY, 12/19/2021



Screenshot from WSPR software as developed by Joe Taylor (K1JT)

> "I do not believe that historical data from the WSPR network can provide any information useful for aircraft tracking."
>
> *Prof. Joe Taylor (K1JT), Nobel Prize in Physics, Inventor of WSPR*

Despite many stories in the media repeating claims that historical WSPR data can be used to track MH370, there are many reasons why these claims are patently false. There is broad agreement among acknowledgeable researchers that have investigated these claims, and a handful of these researchers have documented their concerns. For instance, amateur radio enthusiast Hayden Haywood (VK7HH) has created a **video** (https://youtu.be/KefDzzDAeew) explaining why, in simple terms, WSPR can't track airplanes. MH370 investigator Steve Kent published a **paper** that formally treats skywave propagation and scatter off airplanes, and concludes there is insufficient signal strength (by many orders of magnitude) for WSPR to detect aircraft over long distances. In fact, even WSPR creator **Joe Taylor** (K1JT), who won a Nobel prize in physics for his research on pulsars and gravity, told fellow MH370 Independent Group (IG) member **Mike Exner**, "I do not believe that historical data from the WSPR network can provide any information useful for aircraft tracking."

WSPR Background

WSPR (pronounced "whisper") is an acronym for "Weak Signal Propagation Reporter". Amateur radio stations implementing WSPR send and receive messages using low-power transmissions to test propagation paths on the Medium Frequency (MF) and High Frequency (HF) amateur radio bands. When a participating station successfully decodes the transmission transmitted by another participating station, it sends that information to a central database, and that information is available to the public for retrieval. For each 2-minute contact between stations ("spots"), the available information includes station call signs, locations, transmitted power, and three parameters discriminated by the receiver: signal-to-noise ratio (S/N), frequency, and frequency drift.

The **proposed theory** is that recorded deviations ("anomalies") in the (S/N) and the frequency shifts/drifts are related to radio wave interactions with aircraft some thousands of kilometers distant from either amateur radio station.

The theory behind using bi-static radar (i.e., transmitter and receiver in different locations) for aircraft detection and tracking is well-known, and books (e.g., **this**) have been written on this subject. A special case is when an aircraft crosses the "baseline" between transmitter and receiver, resulting in a "forward scattered" signal caused by the diffraction around the silhouette (projected area) of the aircraft. The Forward Scatter Radar Cross Section (FSRCS) is typically much larger than the RCS that conventional mono-static radar uses to detect targets.

It is this forward scattered signal that is of interest here in evaluating whether WSPR signals can be used to reconstruct the path of MH370. In this article we apply the well-developed theory of bi-static radar to demonstrate that WSPR signals cannot be used to detect MH370 in the manner claimed in this **paper**. The relevant equations are presented in the Appendix, and the inputs and the calculational results for the test cases can be found in the accompanying table in the Appendix.

Detection of MH370 Before Radar Coverage Was Lost

We consider the **claim** that the WSPR data shows that MH370 was detected on the night of the disappearance at 17:16 UTC when it was still under radar coverage as it flew over the Gulf of Thailand towards waypoint IGARI, before the turnback, at FL350 (37,200 ft). At that time, a WSPR transmission from a station in Switzerland (HB9CZF) was received by an Australian station near Canberra (VK1CH) over a distance of 16,527 km on 14.097 MHz at a transmitted power of 1 W. The distance from the Swiss transmitter to the aircraft was 9,868 km and the distance from the aircraft to the receiver was 6,660 km, as depicted in this figure from the **paper**:

Although WSPR contacts greater than 16,000 km are rare, this spot shows they can indeed occur. Based on the distance between the stations, the transmission from Switzerland reached the Australian station via skywave propagation in which the radio waves were refracted off the ionosphere and reflected off the Earth's surface ("hops") about 5 times.

WSPR Signals Forward Scattered from an Aircraft Would be Undetectable at Long Distances

The column labeled "Case 1" from table in the Appendix shows the inputs and the calculational results for this scenario. Assuming that the propagation loss is the same as for free-space propagation, the expected strength of the direct signal at the receiver is -110 dBm, which is about the same value claimed in the **paper** when considering hops between the ionosphere and the Earth's surface. This suggests that the refraction and reflection losses were either calculated to be very small, or were neglected.

At 14.097 MHz, the wavelength is 21.3 m, and the FSRCS for the B777-200ER for waves directly incident to the top or bottom is estimated to be

18,791 m^2, or about 23 times the projected area. The forward scattered signal at the receiver is estimated to be -210 dBm, or about 100 dB (10 orders of magnitude) weaker than the direct signal. Can a signal of this strength be detected and decoded by the WSPR software?
Whether the signal could be detected by the radio and decoded by the software depends on the achievable noise level, as a minimum signal-to-noise ratio (S/N) of around -30 db is required by the WSPR software, where the noise level is referenced to a bandwidth of 2.5 kHz. I ran some simple experiments on my Flex 6400 amateur radio to measure the achievable noise level on the 20-meter band at my home in suburban Roanoke, Virginia. At 10:30 am on December 19, 2021, on a quiet part of the band, when connected to a horizontal resonant antenna, and after setting the bandwidth to 2.5 kHz, I measured a noise floor of -102 dBm. This largely consists of manmade and natural noise received at the antenna. To determine the sensitivity of the radio independent of the environmental noise, I disconnected the antenna and connected the radio to a resistive dummy load of 50 ohms. The noise level dropped to -105 dBm. By using the radio's built-in pre-amplifier configured for its maximum gain of 32 dB, the noise level further dropped to -129 dBm. (Pre-amplification improves sensitivity but increases the distortion from strong signals, and so must be used judiciously.) Even though this noise level would be very difficult to achieve under real conditions, I used this noise level as the reference for calculating (S/N) values on 20 meters. So, for the forward scattered signal strength of -210 dBm, the (S/N) would be (-210 – -129) = -81 dB. This is 51 dB weaker than WSPR requires (-30 dB), i.e., the forward scattered signal is **5 orders of magnitude too weak to be detected and decoded by WSPR!** Considering the very favorable assumptions we made regarding propagation loss, incident angle, and noise floor, we can be quite confident that the WSPR signal originating in Switzerland at 17:16 UTC did not interact with MH370 in any way that was detectable in Australia, as was claimed.

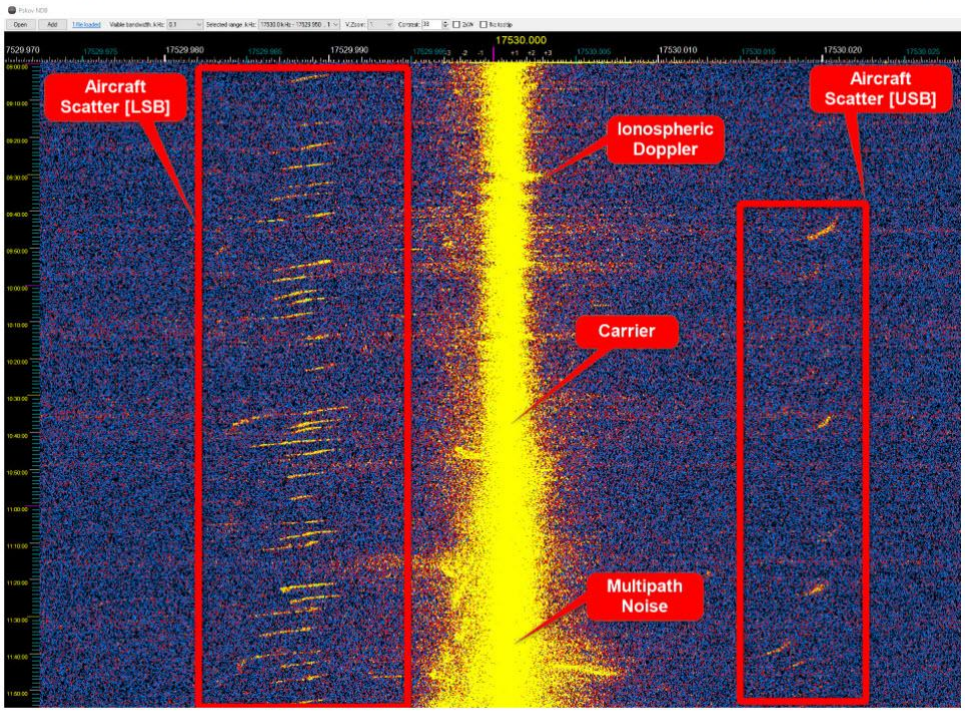
WSPR Signals Forward Scattered by an Aircraft Would Be Masked by the Stronger Direct Signal

Assuming the skywave propagation loss was equal to the free-space propagation loss, the WSPR signals originating in Switzerland and forward scattered by MH370 over the Gulf of Thailand would be received in Australia with a strength of around -210 dBm. However, the direct radio waves that did not interact with the aircraft would be received with a strength of around -110 dBm. That means that **the direct signal strength would be about (-110 – -210) = 100 db (10 orders of magnitude!) stronger than the scattered signal.** Under these

circumstances, the combined signal (direct plus forward scattered) would be absolutely indistinguishable from the direct signal, even if above the noise level (which it was not).
However, the equations presented in Appendix A predict that it IS possible for radio waves to forward scatter from an aircraft and be detected under the right conditions. For example, **Joki et al.** studied how broadcast TV transmissions at around 50 MHz may be passively used to detect, identify, and track airliners over a distance of hundreds of kilometers. Some of the factors that determine whether the aircraft could be detected include:

- The projected area of the aircraft
- Strength of the direct signal received, i.e., high power transmitters near the receiver increase the signal strength
- The distance of the aircraft to the receiver, i.e., the proximity of the aircraft increases the strength of the forward scattered signal
- The frequency of the transmission, higher frequencies increase the FSRCS and therefore the strength of the forward scattered signal
- Frequency-based signal processing to separate the direct signal from the Doppler-shifted forward scattered signal

Recently, amateur radio operator **Nils Schiffhauer** (DK8OK) claims to have observed aircraft scatter by analyzing the signal from an AM broadcast of China Radio International (CRI), which operates on 17.530 MHz with a 250 kW carrier, and uses a beam antenna with a gain of 25 dBi towards Europe. Nils' location is near Hannover Airport in Germany, some 7,600 km away from the CRI transmitter in Xianyang, China. The figure below depicts a "waterfall" plot showing aircraft scatter over a period of 3 hours. The Doppler-shifted signals from many aircraft are clearly visible in the lower sideband (LSB), some 5 to 20 Hz below the carrier frequency.



