RADIO MAGiC
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Telemetry-over-WSPR: Part 2

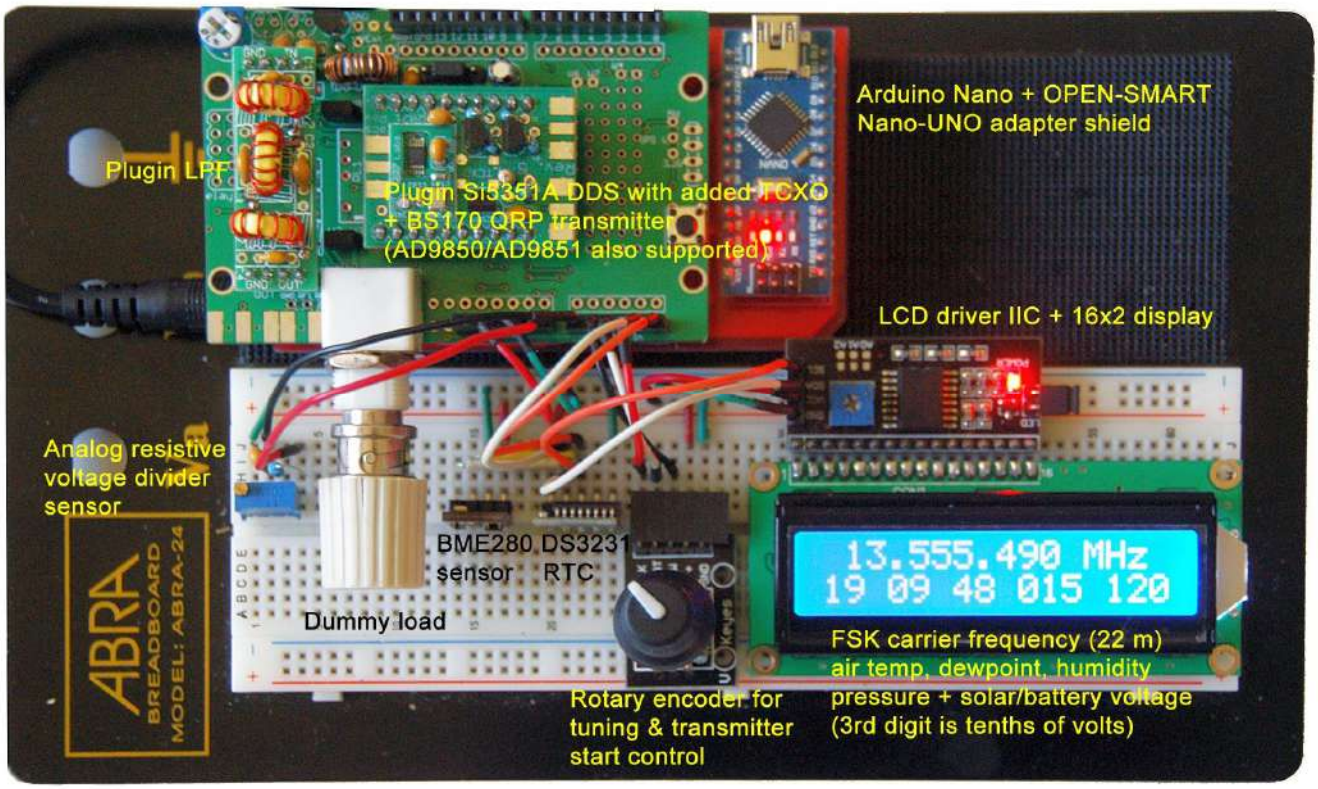
Introduction

I built QRP Labs "Ultimate" Arduino transmitter kit (Figure 1, next page) mentioned in my Part 1 article (*TCA* Sep-Oct 2022) and gave transmitting on the license-free 22 metre (m) industrial, scientific and medical (ISM) band another try to see how well the 4.7 milliwatt (maximum power allowed using a standard dipole antenna) WSPR and WSPR telemetry signals would do given the very small listening audience of radio hobbyists (Amateur and non). Not only were its signals spotted in North America, it was amazing to see how just long the band goes in the late summer evenings until just after my local midnight with regular hops to the Canary Islands plus a couple to Switzerland (and even New Zealand!). And it seems that there are more spotting stations now that the portion known as the "sweet spot" is recognized as a WSPR sub-band.

