

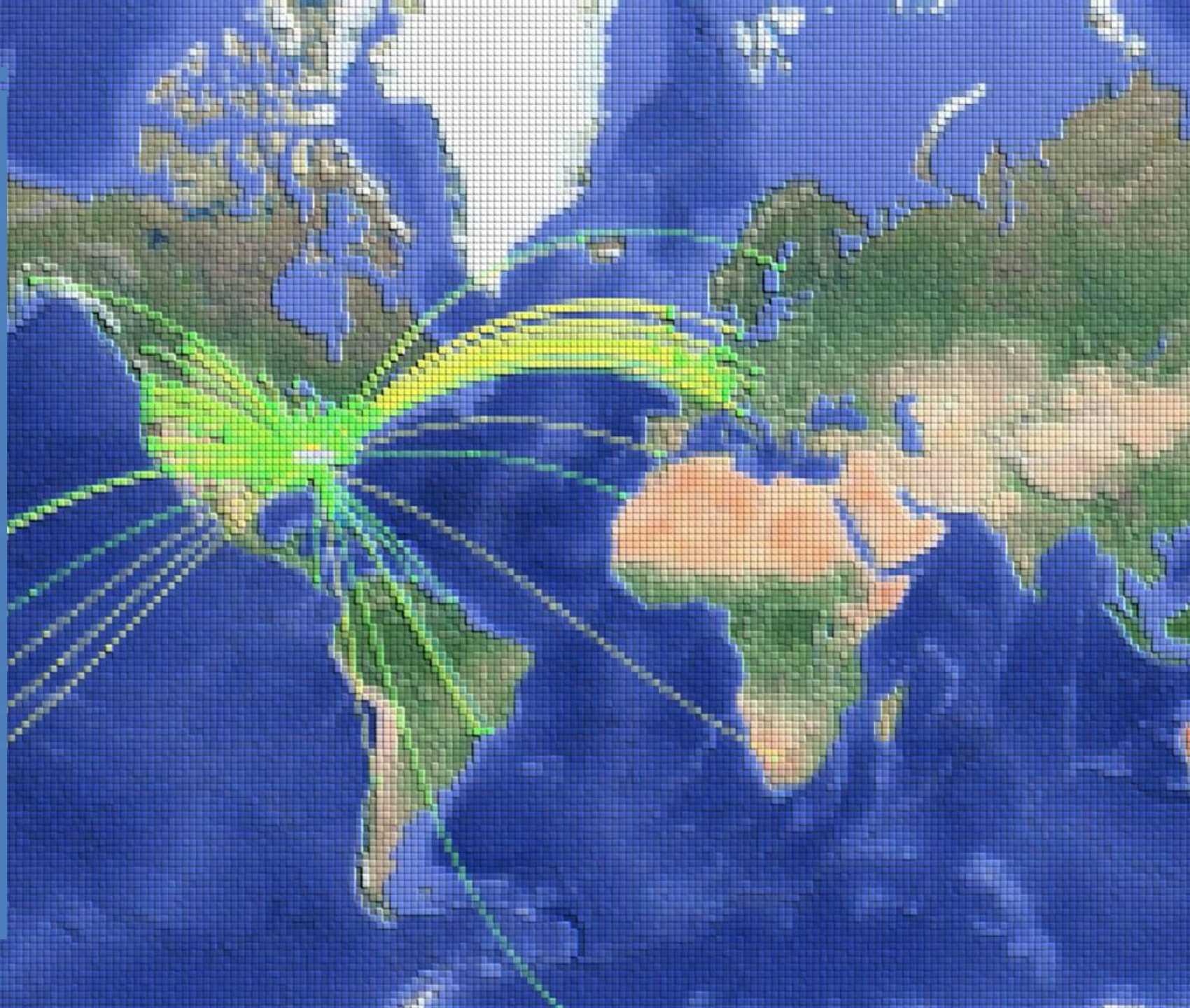
WSPR

*WEAK SIGNAL
PROPAGATION REPORTING*

CHEROKEE AMATEUR RADIO SOCIETY

2021-09-11 TRAINING

PRESENTED BY
TIM WALL – JK4RDF
MARTIN BUEHRING – KB4MG



TOPICS



THEORY



PRATICE



USE CASES

WSPR THEORY

BEHIND THE SCENES & IN THE WEEDS



WHAT IS WSPR



- **Wweak Signal Propagation Reporter - WSPR**
- Designed for probing potential radio propagation paths
- Low-power beacon-like transmissions
- Standard transmissions carry
 - Callsign
 - Maidenhead grid
 - Power in dB relative to mW
 - Example - KJ4RDF EM74 27
- Receiving stations report signals to [WSPRnet.org](https://www.wsprnet.org) and used by other websites and tools
- WJST-X and WSPR 2.0 can decode at -28 dB on a VWSJT scale (2500 Hz reference bandwidth)