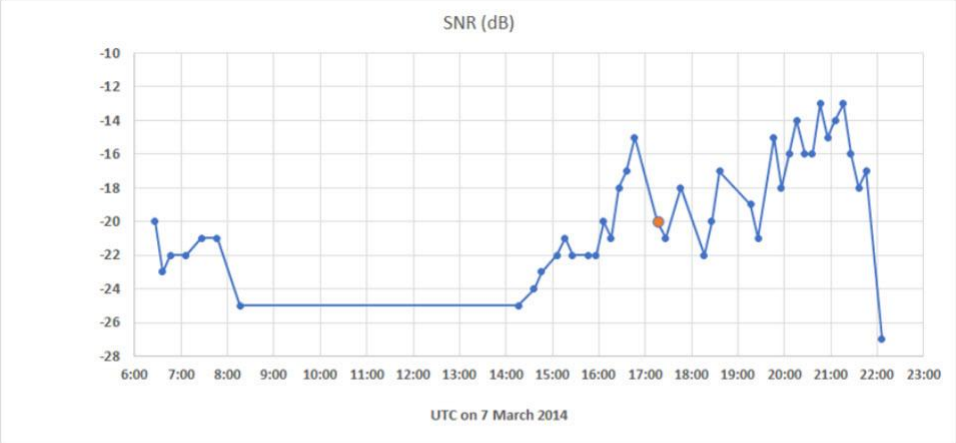
Waterfall plot of CRI broadcast on 17.530 MHz as received by Nils Shiffhauer DK8OK in Germany over a period of about 3 hours. Evidence of aircraft scatter can be clearly seen mostly in the lower side band (LSB).

After processing the data from a 1-hour measurement, Nils calculated that the carrier strength was -59.1 dBm, the average Doppler signal strength was -105.9 dBm, and the average noise level was -108 dBm.
I was curious if the forward scatter equations in Appendix A would produce calculational results consistent with Nils' measurements. After using FlightRadar24 to observe flights passing near his residence, I estimated that planes landing on Hannover Airport's Runway 27R would generally pass within a lateral distance of about 2 km and about 0.85 km (2800 ft) above his residence, which is a slant range of about 2.2 km . A good number of those airplanes were B737s, which I used to calculate the FSRCS. The inputs and the results from the calculations are shown in the column labeled "Case 2" from the table in Appendix.
We know the location, power, and antenna gain of the transmitter, and since we know the received strength of the carrier was -59 dBm, we can calculate the additional propagational loss of the skywave path due to refractions from the ionosphere and reflections from the Earth's surface, which we estimate to be around -33 dB. The signal strength of the aircraft scatter is then calculated to be around -102 dBm, which is only 4 dB stronger than the measured value of -106 dBm. Considering that the value of FSRCS is assumed to be in the most favorable direction, the measured strength of the aircraft scatter is entirely consistent with the calculated value.

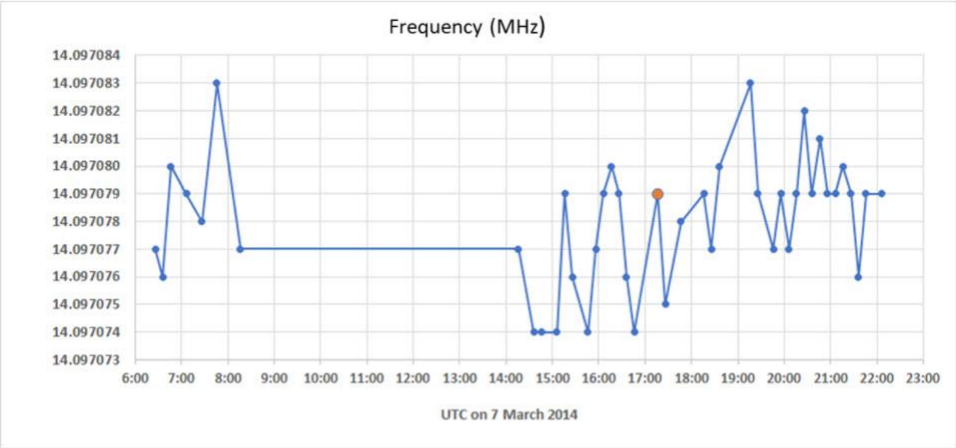
Nils concludes that since the signal from the aircraft scatter is 47 dB below the carrier, it would be impossible to look at the combined signal (which is all that is available in the WSPR database) and determine the contribution of the aircraft scatter. We strongly agree.

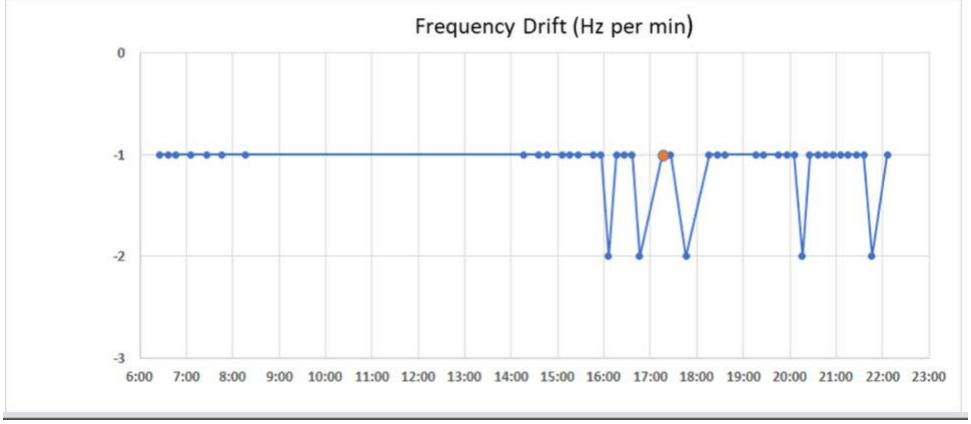
WSPR Signal Deviations are Not Related to Aircraft

Based on the extremely small signal generated by a hypothetical interaction with MH370 at 17:16 UTC, there can be little doubt that at that time, the WSPR database did not record a spot between Swiss and Australian stations consistent with forward scatter from the aircraft. Yet it's claimed that there was a detectable deviation in the recorded (S/N) values between the Swiss and Australian stations that is indicative of forward scatter from MH370. To evaluate this claim, Mike Exner and Bobby Ulich produced the following graph which shows the (S/N) for all WSPR contacts between the Swiss (HB9CZF) and Australian (VK1CH) stations over an time interval of around 16 hours. The particular (red) spot deemed as "anomalous" clearly shows no greater deviation from the trend than any other spot. What is claimed to be "anomalous" is within the scatter range of the other points. The dynamic characteristic of the ionosphere is all that is needed to explain these deviations.



To further demonstrate that there is nothing anomalous about the spot at 17:16 UTC, Mike and Bobby produced the following graphs which show that the reported values of frequency and frequency drift at 17:16 UTC are in no way anomalous to the other values recorded on that day for HB9CZF-VK1CH WSPR contacts.





Conclusions

This article attempts to lay out in simple technical terms why WSPR data cannot be used to track aircraft over long distances, and certainly cannot be used to reconstruct the flight path of MH370. At long distances and at low transmission powers, the received signals from hypothetical aircraft scatter are simply too weak by many orders of magnitude. What is claimed to be discernable “anomalies” in signal strength attributable to forward scatter by aircraft are within the expected deviations in signal strength for long distance skywave propagation involving refraction off the ionosphere. Although aircraft scatter could be detected if the aircraft were close to either the transmitter or receiver and if the transmitted power were sufficiently strong, the detection of the aircraft requires signal processing to separate the Doppler-shifted scattered signal from the much stronger direct signal, and this data is not available in the WSPR database.

Acknowledgements

This article benefited from many private communications with Mike Exner, Don Thompson, Bobby Ulich, Steve Kent, Nils Schiffhauer, John Moore, and Ed Anderson. I also acknowledge the many insightful blog comments from Mick Gilbert, Sid Bennett, and @George G.

Update on December 22, 2021

I asked Joe Taylor for a comment on the material covered in this article. Here was his response, shared with his permission:

As I’ve written several times before, it’s crazy to think that historical WSPR data could be used to track the course of ill-fated flight MH370. Or, for that matter, any other aircraft flight…

I don’t choose to waste my time arguing with pseudo-scientists who don’t understand what they are doing.