On 22 m, I use "1X3ROM" ("1" for non-standard WSPR and "X" for experimental). Zero and "Q" are also valid but normally used by pico ballooners. My telemetry-over-WSPR beacon call signs also start with "1" but will have changing alphanumeric characters (telemetry) in the second to sixth call sign positions. According to the operating rules, you don't have to identify 22 m ISM band transmissions, but I do for several reasons including for the Longwave Club of America (LWCA) group who publish a list of known beacons, modes used and the operators call signs/names and locations in the club's bimonthly publication called *The LOWDOWN*, which includes many interesting articles covering the low down world of radio wavelengths from 600 metres and longer.

Figure 1: Telemetry-over-WSPR Transmitter v2.0

QRP Labs "Ultimate" Arduino transmitter shield kit can use either the Si5351A direct digital synthesis (DDS) or AD9850/AD9851 DDS. I added the optional (but highly recommended) temperature compensated crystal oscillator (TCXO). The resulting DDS frequency variance was only six hertz as compared to 50 hertz to the AD9850/AD9851 DDS, which has no TCXO option. You can also use a GPS for this and also provide the time reference but it adds more cost and circuit/coding complexity.



Even with only a handful of spotting stations, enough daily telemetry-over-WSPR spots were being extracted from the WSPRnet to remotely monitor my RV trailer park campground site conditions and also perform some simple statistical analysis on the steadily growing dataset (Figure 2, next page).

Description and Uses

My telemetry-over-WSPR transmitter is connected to two external sensors (one digital, one analog) whose values (air temperature, dew point, humidity, pressure and solar/battery voltages) are encoded in the call sign field and transmitted every 10 minutes (Part 1 refers). I'm mainly concerned about temperature and solar/battery voltages during the hot summer months, but telemetry and regular WSPR propagation beacons are also useful in many other ways.

You can learn a lot about your and other's transmitter and antenna system(s), detect real-time band openings sooner than other modes can, examine past and present ionospheric propagation during space weather events (solar flares, particle storms and eclipses, etc.), explore seasonal sporadic E-skip and other forms of "exotic" propagation or changes in levels of atmospheric background noise. We know the overall signal-to-noise ratio (SNR) for spotted WSPR signals but we don't really know what the separate signal and noise values are—"Estimating LF–HF Band Noise While Acquiring WSPR Spots"; Griffiths, Robinett and Elmore; *QEX* Sep/Oct 2020. WSPR and other data modes are also now being used to study "skyquakes" created by powerful earthquakes because they can cause the ionosphere to oscillate and/or affect total (free) electron content (TEC) and can affect radio wave propagation for hundreds or even thousands of kilometres away from the epicentre. There's a new theory that WSPR could be used to track aircraft in combination with other technologies— "The Search for MH370: WSPR Technical Report", R. Godfrey, 2022. But I digress…