COMPARISON TO OTHER DIGITAL MODES

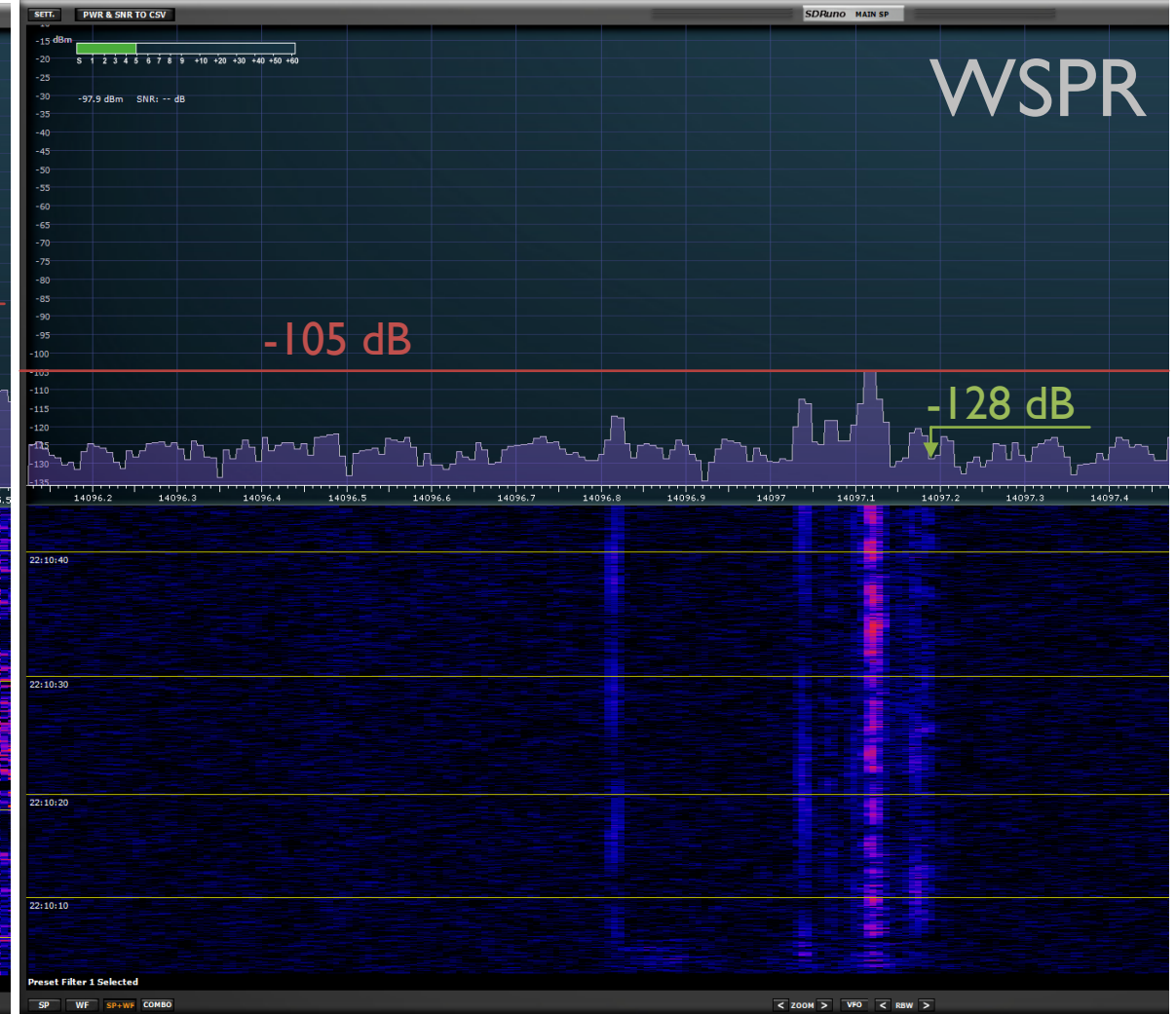
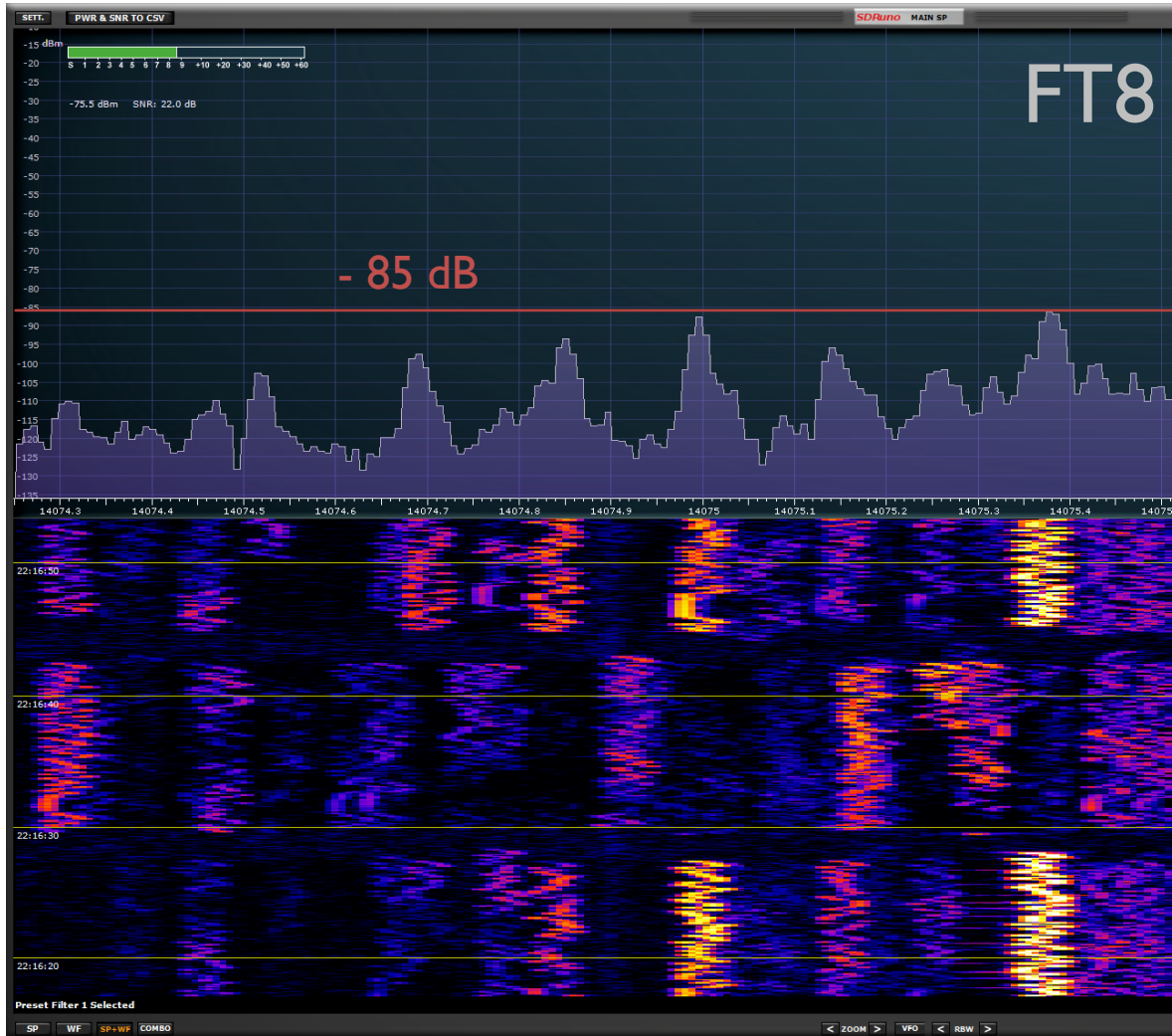
- Emission protocol is FID – frequency-shift keying
- WSPR is considered a slow mode – maybe the slowest of all structured modes (Keying Rate = 1.465)
- WSPR uses the most extensive error correction (n=162 K=50 yields 30.86% message and 69.14% error correction)
- Has smallest bandwidth of structured slow modes (Bandwidth = 5.9 Hz)

Table 15.7
Parameters of Structured Modes

A — Structured Slow Modes

<i>Mode</i>	<i>FEC Type</i>	<i>(n, k)</i>	<i>Q</i>	<i>Modulation Type</i>	<i>Keying Rate</i>	<i>Bandwidth (Hz)</i>	<i>Sync Energy</i>	<i>Transmit Duration (s)</i>	<i>S/N Threshold (dB)</i>
FT4	LDPC	(174,91)	4	4-GFSK	20.833	83.3	0.16	5.04	−17.5
FT8	LDPC	(174,91)	8	8-GFSK	6.25	50.0	0.27	12.6	−20.8
JT4	Convolutional	(206,72)	2	4-FSK	4.375	17.5	0.50	47.1	−23
JT9	Convolutional	(206,72)	8	9-FSK	1.736	15.6	0.19	49.0	−27
JT65	Reed-Solomon	(63,12)	64	65-FSK	2.692	177.6	0.50	46.8	−25
QRA64	Q-ary Repeat Accumulate	(63,12)	64	64-FSK	1.736	111.1	0.25	48.4	−26
WSPR	Convolutional	(162,50)	2	4-FSK	1.465	5.9	0.50	110.6	−31

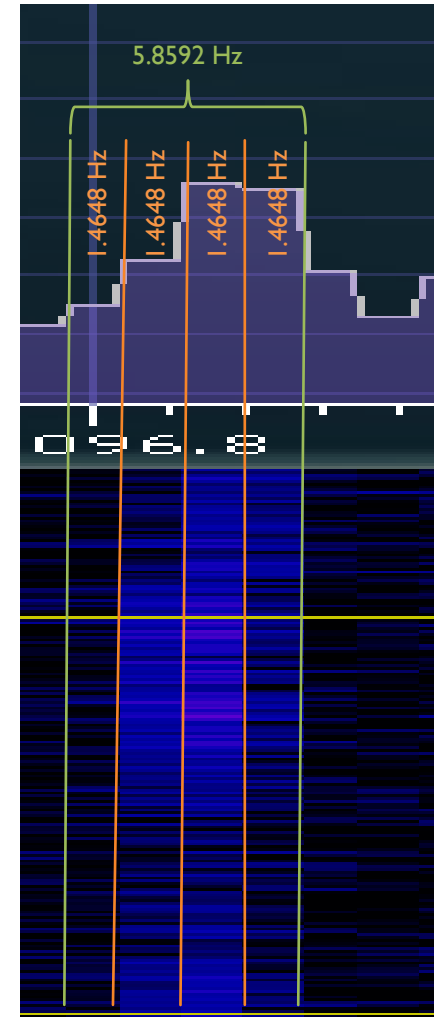
FT8 VS. WSPR SIGNAL USING SDRuno





WSPR NARROW BAND 4-FSK ENCODING

- Message is 162 symbols sent in 110.6 seconds starting on the even minute + 1 second
- Standard message components and size after compression is 50 bits
 - 28 bits Callsign
 - 15 bits Grid
 - 7 bits Power
- Forward Error Correction – FEC
 - Non-recursive convolutional code constraint length $K = 32$, rate $1/2$
- Message 50 bits + FEC 112 = 162
- Data symbols + Sync symbols = Channel symbols (next slide for details)
- Bandwidth – Tone separation: $1.4648 \text{ Hz} \times 4 \text{ Channels} = 5.8592 \text{ Hz}$ (~6 Hz)
- Transmitted at 1.465 baud (keying rate)