Appendix: Equations and Table of Results

Friis Transmission Equation

$$P_{r,d} = G_t G_r G_p \frac{P_t}{4\pi d_{tr}^2} \frac{\lambda^2}{4\pi}$$

Forward Scatter Signal Strength

$$P_{r,fs} = G_t G_r G_p \frac{P_t}{4\pi d_{ta}^2} \frac{\sigma_{fs}}{4\pi d_{ra}^2} \frac{\lambda^2}{4\pi}$$

Forward Scatter Radar Cross Section

$$\sigma_{fs} = 4\pi A_p^2 / \lambda^2$$

Forward Scatter Beam Width

$$\theta \approx {}^{\lambda}/_{d} \; where \; d = \max(L_f, L_w)$$

where the variable definitions and the inputs and results for the two cases can be found in the table below:

AIRCRAFT FORWARD SCATTER				
Victor Iannello, December 2021				
	Symbol	**Units**	**Case 1**	**Case 2**
INPUTS				
Flight	N/A	N/A	MH370	Various
Transmitter	N/A	N/A	HB9CZF	CRI
Receiver	N/A	N/A	VK1CH	DK8OK
Transmitter to Receiver distance	dtr	(km)	16,527	7,592
Transmitter to AC distance	dta	(km)	9,868	7,592
Receiver to AC distance	dra	(km)	6,660	2.2
Frequency	f	(MHz)	14.097	17.53
Receiver antenna gain over isotropic	Gr	(dB)	0	0
Transmitter antenna gain over isotropic	Gt	(dB)	0	25
Propagation gain(loss) over free space	Gp	(dB)	0	-33.2
Noise (2.5 kHz BW)	N	(dBm)	-129	-129
Transmitter power	Pt	(W)	1	250,000
Minimum S/N for WSPR decode	(S/N)min	(dB)	-30	-30
Aircraft type	N/A	N/A	B777-200ER	B737-800
Wingspan	Lw	(m)	60.93	34.32
Wing area	Aw	(m2)	427.8	124.58
Fuselage length	Lf	(m)	63.73	39.5
Fuselage diameter	Df	(m)	6.2	3.76
OUTPUTS				
Wavelength	λ	(m)	21.3	17.1
Aircraft projected area	Ap	(m2)	822.9	273.1
Aircraft linear dimension	d	(m)	63.7	39.5
Forward scatter radar cross section	σfs	(m2)	18,791	3,200
Forward scatter gain	Gfs	(dB)	13.6	10.7
Beam width	θ	(deg)	19.1	24.8
Received signal strength, direct	Pr,d	(W)	1.050E-14	1.218E-09
Received signal strength, direct	Pr,d	(dBm)	-109.8	-59.1
Received signal strength, direct	Pr,d	(S-unit)	S2.9	S9+14dB
Received signal strength, forward scattered	Pr,fs	(W)	9.929E-25	6.406E-14
Received signal strength, forward scattered	Pr,fs	(dBm)	-210.0	-101.9
Noise (2.5 kHz BW)	N	(S-unit)	S-0.3	S-0.3
S/N, direct	(S/N)d	(db)	19.2	69.9
S/N, forward scattered	(S/N)fs	(db)	-81.0	27.1
Relative received strength, forward scattered to direct	Pr,fs/Pr,d	(db)	-100.2	-42.8
WSPR decode link margin, direct	Md	(db)	49.2	99.9
WSPR decode link margin, forward scattered	Mfs	(db)	-51.0	57.1

Reference: **Passive Radar Technology, Prof. Charles Baker, University of Birmingham, NATO STO-EN-243-02.**

This entry was posted on Sunday, December 19th, 2021 at 2:50 pm and is filed under **Aviation**. You can follow any responses to this entry through the **RSS 2.0** feed. You can skip to the end and leave a response. Pinging is currently not allowed.

Comments from various IG site members

1. *airlandseaman* says:
   December 20, 2021 at 11:53 am

   Victor: Thanks for taking the lead on this paper/blog post. It conclusively documents what so many knowledgeable experts have been saying from the very beginning: It is fundamentally IMPOSSBLE to track any aircraft in the SIO with historical WSPR data from March 2014. In fact, it is impossible anywhere on earth at any time. It is pure nonsense.

   It is (long overdue) time for the proponents of this WSPR fantasy to admit they were wrong, and to correct the record so we can get on with the real scientific effort to assist with the search. The viral spread of false information about WSPR has been harmful to 370 NoK, the amateur radio community and the public at large.

2. *Victor Iannello* says:
   December 20, 2021 at 3:17 pm

   @airlandseaman: Thanks, Mike. The WSPR proponents are so dug in at this point that I think there is little chance of agreement. I simply wanted the opportunity for some of us to document (without leveling personal attacks) that we are on the right side of the facts, whether or not the blog article is widely read or understood.

3. *Mick Gilbert* says:
   December 20, 2021 at 7:11 pm

   @Victor Ianello

   Thank you for that concise and cogent rebuttal of one of the key premises that GDTAAA is built upon. As you say though, this considered presentation of the facts is unlikely to dislodge the few who have adopted publicly entrenched positions on the 'methodology'.

4. *370Location* says:
   December 21, 2021 at 7:18 am

   @WSPR:

   It's good to see this new critique on the claims for using WSPR to locate MH370. I hope the counterpoint gets picked in the news media, which has so far simply repeated the infinitely improbable bunk.

I recently posted some analysis stats here looking for variations in drift by actual ADS-B position distance from a day of WSPR paths. The author posted a response on his blog. He then blocked my reply there, so my reply instead is … on Reddit, where hams are asking about WSPR:

https://www.reddit.com/r/amateurradio/comments/rhwiqg/applying_high_frequency_weaksignal_propagation/hp60ztd/?utm_source=reddit&utm_medium=web2x&context=3

It was initially baffling that he would be insisting I wrote about planes flying at ionospheric altitudes, or his explaining ATC rules to prevent a high density of two planes every 5 km along flight paths.

My guess is that he mistook my mention of only sampling planes above FL150 as meaning 150,000 ft instead of 15,000 ft.

He also must have assumed that I somehow meant two planes for every 5 km along his great circle paths instead of laterally distant from them. Even though I described the 3-5K sample average number of planes aloft and up to 30 along his path, his interpretation would mean 16,000 planes along each WSPR path.

I don't think he was intentionally changing my words into a straw man argument, but genuinely misunderstood them.

— Ed Anderson

5. *Victor Iannello* says:
December 21, 2021 at 9:38 am

> @Mick Gilbert, @370Location: The technically astute will understand that WSPR can't be used to track aircraft when the target is thousands of kilometers from either station, even with the most generous of assumptions regarding propagation loss, radar cross section, and noise floor. We are not inventing new physical principles–as such, we can perform the analysis using known theory with the most favorable of assumptions.
>
> I am not expecting a coherent rebuttal.

6. *ALSM* says:
December 21, 2021 at 3:29 pm

Re: Claim by the former guy that I made up the quote from K1JT, here is one email, verbatim, received from Joe on Sat 5/15/2021:

Hi Mike,

This is nutty. There is no conceivable way that historical WSPR data could be used to track an aircraft.

— Joe Taylor, K1JT

So, technically it is true that Joe did not say “It’s nuts.”. He said: “This is nutty.” So, I apologize if anyone was misled by my error. lol

7. *Victor Iannello* says:
December 21, 2021 at 3:38 pm

@ALSM: It’s very hard to dispute that crystal clear statement, but some will try.

8. *Victor Iannello* says:
December 21, 2021 at 4:14 pm

All: Here’s what Joe Taylor told me today in an email when I again asked him for a comment on using WSPR to find MH370. I repeat his comments with his permission:

As I’ve written several times before, it’s crazy to think that historical WSPR data could be used to track the course of ill-fated flight MH370. Or, for that matter, any other aircraft flight…
I don’t choose to waste my time arguing with pseudo-scientists who don’t understand what they are doing.

I think that sums it up nicely.

9. *Mick Gilbert* says:
December 21, 2021 at 4:52 pm

@Victor Ianello

Re: “*I am not expecting a coherent rebuttal.*”

And you wouldn’t have been disappointed. A rambling shambles of same old, same old.

We’re initially treated to an episode of the misplaced use of a common character trait between open and closed boiling vessels as a means of ironic disparagement. Of all things, we’re treated to a critique of the Independent Group for having made multiple assessments of possible crash locations over the years. No one has published more papers claiming a greater number of crash locations over the years than he has. By my reckoning he has pinpointed the crash site variously as far north as 19S, 23S, 26.9S, 30S, a couple of stabs in the 34s (34.23S and 34.4S), as far south as 35S, and also 37S. There’s possibly more, I lost track sometime back.

We’re then told that the “challenge” to download live or historical WSPR data and test it hasn’t been taken up. Bullshit! Many of us have looked at the historical data and demonstrated that there is nothing discernible in it. Unless I’m very much mistaken, you have

done exactly that with the HB9CZF-VK1CH data in the example detailed above. Talk about none so blind!

And speaking of blind, the author of Gaussian Distributions Trashed and Associated Analytical Atrocities says that the blind test with QF6036 has been ignored. More bullshit. It hasn't been ignored at all. To the contrary, when some of us looked at his "position indicators" in that test, for seven of the nine for which there is ADS-B data, we found that none of his guesses were correct. The aircraft had barely travelled 130 kilometres from the known take-off location and his first "position indicator" was in error by over 35 kilometres! His methodology routinely fixed the position of the target aircraft where the actual aircraft demonstrably was not. This abject failure of the methodology to do what it was meant to do was hailed by the "adjudicators" as highly successful. Makes you wonder what subterranean depths needed to be plumbed to slip under the bar for failure.