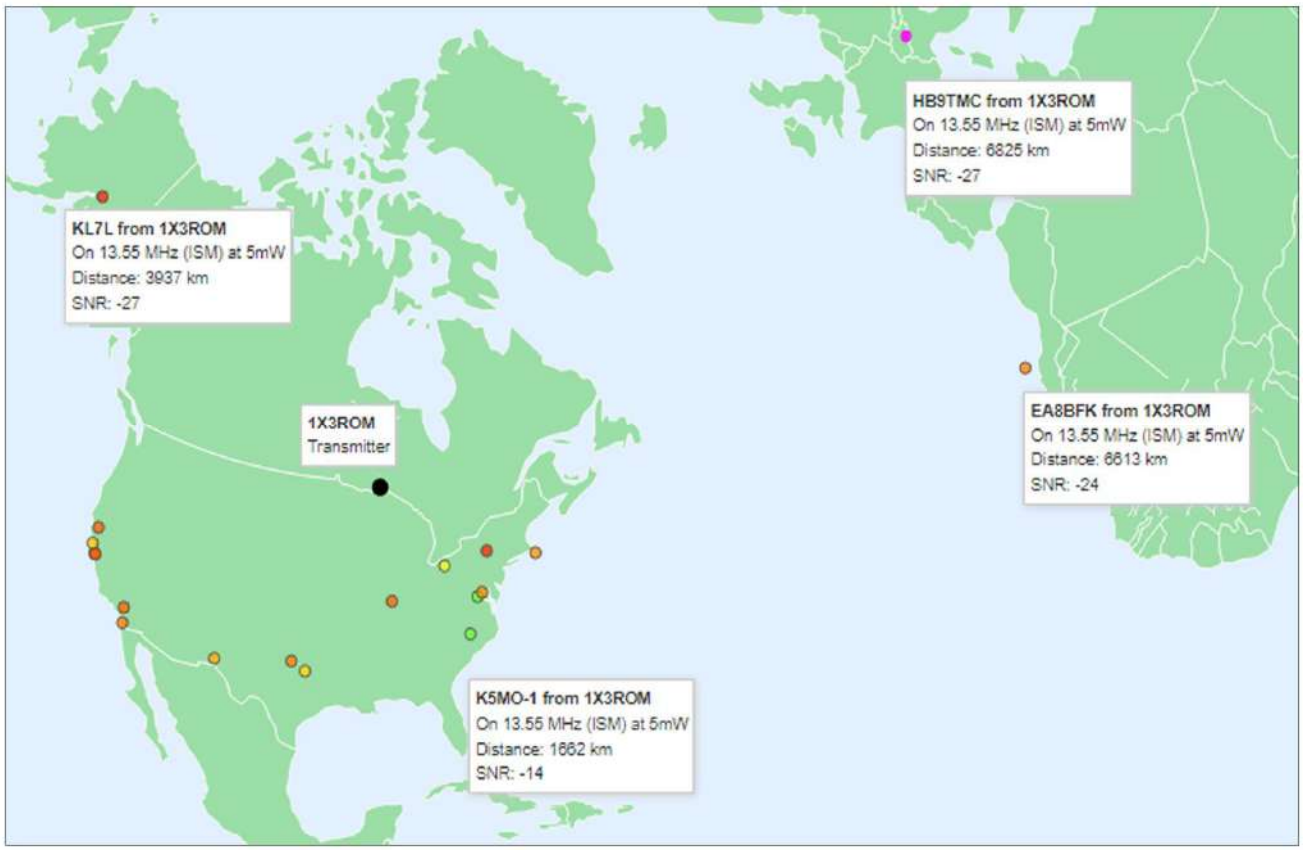


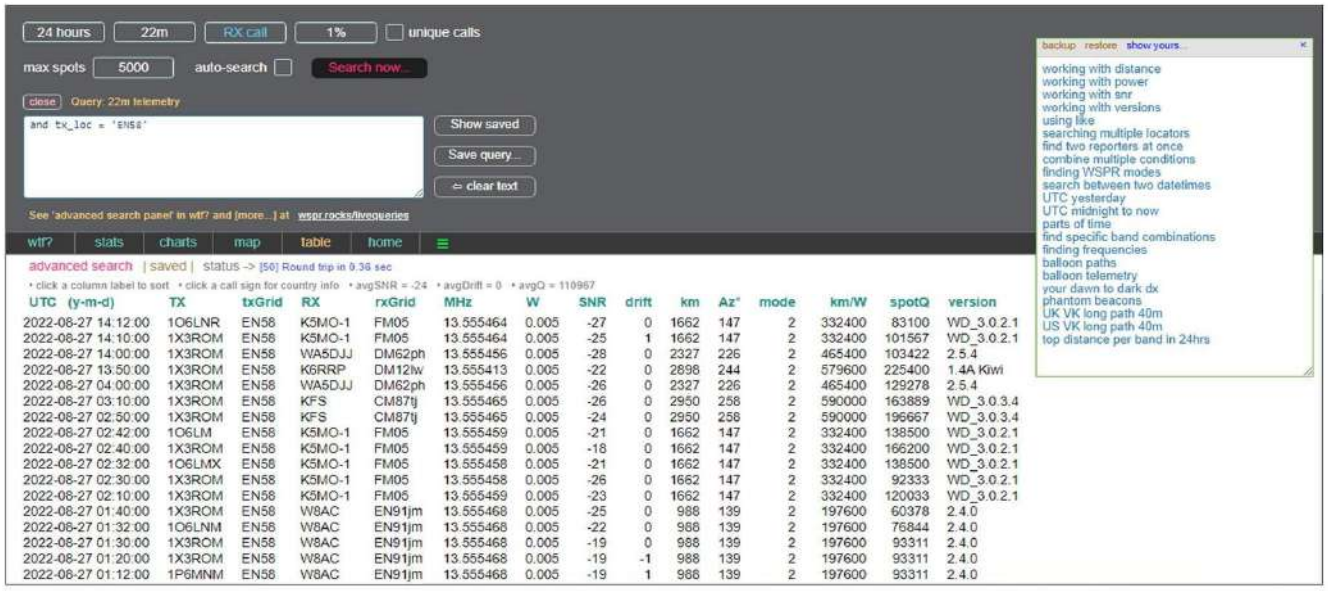
Figure 2: Telemetry-over-WSPR Signal Spotting
Image Credit: DXplorer.com.