CODING EXAMPLE



Message

Message: KJ4RDF EM74 27

Source-encoded message (50 bits, hex): 8A CE 52 5B A9 96 C0

Data symbols:

```
1 1 0 0 0 1 1 1 1 1 0 1 1 1 0 0 1 0 1 0 0 1 1 0 1 0 1 1 0 0 1 0 1 0 1 1 0 0 1 0 1 0 0 1 0 1 1 1 1 0 0 0 0 1 0
0 0 1 1 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 1 0 0 0 1 0 1 0 1 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 1 1 1 1 0 1 0 0 0 0 1 1 0 0 0 1
0 1 0 0 1 0 1 1 1 1 0 0 0 1 0 1 0 0 0 1 1 0 0 0 0 0 0 1 1 0 1 0 0 0 0 0 0 1 0 0 0 1
```

Sync symbols:

```
1 1 0 0 0 0 0 0 1 0 0 0 1 1 1 0 0 0 1 0 0 1 0 1 1 1 1 0 0 0 0 0 0 1 0 0 1 0 1 0 0 0 0 0 0 1 0 1 1 0 0 1 1 0 1 0 0 0 1
1 0 1 0 0 0 0 1 1 0 1 0 1 0 1 0 1 0 0 1 0 0 1 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 1 0 0 0 0 0 1 0 0 1 0 0 1 1 1 0 1 1 0 0 1 1
0 1 0 0 0 1 1 1 0 0 0 0 0 1 0 1 0 0 1 1 0 0 0 0 0 0 0 1 1 0 1 0 1 1 0 0 0 1 1 0 0 0
```

Channel symbols:

```
3 3 2 0 0 0 2 2 3 2 2 2 1 3 3 2 0 0 3 0 2 1 0 3 3 1 3 0 2 2 0 0 2 0 3 0 2 3 2 1 0 2 0 2 0 0 3 0 3 1 2 2 3 3 0 1 0 0 2 1
1 0 3 2 0 0 0 1 1 0 1 0 3 2 3 2 1 0 0 3 0 0 1 2 1 3 0 2 0 1 1 0 1 0 1 0 2 2 3 2 2 0 0 2 3 2 2 1 2 0 1 1 1 2 3 3 0 0 1 3
0 3 0 0 2 1 3 3 2 2 0 0 0 3 0 3 0 0 1 3 2 0 0 0 0 0 0 3 3 0 3 0 1 1 0 0 0 3 1 0 0 2
```

Decoded message: KJ4RDF EM74 27 ntype: 27

Coded Using: <http://physics.Princeton.edu/pulsar/K1JT/WSPRcode.exe>

Logic

- Original message: “KJ4RDF EM74 27”
- Compressed and converted to hexadecimal (0 – F)
- FEC added and converted to binary (0 - 1)
- Sync symbols known on both sides, TX/RX
- Data and sync symbols generate channel symbols

Binary	Decimal
0 (00)	0
1 (01)	1
10	2
11	3

- Sent/received using 4-FSK modulation, frequency channels 0 - 3
- Process reversed on receive to decode to original message

WSPR IN PRACTICE

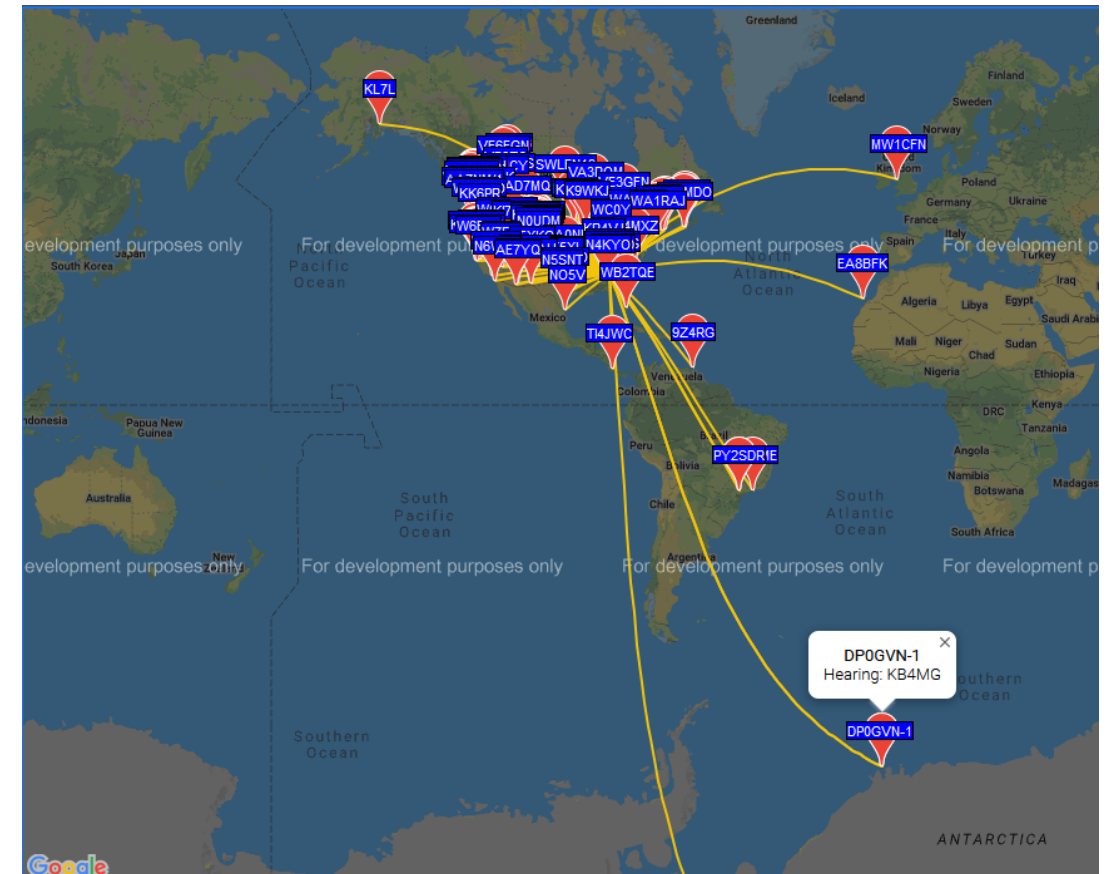
SETTING UP TO RUN WSPR MODE



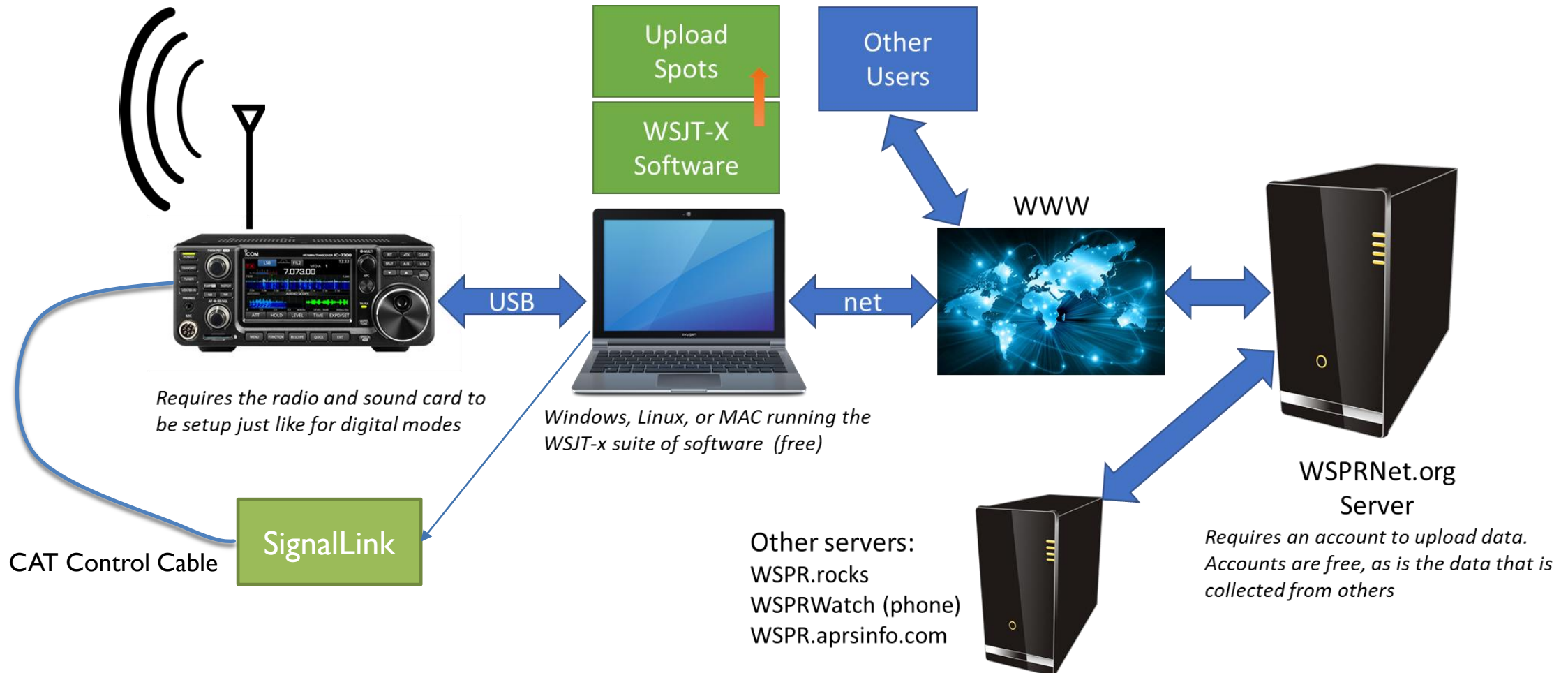
SETTING UP WSPR



- Use your radio and WSJT-x suite of software for the WSPR app
- Stand-alone solutions like SOTA BEAMS (<https://www.sotabeams.co.uk/wsprlite-antenna-tester/>)
- Kit building or Home brewing a WSPR device