Then we're told that Dr Robert Westphal's Geocaching in the Ionosphere paper has been ignored. More bullshit! The shortcomings in that paper have been addressed. When it was pointed out to Dr Westphal that regards his examples of the Davis Station helicopter operations and the Qantas Antarctic sight-seeing flight being "detected" in WSPR links between Australian transmitters and New Zealand and Japanese receivers respectively, in neither case were the target aircraft anywhere close to the propagation paths between the stations, he responded that,

"*… the WSPR signal from DP0GVN in Antarctica, assuming an isotropic radiation in all directions, hit the helicopters at Davis and was scattered amongst other directions to ZL2005SWL in New Zealand.*"

Utterly impractical, but if it were true then it would mean that Guessing, Doodling and Tracing yada yada yada could not work. If WSPR signals that have been scattered off targets that are not on the great circle propagation paths can register in the received and recorded spot data, then it is not possible to discern the location of the target. In fact, you'd have no idea which or even how many targets you were dealing with. It is beyond astounding that the author doesn't understand this – if Dr Westphal is right then he is wrong.

Of course, all of this to and fro can easily be resolved. If he is so sure of his work let him submit it to a peer-reviewed professional journal such as Nature or Radio Science. We'll wait.

10. *Mick Gilbert* says:
December 22, 2021 at 1:46 am

‘*… pseudo-scientists who don’t understand what they are doing.*‘

To quote ET, “Ouch.”

11. *Victor Iannello* says:
December 22, 2021 at 7:22 am

@Mick Gilbert: What he refuses to acknowledge is that his theory fails even with the most favorable of assumptions.

Regarding the Qantas test flight, an earlier version of the article addressed the absurdity of this result, too. The signal must pass over one station, propagate thousands of kilometers to reach the plane, backscatter, then propagate back thousands of kilometers to reach the receiver. So in this case, the “anomaly” is determined by comparing it to what? If there is no aircraft, there is no backscatter. So is the base case the short path between the transmitter and receiver? I couldn’t make any sense of what was claimed, so I elected to just include the MH370 at 17:16 UTC because we do have ground truth at that time.

There’s also a lot that could be said about the unscientific methods used by the arbiters of the Qantas blind test who proclaimed the test was a resounding success despite the obvious shortcomings.

12. *Nils Schiffhauer* says:
December 22, 2021 at 11:06 am

… thanks, Victor, for your work. I think it somewhat brave to bother K1JT with this topic, although I know from personal communication with him that he has a great ear for radio amateur‘s questions, answering them patiently …
He now should have had the last word in this dead case. Charlatanry or pseudo-science is the right commentary to what [was] presented. Any time spent to publish more data and scientific arguments is wasted. It is not a case of science, but, as I said before, social-psychology. Also interesting, but not to be discussed here.
73 Nils, DK8OK

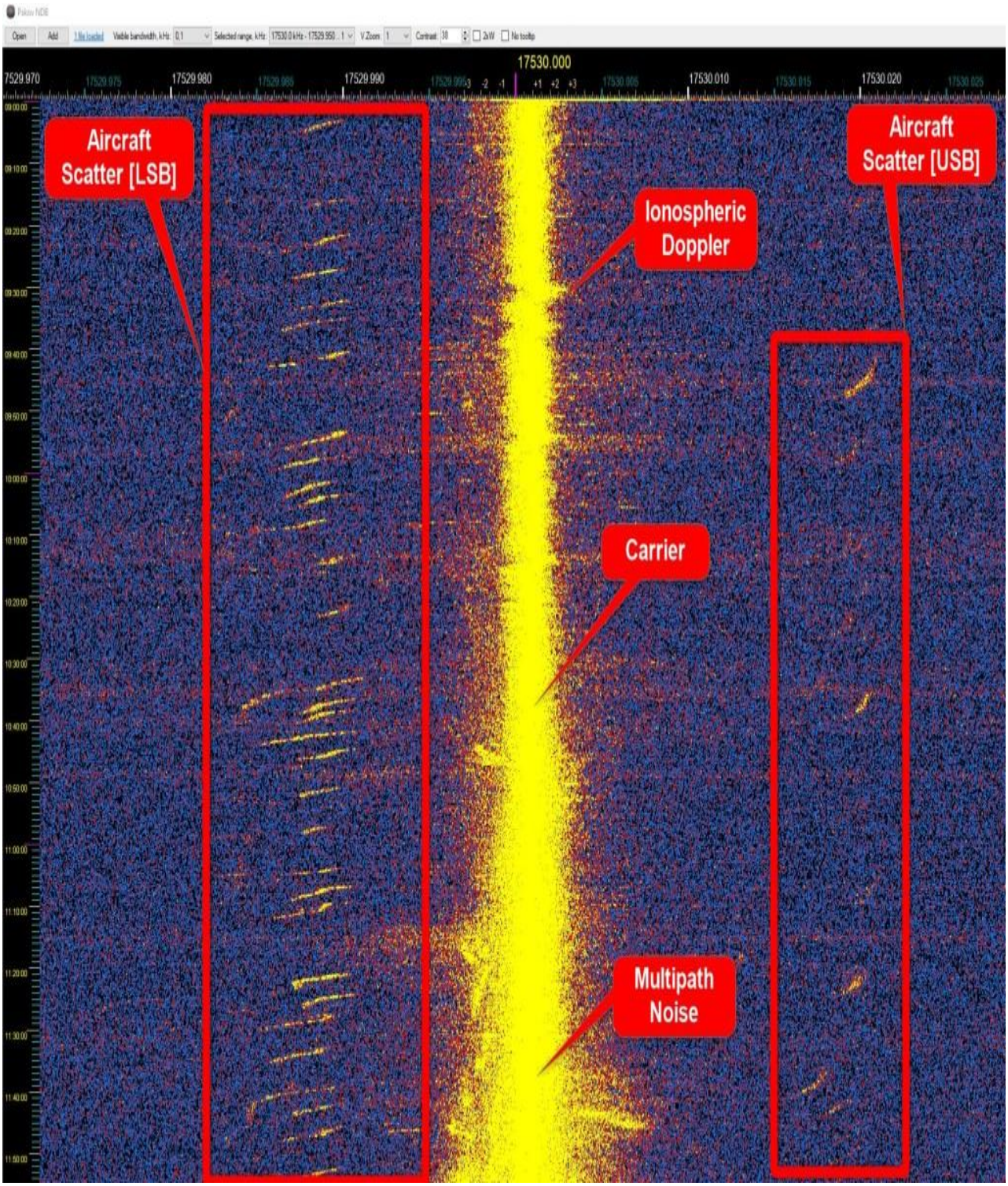
13. *Victor Iannello* says:
December 22, 2021 at 11:46 am

@Nils: Thank you, and I won’t be bothering Prof Taylor again on this topic. I think it would be interesting to perform scientific experiments to quantify the aircraft scatter in the HF bands under various

conditions, but those experiments won't lead to a methodology for using WSPR data to find MH370.

Appendix B - MH370 and WSPR: Aircraft Scatter on HF – A Critical Review

Some articles had been published stating that processing of WSPR logs can assist in reconstructing the route of an aircraft (i.e., MH370) by a method known as bistatic radar. Nils Schiffhauer, DK8OK, has some doubts. Read his reasoning below.



Some Doppler traces in vicinity of the carrier of China Radio International from Xian-Xianyang, broadcasting with 500kW (250kW carrier) on a curtain array antenna providing nearly 25dBi gain towards 190°. More on the lower than on the upper sideband you see some aircraft Doppler traces at distances of 8Hz to 17Hz (LSB), corresponding to a relative velocity of the aircraft from about 200 to 600 km/h. Frequency resolution: 0.0047 Hz.

Again and again, efforts by radio amateurs make the rounds to have identified the crash site of MH370, for example, on the basis of the evaluation of WSPR logs. For this purpose, they primarily evaluate “unusual” level changes in the WSPR logs.

The fact that RF signals are scattered by the metal hull of aircraft is nothing new. The best way to see this effect is to look at the Doppler tracks that form at a certain distance from the actual carrier frequency of the transmitter. This is based on the theory of bistatic radar (see for example "Bistatic Radar" by Nicholas J. Willis, Raleigh NC, 1995).

Aircraft Scatter: Bistatic Radar

This concept has been used worldwide for decades, in the HF range primarily in the form of various over-the-horizon (OTH) radars.
In principle, a signal with known properties (amplitude, waveform …) is transmitted and received again after having passed through the "channel". Comparing the transmitted signal with the received signal, the properties of the channel can be deduced.
Professional systems with powerful transmitters, beam antennas with high gain and signals with precise characteristics, whose scattering is evaluated with highly specialized algorithms, allow the detection of even small aircraft and ships in rolling seas. Intelligent evaluation includes the extensive elimination of interference factors, from sea clutter to changes in the ionosphere. These also have a considerable influence on the received signal – including amplitude and frequency (Doppler and split-up into x and o rays).

WSPR: A challenging mode

Transferring this technology to the evaluation of level and frequency of WSPR signals faces a couple of challenges:

- The effective transmit power of WSPR signals is only roughly known at best, but in terms of magnitude it is at least 50 dB below that of professional OTH equipment.
- The quality of the transmitted signal in terms of frequency stability, noise and possible amplitude changes (power supply!) is not known.
- The changes of the ionosphere (attenuation, Doppler, multipath …) is not known.
- The waveform WSPR, as well suited as it is for QRP communications, has not been developed for its use as bistatic radar.

All previous evaluations, especially in connection with flight MH370, are based primarily on evaluations of *level changes*, measured as just one mean value of a 110 seconds long transmission. It has been postulated that aircraft scatter increases the *overall level of the signal*. ("Drift" seems not to be a proxy for "Doppler", see below). A possible evaluation of the Doppler shift fails so far largely because of the data situation. This also prevents the inclusion of the current state of the ionosphere and its local fine structure. Catching up ray tracing – moreover only two-dimensional! – can by no means compensate this disadvantage.

Correlation vs. Causality

However, far-reaching expectations are attached to the existing and modest material ["Sensational new finding for MH370 flightpath"], which in my opinion are already epistemologically, but also technically on feet of clay. This is like one can make Mozart's "Kleine Nachtmusik" sound out of pure noise by suitable filtering. This also happens to high-ranking scientists, for example, when they detect neuronal correlates in the brain of a dead

salmon and erroneously conclude that it is solving mathematical problems … there has been everything. Correlation doesn't always mean causality.

My doubts about using WSPR logs for the purpose of locating aircraft are based on two main points:

- We know little to nothing about the actual state of the fine structure of the ionosphere, which *primarily* affects the signal.
- We have only guesses about the extent to which (amplitude, Doppler …) an object flying in an unknown direction scatters the signal (type, height, direction, speed …).

Furthermore, raytracing in those examples calculates with unusually low elevation angle of under 3°. PropLab 3.1 [most recent build #43] sees the main elevation of, e.g., a vertical dipole at more than 20°.

Just as an aside, when the central paper on "WSPRnet Propagation Technical Analysis" states, "Flat ice or calm ocean provide the best surface's for WSPRnet signal reflection.", the opposite is true, at least as far as the conductivity of ice is concerned. It has the worst conductivity and thus reflectivity of all soils on the earth's surface and, at 10^{-4} S/m, is in last place in this respect according to ITU-R P.527-4.

HF Scatter: What the Experts say

The relevant literature on HF radar deals with such central matters as radar cross section (which defines the return power of an modeled object, which can vary by several 10 dB under different circumstances), scatter in Rayleigh and Mie regions (dependence on wavelengths and dimensions of the object), and inhomogeneities of different layers of the ionosphere – concepts of which most previous studies on the subject of "WSPR and MH370" make sparse use at best.
I do not want to bore now with long-tongued recounting of these things, but to pick out thesis-like only some points from the NATO paper "HF-OTH Skywave Radar for Missile Detection" as a quotation (**bolded** by me):

* We must deal with heavy propagation losses due to the very long travelling distances as well as strong absorption losses mainly due to the D layer of the ionosphere. The whole **loss contribution** can be **up to 100-150 dB.**

* The **apparently** simple propagation mechanism hides the complexity of the ionosphere structure. This implies a challenging target localization that could be achieved by a smart system calibration combined with a **three dimensional** reconstruction of the signal path through the ionosphere.

* OTH radar system functionalities are **strongly dependent** on the ionosphere and on the environment noise level that means geographically dependent performances. Accordingly the radar siting represents one of the key choices.

* **High values of peak power are necessary** in such systems to deal with strong losses.

* It is **essential a simulative approach** that can provide a predicted radar cross section variability as a function of the operating frequency and of the aspect angles that are unusual for ordinary radar systems.

Certainly, these military requirements do not have to be transferred 1:1 to our more semi-professional approach. Nevertheless, they set such narrow limits to even our modest approach that their meaningful application threatens to disappear almost completely in fading and noise.

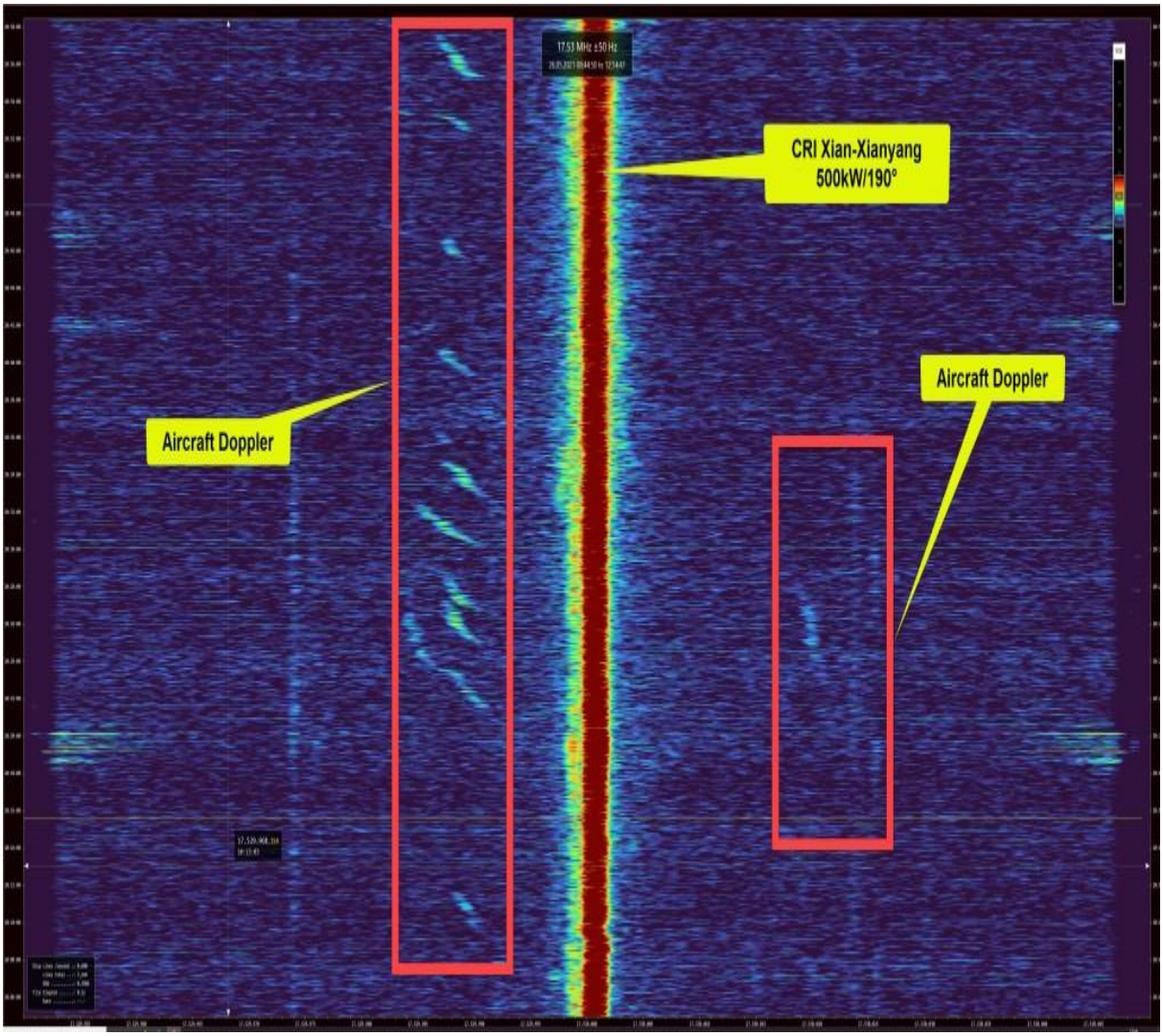
Amateur's Choice: +70 dB – and more

In order to verify at least some basic assumptions in practice, I have conducted a series of investigations on carriers of shortwave broadcast transmitters. These have several key advantages over WSPR:

- They provide a known signal in terms of frequency stability and amplitude.
- Their effective transmit power is about 70 dB higher than that of WSPR transmitters.
- Each station transmits continuously for at least 30 minutes, allowing relatively large integration times to improve the frequency resolution (up to 0.005 Hz, or adding *another* 57 dB in a 2'500 Hz channel) and thus the sensitivity for detecting the Doppler signals.
- This setup allows a clear separation of original signal (via ionosphere) and aircraft scatter by shape and frequency. This eliminates what I consider to be the biggest unknown of the WSPR approach.

However, there is one drawback: only between 0 and 10% of even these strong transmitters can be used to detect Doppler traces from aircraft. Only with a smart match of frequency, time, flightpath, propagation … you will have some success.