USING WSPR WITH YOUR HF RADIO



WSPR SETUP USING WSJT-X

The screenshot shows the 'Settings' window of WSJT-X, specifically the 'Radio' tab. The 'Rig' is set to 'Icom IC-705' and the 'Poll Interval' is '1 s'. The 'CAT Control' section has 'Serial Port' set to 'COM5'. Under 'Serial Port Parameters', 'Baud Rate' is '9600'. 'Data Bits' are set to 'Eight', 'Stop Bits' to 'One', and 'Handshake' to 'None'. 'Force Control Lines' has 'DTR' and 'RTS' set to their default values. The 'PTT Method' section has 'CAT' selected with 'Port' set to 'COM5'. 'Transmit Audio Source' is set to 'Front/Mic'. 'Mode' is set to 'Data/Pkt'. 'Split Operation' is set to 'Fake It'. There are 'Test CAT' and 'Test PTT' buttons. At the bottom are 'OK' and 'Cancel' buttons.

Must be configured for CAT control for your particular rig

YouTube or online help can be your friend here for many types of rigs.

The Audio tab should be set to use your appropriate audio channel from your PC. For USB, this is called the USB Audio CODEC

ENABLE REPORTING



Settings

General Radio Audio Tx Macros Reporting Frequencies Colors Advanced

Logging

☒ Prompt me to log QSO Op Call:

☐ Log automatically (contesting only)

☐ Convert mode to RTTY

☐ dB reports to comments

☒ Clear DX call and grid after logging

Network Services

☒ Enable PSK Reporter Spotting ☐ Use TCP/IP connection

UDP Server

UDP Server: ☒ Accept UDP requests

UDP Server port number: ☒ Notify on accepted UDP request

☒ Accepted UDP request restores window

Secondary UDP Server (deprecated)

☐ Enable logged contact ADIF broadcast

Server name or IP address:

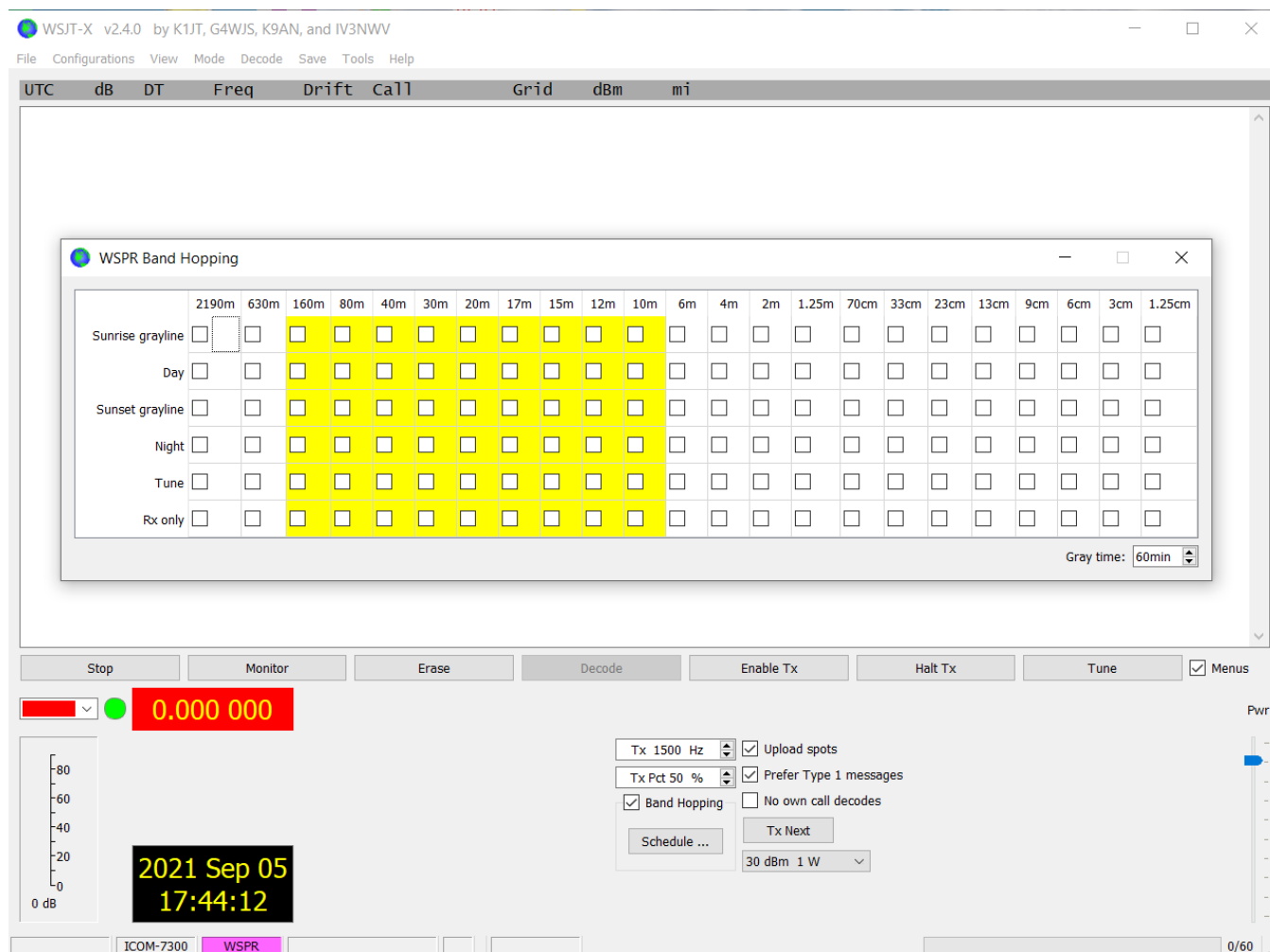
Server port number:

OK Cancel

Be a part of the WSPR Community and enable the reporting function.

Reports will be sent by Internet to the WSPRNet Server so people can see what you are receiving at your location.

ANTENNA AND PROPAGATION TESTING



If your use case is for testing your antenna or checking propagation, the Band Hopping feature may be of interest.

Really great if you have a multi-band antenna

Can be used to check propagation across multiple bands.

Notice there is an RX only option as well time of day and TUNE option for antennas needing tuning for each band.