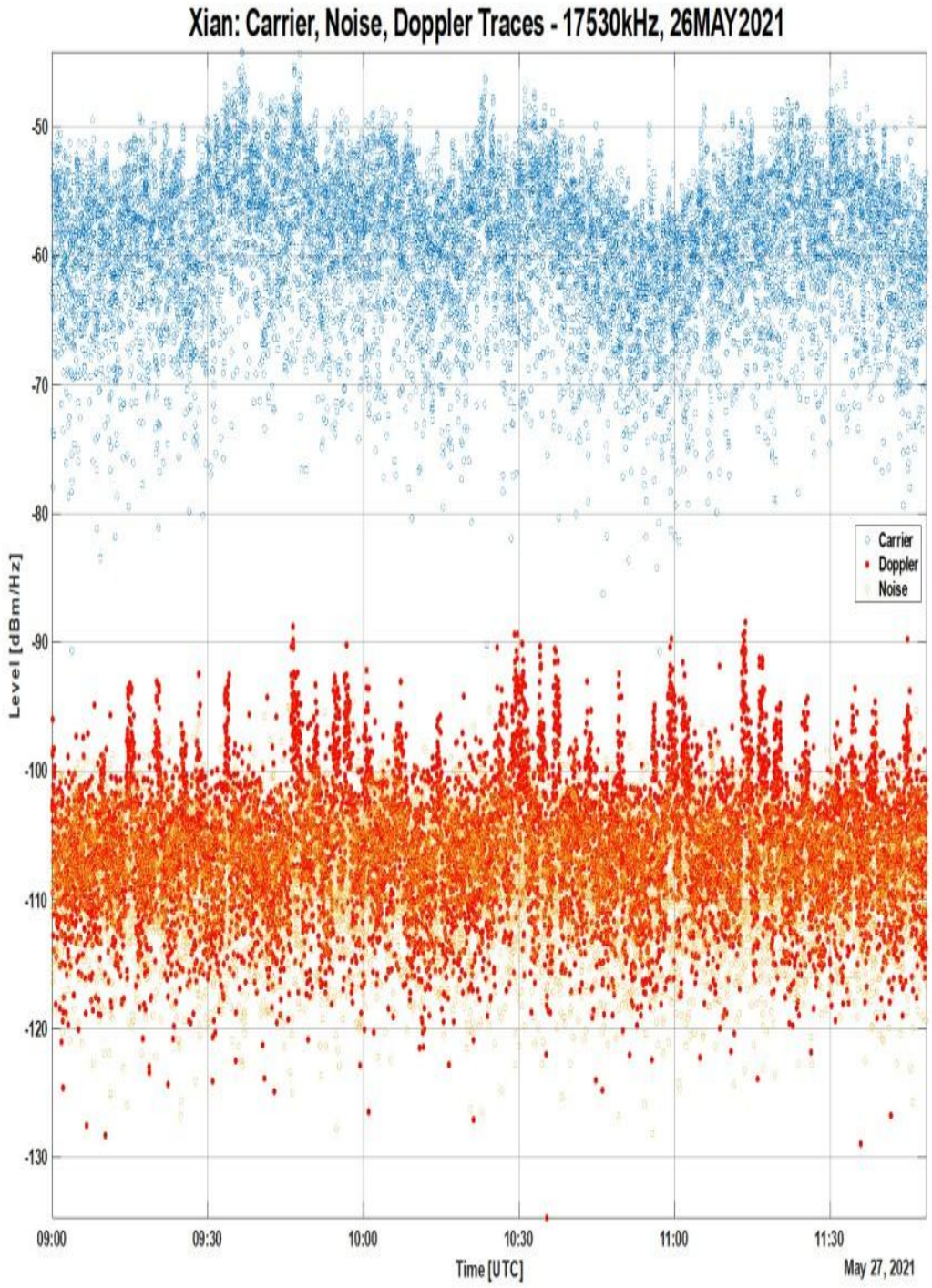
Let me pick a typical example from a series of experiments – all with similar outcomes. The Chinese transmitter at Xian is received with 500 kW (carrier: 250 kW) on a GPS-locked SDR Elad FDM-S3. Its carrier on 17'530 kHz was first displayed under magnifier of two software, namely PSKOV (screenshot on top of this blog, for a first introduction click here) with 0.005Hz resolution, and SDR software SDRC with 0.39 Hz resolution, see screenshot below. The latter provides the numerical output used in the following post-processing.



Situation with software SDRC, compared to the PSKOV-screenshot at top of this blog.

Needle in a Haystack?

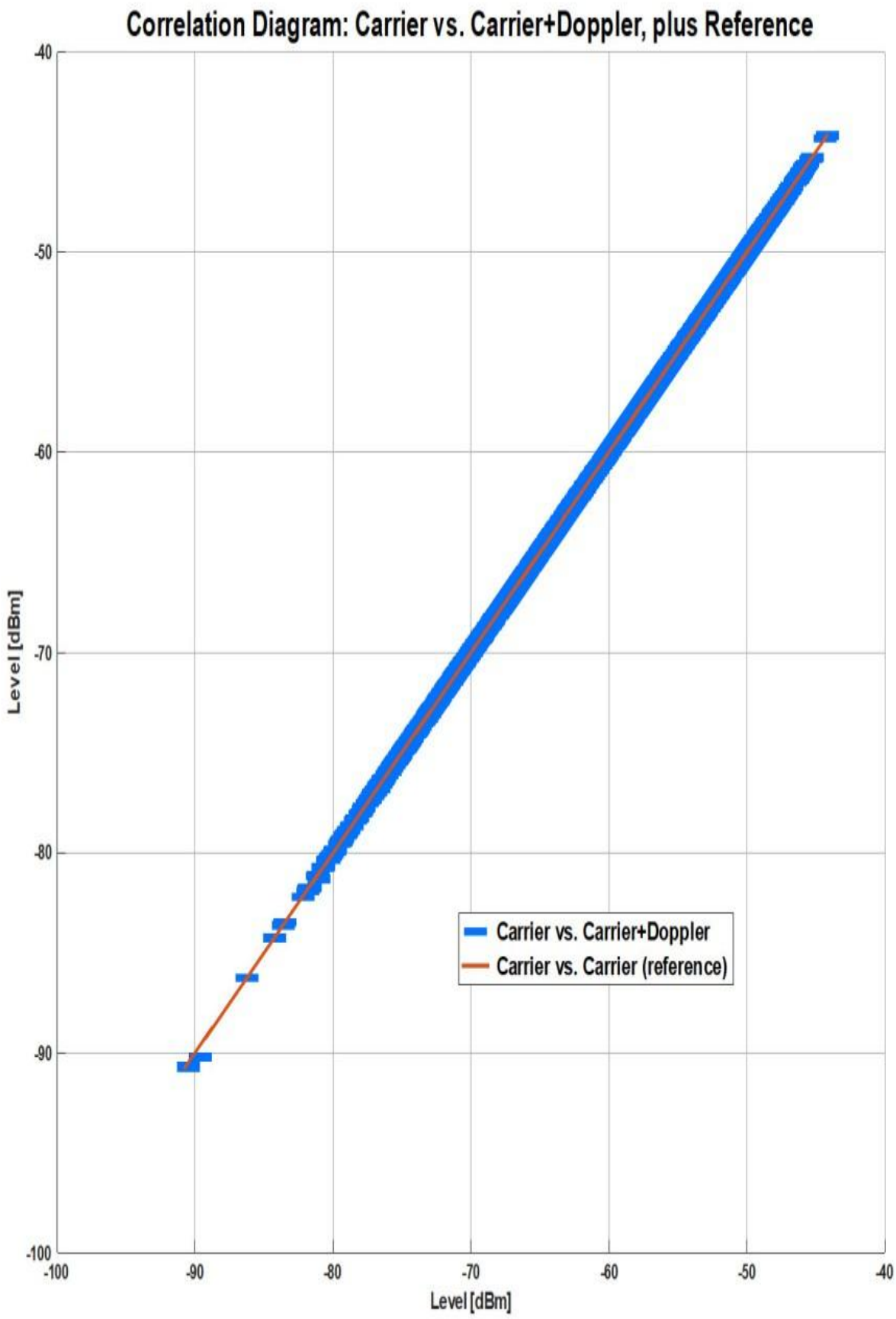
The next step is to answer the following question: Is it possible to detect the influence of the Doppler tracks in the overall signal? After all, this is the method that is tried using WSPR. For this I first divide the total signal of 100 Hz width into three channels: Carrier, Doppler and Noise, see below. The Doppler signals are clearly visible, the respective correlation coefficients between the channels “Carrier”, “Doppler” and “Noise” are all well below 0.1, which shows the independence of the three different signals from each other and their separation. Mean Level of Carrier is -59.1 dBm, standard deviation 5.71. Mean Level of Noise is -108 dBm, standard deviation 4.5.



Signal levels over 10’000 seconds for all three channels.

In the following step, I sum up the channels “Carrier” and “Doppler” (de-logarithmize the dBm values in mW, addition, re-logarithmize the mW values to dBm).

If I now compare the data “Sum level of Carrier and Doppler” with the “Carrier”, the correlation diagram shows a near-complete agreement between both data sets – see screenshot below:

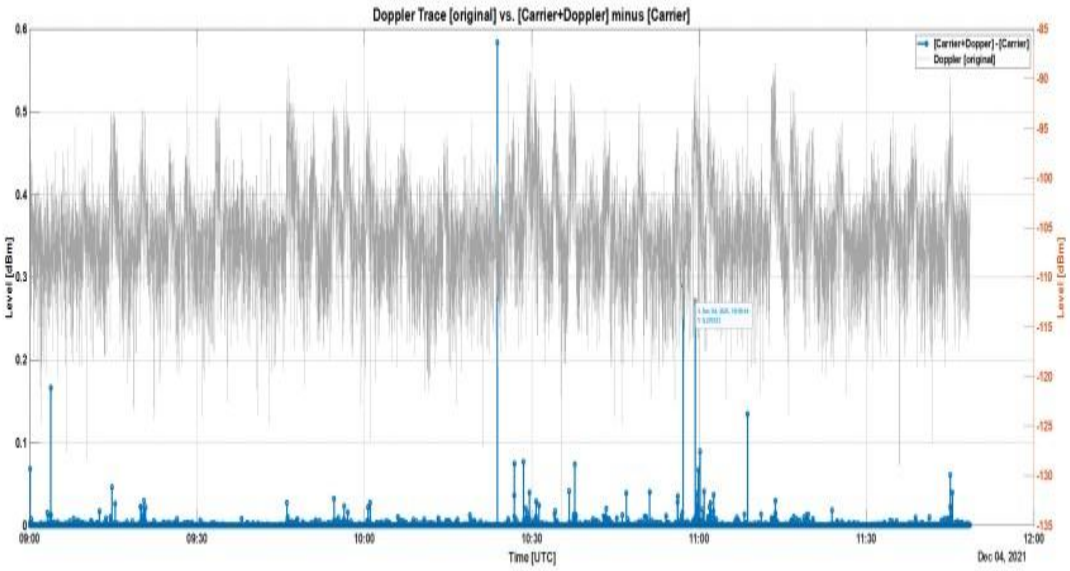

Correlation Diagram: Carrier vs. Carrier+Doppler, plus Reference
Level [dBm]
Level [dBm]
-40
-50
-60
-70
-80
-90
-100
-100
-90
-80
-70
-60
-50
-40
Carrier vs. Carrier+Doppler
Carrier vs. Carrier (reference)

Correlation diagram fo Carrier and Carrier+Doppler (blue marks) shows only miniscule differences from 100% identity (red line).