RUNNING WSPR ON YOUR COMPUTER - WSJT-X IN WSPR MODE



Time stamp

dB level

Frequency

Callsign

Grid

Base
Frequency

Distance in
Miles

Enable TX

Time slot
Progress Bar

WSJT-X v2.4.0 by K1JT, G4WJS, K9AN, and IV3NWW

File Configurations View Mode Decode Save Tools Help

UTC	dB	DT	Freq	Drift	Call	Grid	dBm	mi
Transmitting WSPR								
2134								20m
2152	-32	0.5	14.097063	-2	K5PK	EM10	33	752
2152	-14	0.2	14.097105	0	AB3XL	FM19	37	560
20m								
2154	-25	0.2	14.097071	0	KE7A	EM12	37	706
2154	-27	0.4	14.097078	0	W1STR	FN42	33	936
2154	-18	0.2	14.097099	0	N2HQT	FN13	37	755
2154	-16	0.0	14.097121	0	K7WXB	DN40	37	1481

Stop Monitor Erase Decode Enable Tx Halt Tx Tune ☒ Menus

20m **14.095 600**

2021 Aug 25 21:56:18

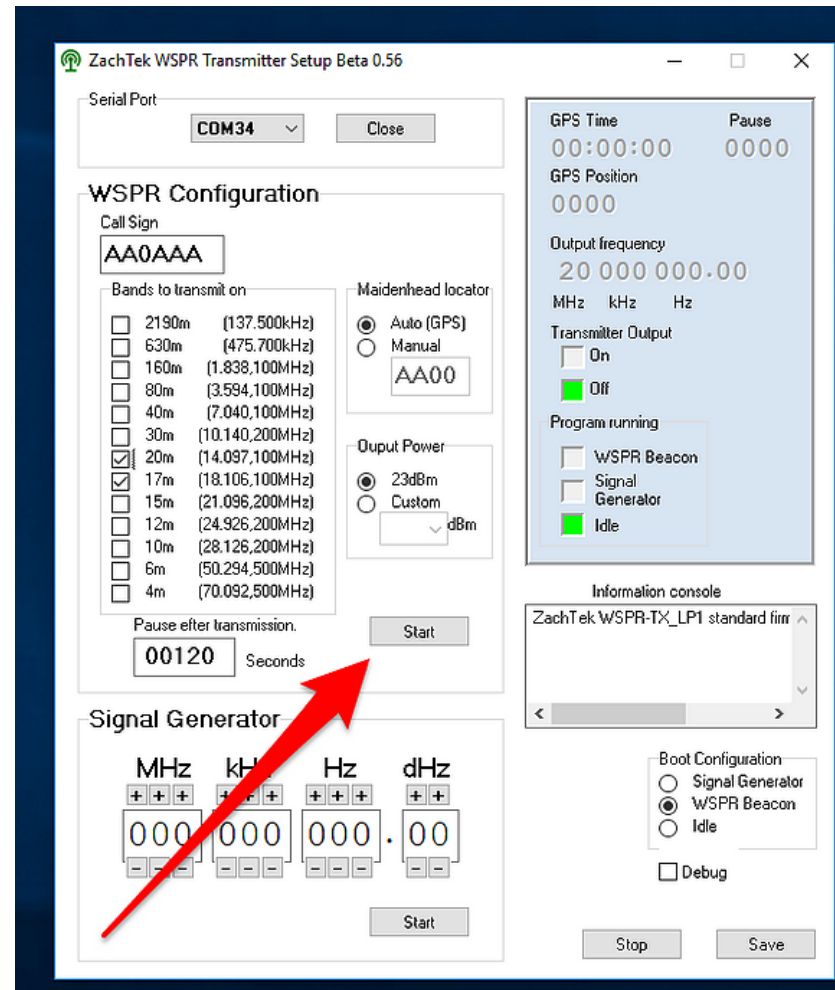
Receiving ICOM-7300 WSPR Last Tx: KB4MG EM74 30

18/120

Tx 1500 Hz ☒ Upload spots
Tx Pct 50 % ☒ Prefer Type 1 messages
☐ Band Hopping ☐ No own call decodes
Schedule ... Tx Next
30 dBm 1 W

Pwr

STAND-ALONE PRODUCTS FOR WSPR

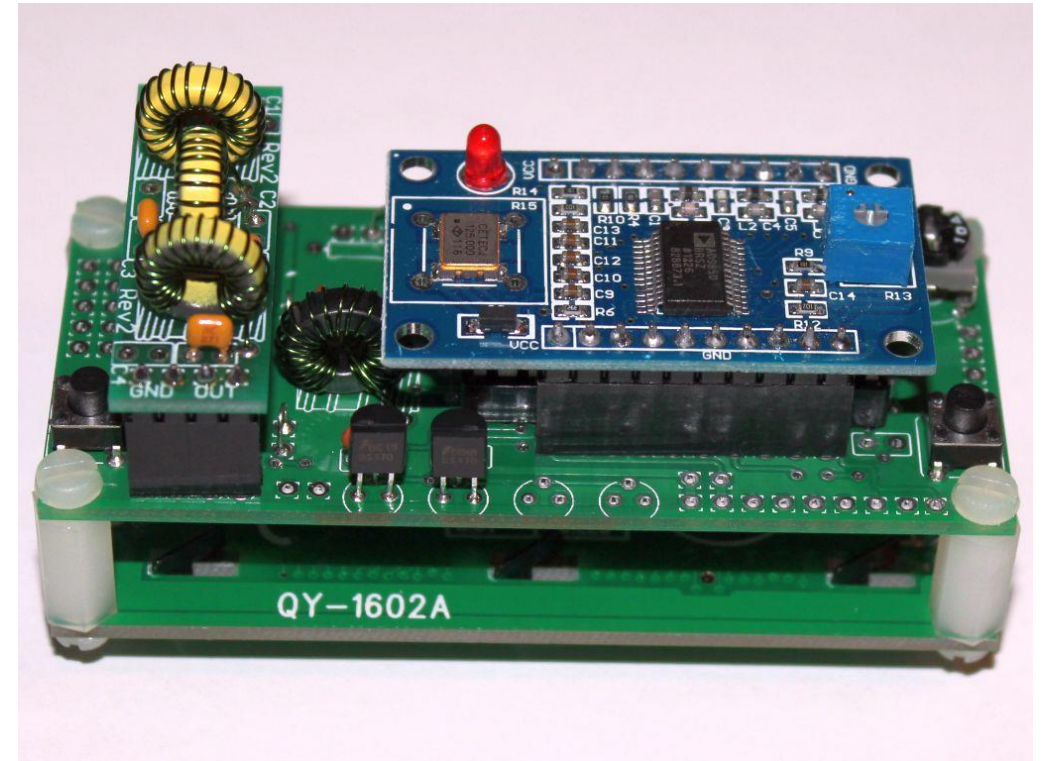


- Most are transmit-only devices
- Require a PC for setup of your call sign, grid square, band(s), and operation times.
- Assume a “tuned” antenna is connected
- Optional GPS for time base
- Turn-key operation, nothing to assemble
- Costs are \$80 to \$140
- Vendors :
 - SOTABEAMS
 - ZACHTEK –also has a receiver
 - QRP-LABS

WSPR DIY



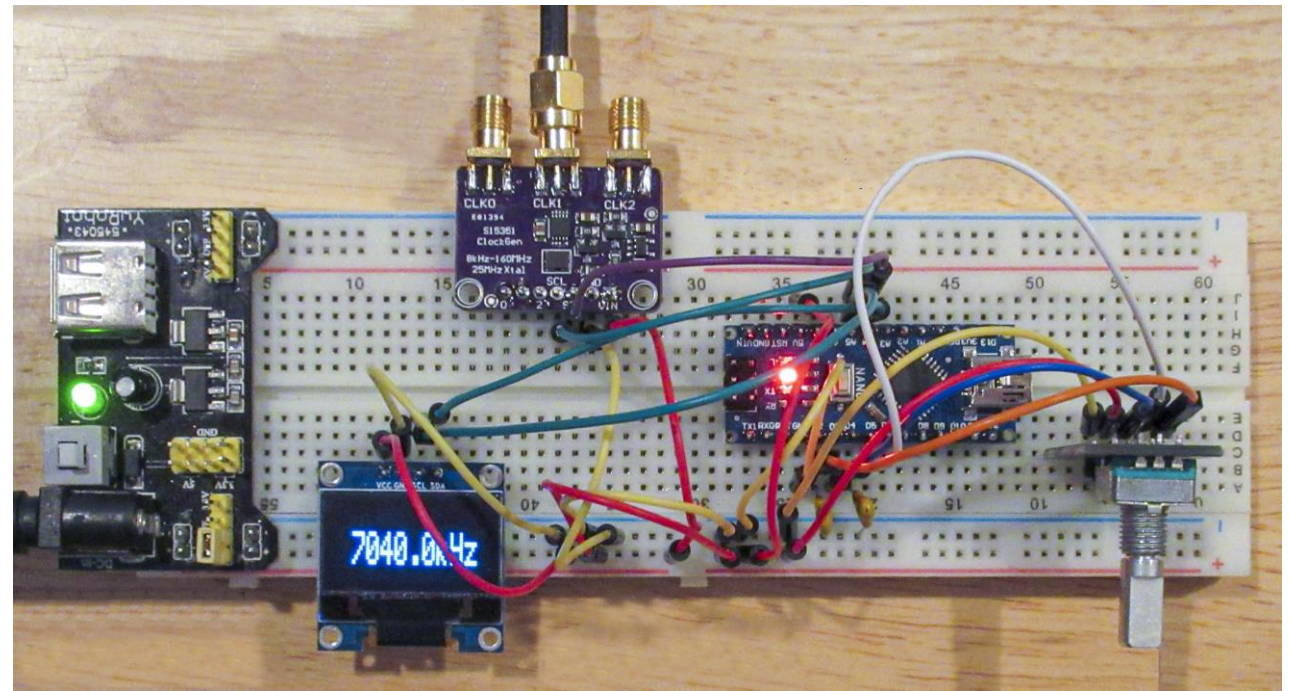
- Kits are a great way to really get closer to the technology and have a sense of accomplishment
- Builds skills in soldering, winding toroids, and troubleshooting any problems
- Kits can be very cost effective. \$30-\$60 ranges
- Allows for some experimentation



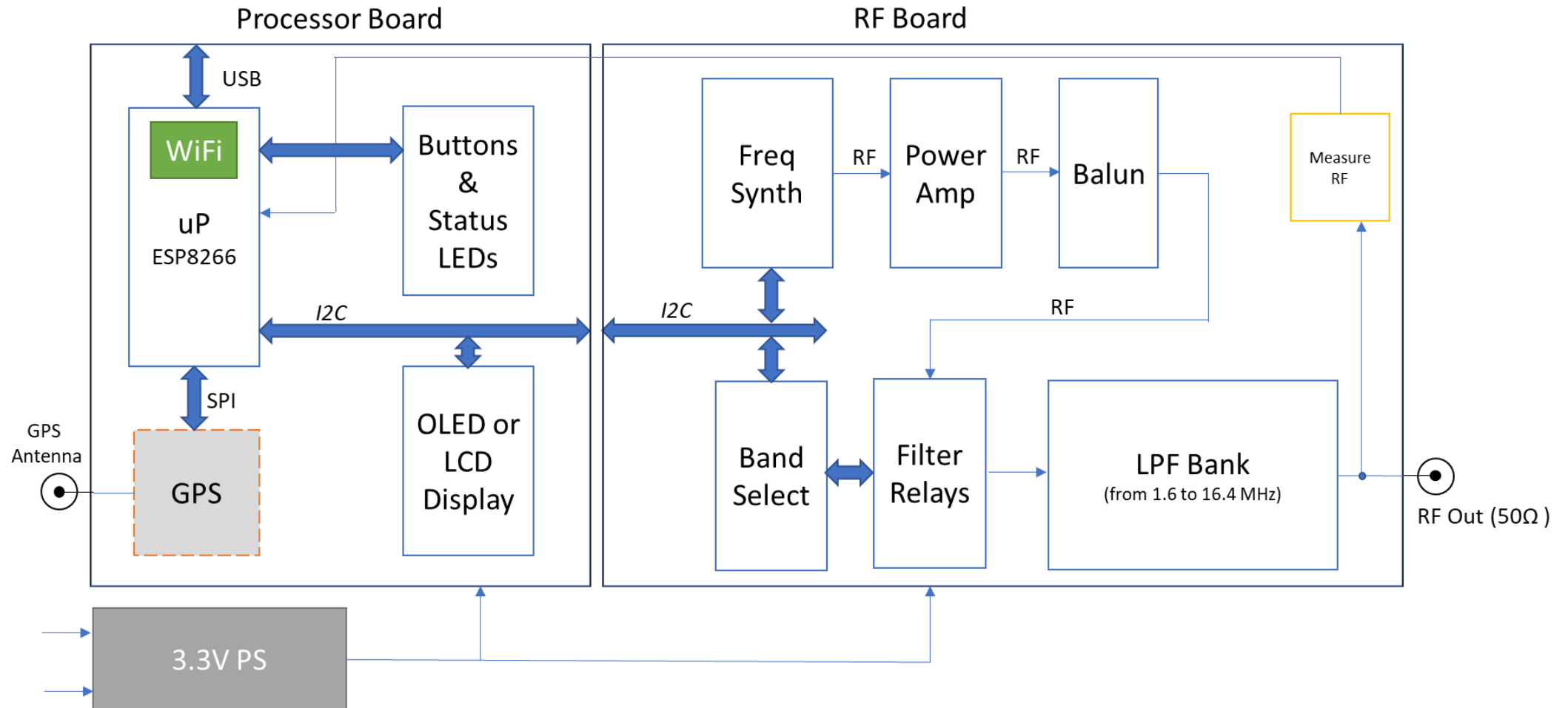
HOMEBREW WSPR



- Homebrewing is possible with inexpensive components and modules.
- Articles in various magazines and books can be the inspiration for your project
- QST has had a few articles on WSPR. December 2020 issue shows the design and Arduino code to build a single band transmitter
- Learn to breadboard a design that you may want to build a permanent version of.