Are rounding errors the reason for those miniscule differences? No, as we see in the following screenshot where you can see that the *Doppler trace increases the signal of the carrier by 0.2 dB to 0.3 dB at most*, except for a single exception: 0.6 dB.

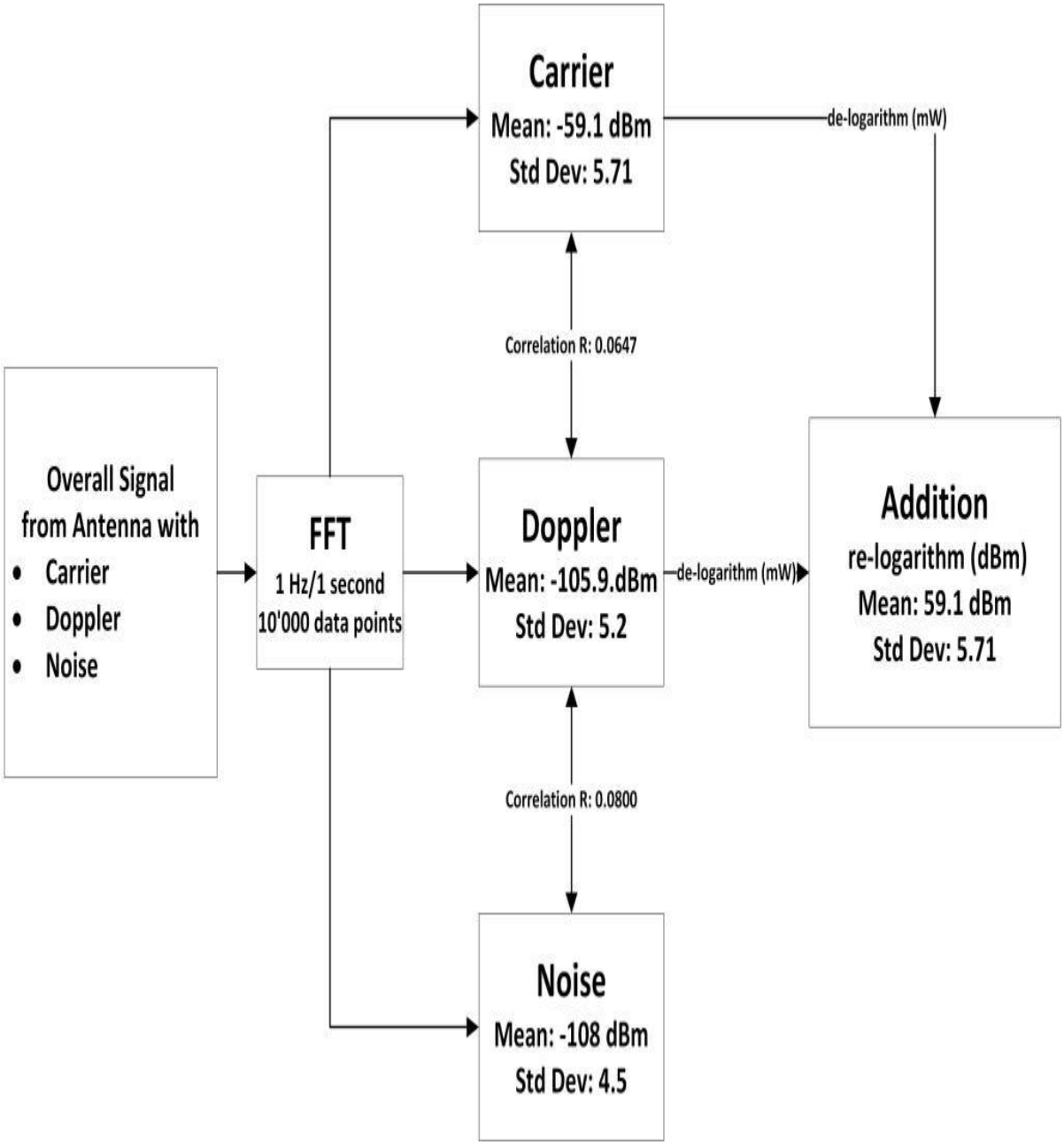
But these values are almost completely lost in the overall signal with its standard deviation of 5.71, if they are not anyway below the measurement accuracy of many SDRs and their software.

The screenshot below draws the difference between [Carrier+Doppler] and [Doppler] – values left Y-scale – together with the original Doppler signal – right Y-scale. Judge for yourself …



The Doppler traces are practically lost in the fluctuations of the carrier signal.

For the complete overwiew of the steps see the workflow below:



Workflow, done with Elad FDM-S3, SDRC, MatLab R2021a.

WSPR & Aircraft Scatter? I have my doubts.

We started with the challenge to see some signal enhancement by scattering from aircraft in WSPR logs. Those should lead to “unusual” changes within the signal. A WSPR transmission lasts for 110.6 seconds and delivers just one mean SNR value representing his time (plus drift with a resolution of 1 Hz only).

It was suggested that from these signal levels (and drift data) aircraft scatter can be derived. This had been tried to underpin with 2-dimensional ray-tracing propagation simulation, based on statistical, rather then real data.

I tested those assumption with 10'000 level data at one second resolution, +70 dB in transmitting power, added by a few 10 dB of processing power. Doppler traces from 30+ aircraft had been analyzed. Backed by this, it can be stated:

- On HF over longer paths (from two hops/with multipath propagation), usual aircraft scatter has *nearly no effect on the overall reception level*. Without prior knowledge, it is hard, or even impossible, to conclude aircraft scatter from the sum signal.
- Doppler effects occure in the region of about 5 Hz to 20 Hz and don't coincide with the much lower "drift", I saw in the WSPR logs.
- The power of a typical WSPR setup is many ten dBs down to what it should be to reliably identify aircraft scatter.
- We usually know near nothing about the transmitter's and receiver's site – power, noise, drift etc.
- We know near nothing about the channel (propagation) at the refracting points. This makes it difficult to separate different effects from each other, of which aircraft scatter is just a minor one, with multipath fading being the absolutely prevailing one.
- The statistical population/resolution of the data one gets from the WSPR logs is too small (due to the 110 seconds) to apply robust statistical methods to cope for a dynamic environment.
- The simulation capabilities of PropLab are not sufficient for such long-range statements due to, for the given case, poor temporal and spatial resolution of the usable ionospheric data. In addition, the simulation with PropLab was, to put it mildly, not optimally implemented – 2D instead of 3D, airy assumptions about the angle of incidence of the signal, and wrong assumption about ground conductivity.

My final conviction is: the detection of aircraft scatter and its assignment to specific flights from WSPR data is far more wishful thinking than reality. Only with considerable prior knowledge and using other data sources as well as possible coincidences these statements can be explained. WSPR in itself is not likely to contribute to this.
There are far more RF signals that are far better suited for this purpose for a variety of reasons. Trump, however, would be digital beacon project, whose waveform is suitable for also *qualitative* studies of the propagation path. Here, a private initiative seems to be active, after amateur radio clubs continue to stick to analogue technology (NCDXF, once meritorious).

Just a quick answer …

… to a question, I have been asked:

Q: "WSPR is sampling SNR for 110 seconds, boiling this down to one value. The resolution of your approach is one second. Does this influence the results?"