KB4MG HOMEBREW DESIGN – STILL TO BE BUILT



WSPR USE CASES

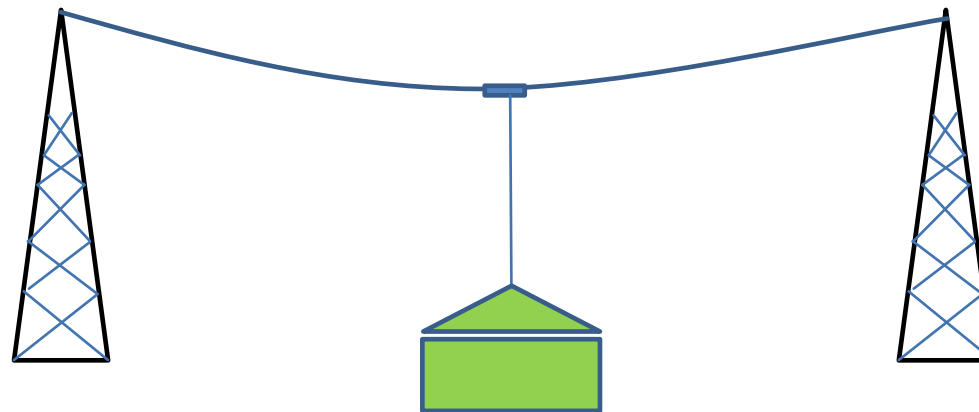
BE THE SUPERHERO OF PROPAGATION



USE CASE: ANTENNA COMPARISONS



versus

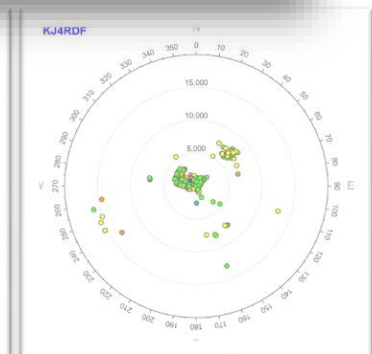
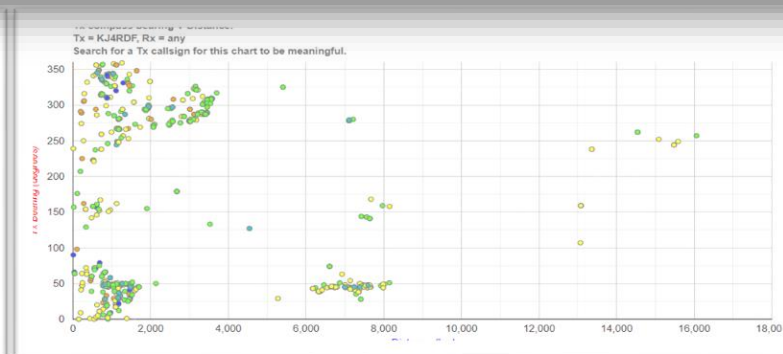
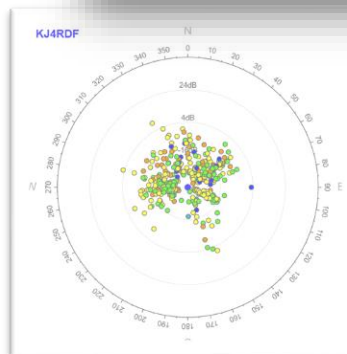
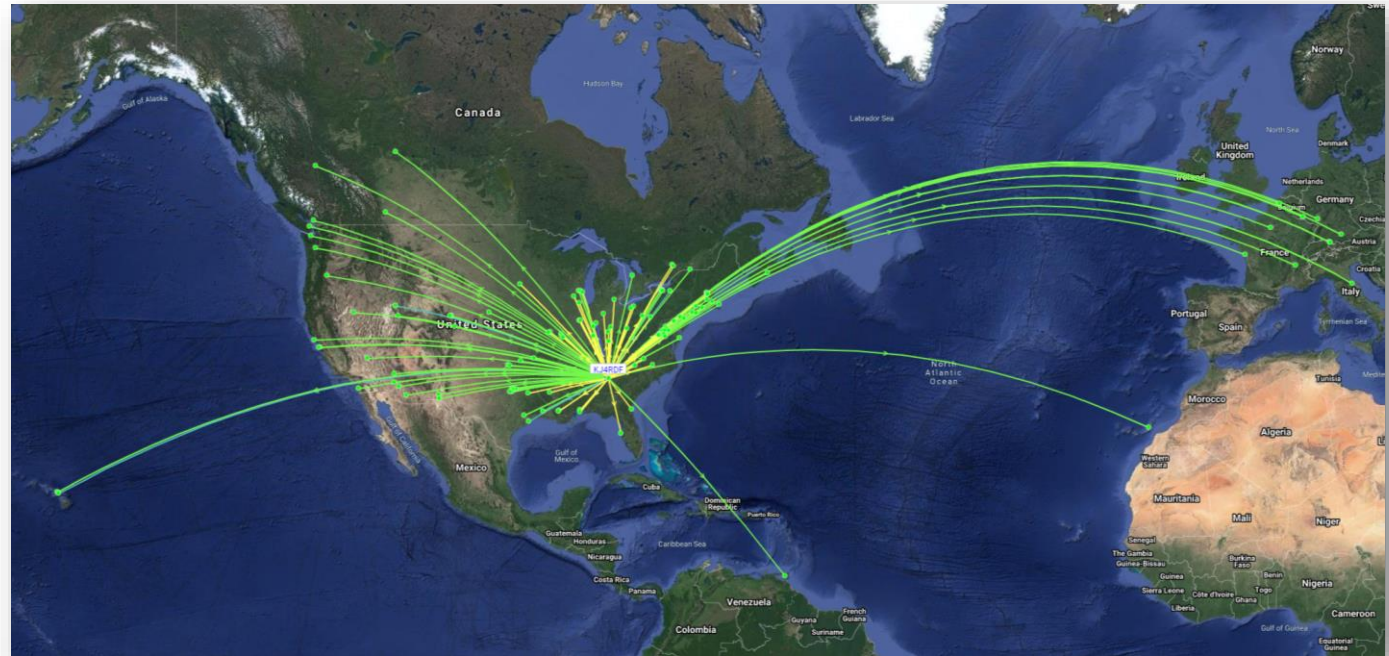


- What if you have two HF antennas to choose from? Which one should you use for the current propagation conditions?
- What is working better for DX?
- What if I lower my dipole for NVIS? What stations can pick me up and where?

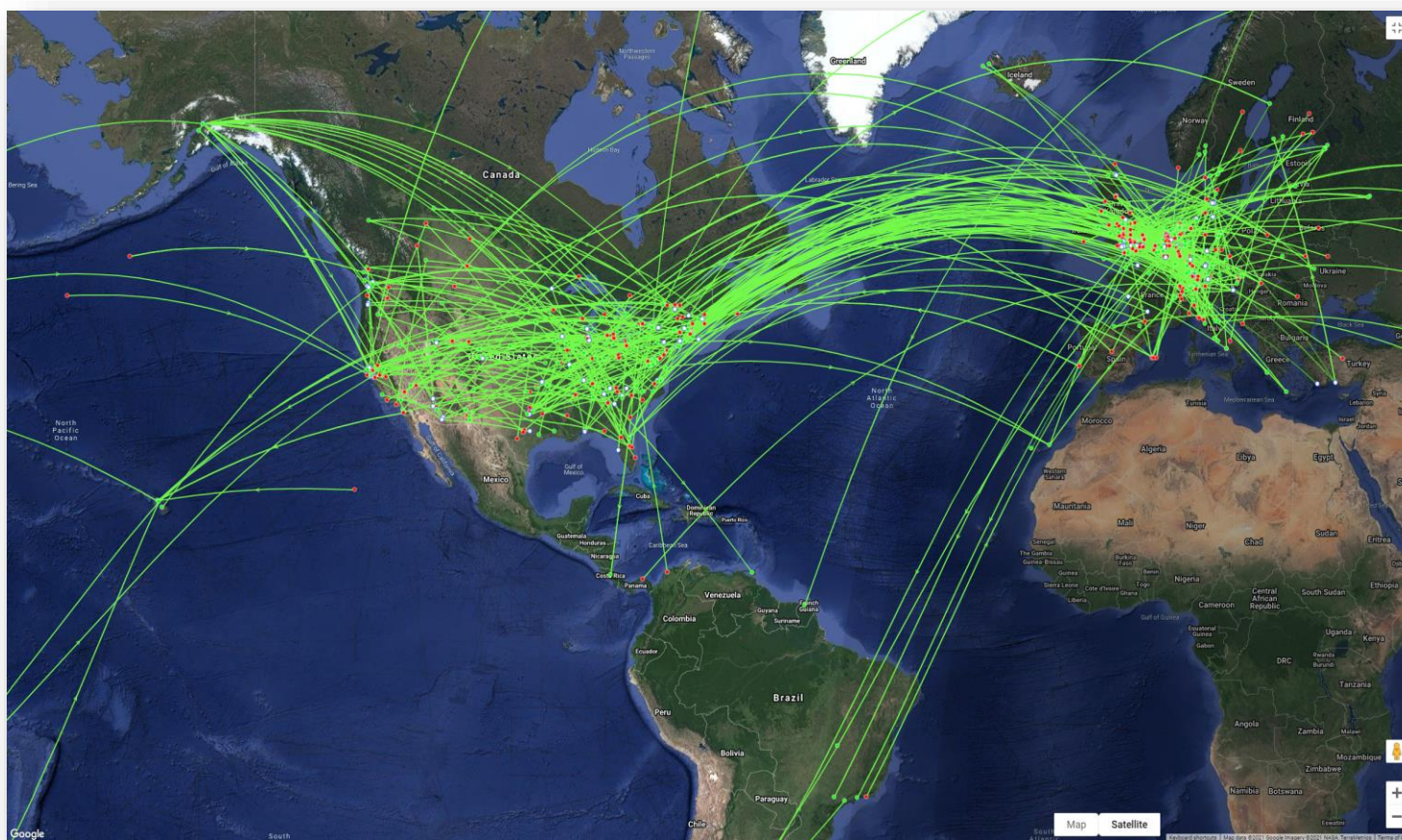
USE CASE: ANTENNA PATTERN STUDY



- WSPR reports provide geographic locations for receiving stations
- Running WSPR for a period of time will show you generally how your antenna system is radiating
- WSPR.Rocks offers a map view that is the easiest to understand
- Also offers advanced charts and graphs to show details on compass and bearing,



USE CASE: QUICK SIGNAL PATH & BAND PREDICTOR



1 hour 20m RX call TX call ☒ unique calls

max spots 5000 auto-search ☐ [Fetch data...](#)

[wtf?](#) [stats](#) [charts](#) [map](#) [table](#) [home](#)

- Using WSPR.Rocks run query on the last hour for all calls sent and received
- Limit it by target band – Ex 20m
- View on map to see where paths are open
- Big evening on 20m into Europe
- Not so good to Asia or South America

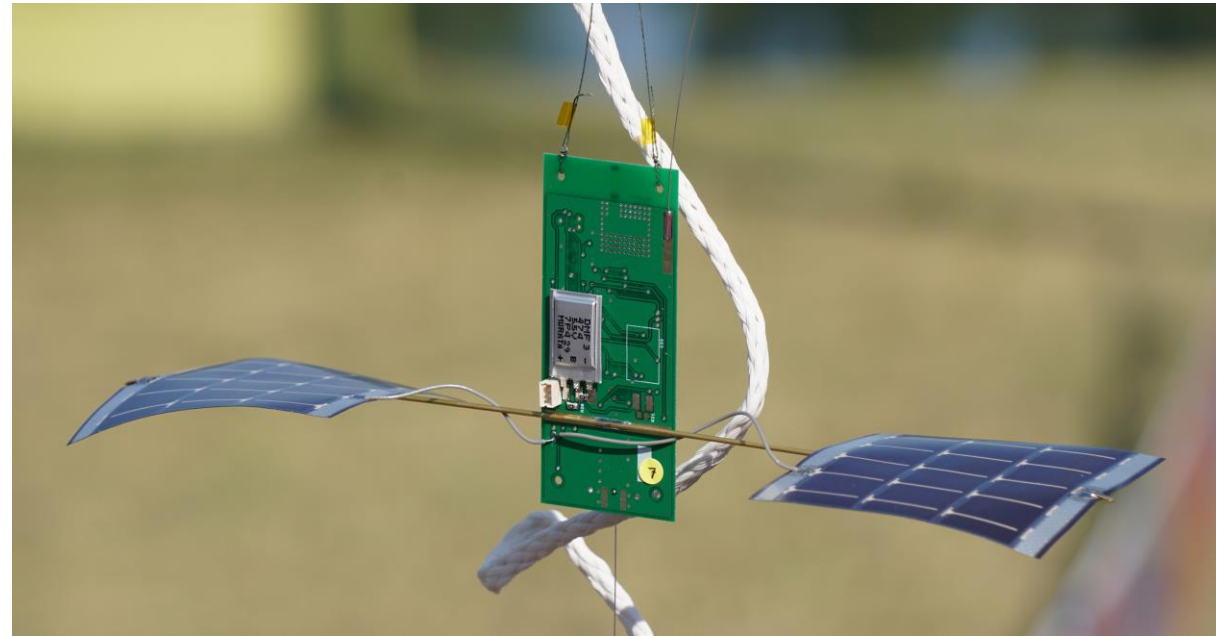
Query run on 2021-08-26 @ 21:00 UTC

AMATEUR RADIO BALLOONS

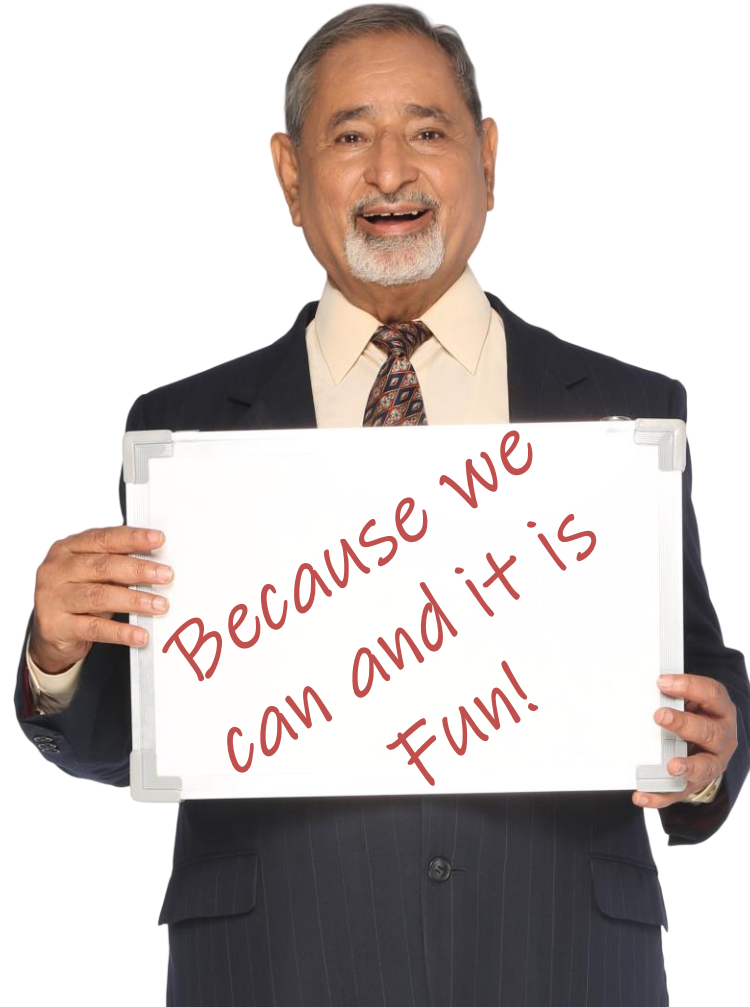
WSPR can be used on high altitude balloon launches

These also generally have APRS as well as WSPR

Recently KM4ZIA – Jack McElroy and his sister Audrey launched a balloon here in Georgia that was tracked by radio amateurs, going around the world 5 times and crashing somewhere near Qiqihar, China.



USE CASE: BECAUSE WE CAN



WSJT-X v2.4.0 by K1JT, G4WJS, K9AN, and IV3NWW

File Configurations View Mode Decode Save Tools Help

UTC	dB	DT	Freq	Drift	Call	Grid	dBm	mi
1916	-27	0.5	14.097146	0	N5MCB	EM13	30	715
1916	-34	0.1	14.097166	0	KC5NK	EM13	37	715
1916	-17	3.2	14.097174	0	VE2DPF	FN35	37	998
1916	-26	0.0	14.097182	1	N1PCE	FN44	30	1020
1916	-22	0.2	14.097191	0	K7CMI	DN57	27	1569

1918	-17	0.2	14.097065	0	<KE7A>	EM12KX	37	730
1918	-23	0.1	14.097070	-1	VE3NM	FN14	37	825
1918	-17	-0.1	14.097093	0	K5RND	EM22	37	612

1920	-17	0.3	14.097055	0	WA2KQD	FN30	37	775
1920	-24	0.5	14.097076	0	NK5G	EM20	23	657
1920	-19	-2.4	14.097099	0	K1YZY	FN41	37	900

Stop Monitor Erase Decode Enable Tx Halt Tx Tune ☒ Menus

20m 14.095 600

80
60
40
20
0
60 dB

2021 Aug 05
19:22:07

Tx 1436 Hz ☒ Upload spots
Tx Pct 20 % ☒ Prefer Type 1 messages
☐ Band Hopping ☐ No own call decodes
Schedule ... Tx Next
27 dBm 500 mW

Receiving WSPR Day 7/120

OPEN DISCUSSION



APPENDIX / REFERENCES

REFERENCES & RESOURCES

- WSPR – General Info
 - Site at Princeton University
<https://physics.princeton.edu/pulsar/k1jt/wspr.html>
 - ARRL Handbook Chapter 15
 - 15.4.3 Slow Modes
 - Table 15.7 Parameters of Structured Modes, A - Structured Slow Modes
- Signal Comparisons using SDRplay and SDRUno
<http://sdrplay.com>
- WSPR Narrow Band Encoding Protocol and Details
https://physics.princeton.edu/pulsar/k1jt/WSPR_2.0_User.pdf
- Error Correction
 - ARRL Handbook Chapter 15, 15.1.2 Error Detection and Correction
 - Tutorials Point: Error Detection and Correction
https://www.tutorialspoint.com/computer_logical_organization/error_codes.htm
 - Convolution Code
 - ARRL Handbook Chapter 15, Page 15.8 – 15.9
 - A Visual Guide To Forward Error Correction Part Two - Convolutional Codes -
<https://john.soban.ski/visual-guide-to-forward-error-correction-part-two.html>
 - Iain Explains Signals, Systems, and Digital Comms on YouTube.Com https://youtu.be/EgYKMDBj_zQ
- FSK Modulation
 - Tutorials Point: Frequency Shift Keying
https://www.tutorialspoint.com/digital_communication/digital_communication_frequency_shift_keying.htm
 - BFSK (2FSK) vs. 4FSK
<https://www.rfwireless-world.com/Terminology/2FSK-modulation-vs-4FSK-modulation.html>
 - Stand Alone WSPR Products
 - SOTA Beams <https://www.sotabeams.co.uk/wsprlite-antenna-tester/>
 - ZACHTEK <https://www.zachtek.com/>
 - QRP-LABS <https://www.qrp-labs.com/>
 - WSPR – Reporting Sites
 - WSPRnet <http://wsprnet.org>
 - Central DB ✓
 - User Forums ✓
 - A bit dated ✗
 - WSPR.Rocks <http://wspr.rocks>
 - Modern and easy to use ✓
 - Nice tools and charts ✓
 - PSK Reporter <http://pskreporter.info>
 - Uses azimuthal projection map ✓✓
 - Limited data on WSPR ✗