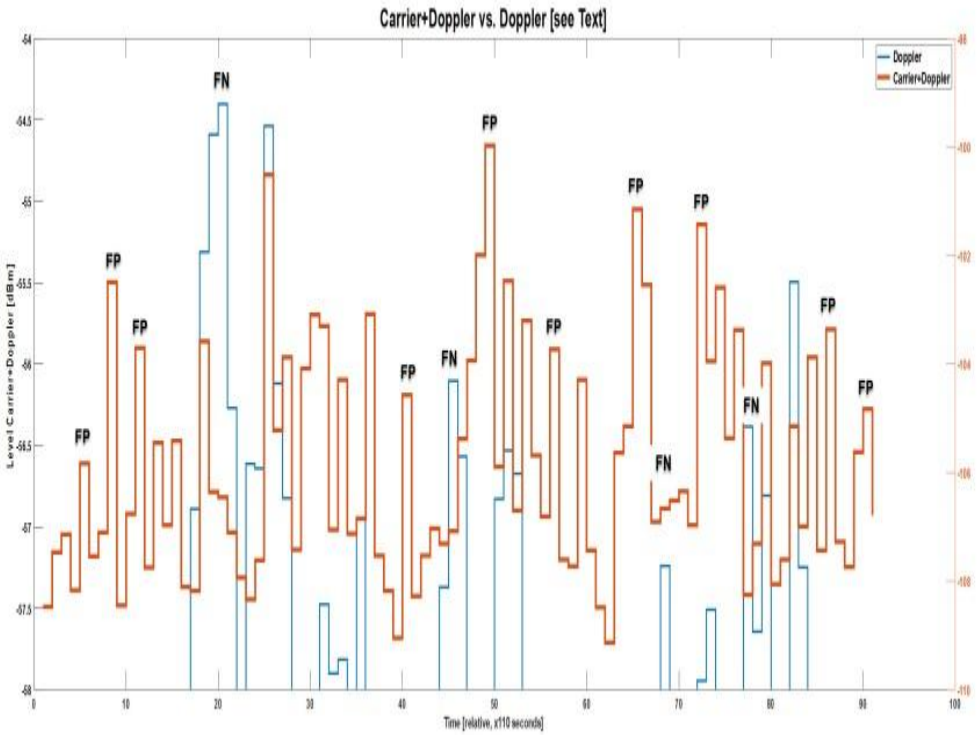
A: "Surely – higher resolution = more details, better insights!"

Q: "Can you show me?"

A: "I warn curious, but that you are, gladly!"

The screenshot below offers an answer to the question: "What does the WSPR log see, which only notes the sum voltage and also this only as an average value (?) – and also this not every

second, but in intervals of 110.6 seconds?" Because with WSPR one has only this one sum value. For this purpose, exactly this situation was simulated with the originally good 10,000 data values collected every second and these were divided into groups of 110 seconds each, whose mean value was formed. This then corresponds to the SNR value in the WSPR logs.I boiled down my data of "Carrier+Doppler" and "Doppler" to 91 groups of 110 seconds each, and then I calculated the mean values of each group. In my view that should match the SNR values of WSPR ("Carrier+Doppler").



Sum level and Doppler level. Allegedly, one should be able to conclude from "unusual" sum levels to aircraft Doppler. Which without prior knowledge leads predominantly to false-positive (FP) and false-negative (FN) results, of which only some are entered here. Rolling the dice gives a better result.

I then calculated the 95% confidence interval from these largely normally distributed mean values and restricted the plot in the above screenshot to those values that lie above the upper limit of this confidence interval of 58.02 dBm. These are "unusual" values in my eyes, although this is only a reasonable guess, because the authors do not specify further what they mean by "unusual". The course of the values "Carrier+Doppler" is scaled on the left Y-axis, from -58 dBm to -54 dBm.
According to theory, a Doppler signal should now be lurking behind each of these values above -58 dBm, at least in the "unusual" peaks. Is this true? To check this, I plotted the corresponding processed Doppler levels in the same diagram, scaling on the right Y-axis, -110 dBm to -98 dBm.
Already a first look shows that the connection of both curves is rather random. With FP like "false positive" I marked for clarification at least some of those positions, where due to the "unusual" sum signal an aircraft Doppler would have been expected – but was not present. With FN are marked, vice versa, some of the positions, where there was a Doppler signal, but

no “unusual” course of the sum level indicated it. A clear assignment “unusual sum signal -> aircraft Doppler” is therefore unlikely.

Comments welcome: dk8ok at gmx.net

P.S.

Oh, yeah, we had some comment! Richard Godfrey rebuked my technical-scientific based criticism on his website (“Serving the MH370 Global community”), which explicitly invites discussion, with the following “arguments”:

“You are not welcome on this blog!You were thrown out of the German Radio Amateur Club (DARC) in 1992. Despite 3 appeals at regional and national level as well as in court, you are still excluded from membership 29 years later. There are very good reasons for this. …I have complained to Christian Entsfellner DL3MBG, the current Chairman of DARC, about your demands to protest against my work and that of Dr. Robert Westphal (DJ4FF) officially on the DARC website regarding MH370 and WSPRnet.Your paper is plain wrong and your arguments are misplaced.I suggest you go elsewhere as I am sure there are other MH370 websites who will welcome the likes of you. Und Tschüss!”

” Ambition should be made from sterner stuff.” [Shakespeare, Julius Caesar, Act III]

I like to recommend a website where you find much ado about sterner stuff concerning MH370 and WSPR:
MH370 and Other Investigations – Following the Data Towards Discovery.

Follows is some comments from some Radio Ham operators.

Pinned by Ham Radio DX

N0SSC

7 months ago

Thanks for the analysis! I really didn’t think it was true either. Radio waves aren’t laser beams; they’re influenced by constantly changing variables that the author just kinda shrugged off. For example, ionospheric electron density is highly variable even on calm days and during night. (source: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JA024025). Also, using RSSI expectations vs. a ray traced model of propagation (which is how I think his software is working) not only leaves out variability but also the fact that not every WSPR station puts out the exact amount of power they report - antenna pattern, cable loss, or just putting it in wrong. That only scratches the surface….don’t get me started about proving the null hypothesis!

jed Beer

7 months ago

Great video presenting a balanced opinion and taking into account that the claims in the article are possible but not probable. I spent 9 years working in air defence radar and I've been a ham for 6 months, the original news article caught my interest but seemed like a heck of a reach. This "engineer" obviously needs funding, if he believed his pub theory then he would have chosen a regular flight and looked at the data over more than one point in time.

J

John Moore

7 months ago

Nice presentation Hayden. I think it's fair to say that 99% of the ham radio fraternity would see view this theory as BS on steroids and when you read their aggressive responses on their blog to anyone that questions their claims you start to wonder about their motivations.The other thing that catches your attention is the repeated reference to a series of links to scientific studies that supposedly support their theory, which they use to hide behind to avoid answering valid questions of doubt.

Tony O'Donnell

7 months ago

Well said Hayden. I originally saw the Hackaday article and was surprised they published it. I dismissed it then as rubbish and was gobsmacked to see it appear more recently on the ABC's website. Thanks for your efforts to debunk it. 73, Tony VK2QW.

Antoine Roquentin

7 months ago

I have experience with aircraft scatter on the 12, 10 and 6m bands and agree with your analysis. Also noteworthy, WSPR does not report signal strength, only SNR, which brings additional factors into the dB value reported by the decoder. Single dB values can have a big uncertainty.

THE REAL RFI-EMI-GUY

1 month ago

I am not totally convinced it is impossible. If in fact receiver data exists from that fateful day, it should be possible to test the theory on known aircraft flight plans from that very period and part of the world. That would be a convincing test. The Inmarsat data was a red herring and distraction from the search. Too much emphasis was placed on the doppler shift of the Inmarsat pings. The extreme doppler shift that was reported to be aircraft deviating direction, could have easily been oscillator frequency drift corresponding with depressurization of the fuselage or even fire on board.

T

Tristan

6 months ago

Great video on the subject and some excellent points. I agree completely, over such a long path, with so many variables how could you ever know if you were tracking an aircraft let alone identify which one. Thanks for the video.

Philip Gardner

6 months ago

Could not have agreed with you more. Without a ham radio on the aircraft transmitting the data all we have is a theory looking for the data rather than data looking for a theory.

Joe Blow

7 months ago

Lets say it was possible to track aircraft via WSPR. How would we know that the aircraft tracked on March 8th 2014 was actually MH370? And another thing, how come no one mentioned using WSPR 7 years ago? Why now? .....Nice analysis, thanks

ALL ABOUT DX

7 months ago

Great analysis Hayden, can't agree more. Enjoyed this video a lot since I'm actually an Avionics Engineer. 73 de Kevin

Stu M0TTQ

7 days ago

I see this story has come back round again and it is disappointing to see major news organisations quote Mr Godfrey as an "expert" when he is clearly not an expert on HF radio propagation. The questions you put about repeating this methodology on other planes are fair ones, and of course Godfrey & co will not do this - because it would expose them as charlatans.

Shnaz Shin

6 days ago
He claims he has done this for 4 recent "invisible" flights (transponder turned off). Some Qantas flights and Australian Air Force flights. Is he lying?
REPLY

Stu M0TTQ

6 days ago
@Shnaz Shin I think he should publish things which can be properly peer-reviewed. His latest claims are unverifiable. Based on what we already know about WSPR and HF radio propagation, I already know he is making stuff up, but neutral observers deserve proper information from Mr Godfrey & co

Erik Geerts

6 months ago
Thanks for your balanced opinion. Great analysis Hayden, can't agree more. 73' PD0RDG Amsterdam The Netherlands

FEPLabs Radio

7 months ago
Good video! You very nicely did not say that guy is crazy as a loon.

Submarine Radioman WA3MCK

7 months ago
WA3MCK - well done Hayden... I think someone is looking for grant money...

rttakezo2000

7 months ago
I don't see any references to peer reviews of this "research". I sincerely hope money wasn't provided for this paper.
4
REPLY
Hide reply

Michael L Jenner

7 months ago
Well done Hayden! You explained that so well. Some people still believe the earth is flat too!! VK7FB

Sammy Lee

3 weeks ago

Agreed. Another red herring. WHY???????

Pattaya Places

7 months ago

Yes, the article was complete BS. Same conclusion as you mate. hs0zjx

Jay Dee

5 days ago

Another crackpot theory..