WSPR Rocks! Plus Telemetry-over-WSPR Balloon Decoding

Created by Phil Barnard, VK7JJ, the WSPR Rocks! website has many features to extract, analyze and present WSPR data in many informative ways without needing to know how the magic is actually performed (Figures 3A and 3B).

Figure 3A: WSPR Rocks! Sample Custom Search

I'm searching for 22 metre WSPR telemetry beacons ("1%" wildcard search) transmitted from my grid ("and tx_loc = EN58") for the past 24 hours. Image credit: WSPR Rocks!



UTC (y-m-d)	TX	txGrid	RX	rxGrid	MHz	W	SNR	drift	km	Az	mode	km/W	spotQ	version
2022-08-27 14:12:00	1O6LNR	EN58	K5MO-1	FM05	13.555464	0.005	-27	0	1662	147	2	332400	83100	WD_3.0.2.1
2022-08-27 14:10:00	1X3ROM	EN58	K5MO-1	FM05	13.555464	0.005	-25	1	1662	147	2	332400	101567	WD_3.0.2.1
2022-08-27 14:00:00	1X3ROM	EN58	WA5DJJ	DM62ph	13.555456	0.005	-28	0	2327	226	2	465400	103422	2.5.4
2022-08-27 13:50:00	1X3ROM	EN58	K6RRP	DM12lw	13.555413	0.005	-22	0	2898	244	2	579600	225400	1.4A Kiwi
2022-08-27 04:00:00	1X3ROM	EN58	WA5DJJ	DM62ph	13.555456	0.005	-26	0	2327	226	2	465400	129278	2.5.4
2022-08-27 03:10:00	1X3ROM	EN58	KFS	CM87tj	13.555465	0.005	-26	0	2950	258	2	590000	163889	WD_3.0.3.4
2022-08-27 02:50:00	1X3ROM	EN58	KFS	CM87tj	13.555465	0.005	-24	0	2950	258	2	590000	196667	WD_3.0.3.4
2022-08-27 02:42:00	1O6LM	EN58	K5MO-1	FM05	13.555459	0.005	-21	0	1662	147	2	332400	138500	WD_3.0.2.1
2022-08-27 02:40:00	1X3ROM	EN58	K5MO-1	FM05	13.555459	0.005	-18	0	1662	147	2	332400	166200	WD_3.0.2.1
2022-08-27 02:32:00	1O6LMX	EN58	K5MO-1	FM05	13.555458	0.005	-21	0	1662	147	2	332400	138500	WD_3.0.2.1
2022-08-27 02:30:00	1X3ROM	EN58	K5MO-1	FM05	13.555458	0.005	-26	0	1662	147	2	332400	92333	WD_3.0.2.1
2022-08-27 02:10:00	1X3ROM	EN58	K5MO-1	FM05	13.555459	0.005	-23	0	1662	147	2	332400	120033	WD_3.0.2.1
2022-08-27 01:40:00	1X3ROM	EN58	W8AC	EN91jm	13.555468	0.005	-25	0	988	139	2	197600	60378	2.4.0
2022-08-27 01:32:00	1O6LNM	EN58	W8AC	EN91jm	13.555468	0.005	-22	0	988	139	2	197600	76844	2.4.0
2022-08-27 01:30:00	1X3ROM	EN58	W8AC	EN91jm	13.555468	0.005	-19	0	988	139	2	197600	93311	2.4.0
2022-08-27 01:20:00	1X3ROM	EN58	W8AC	EN91jm	13.555468	0.005	-19	-1	988	139	2	197600	93311	2.4.0
2022-08-27 01:12:00	1P6MNM	EN58	W8AC	EN91jm	13.555468	0.005	-19	1	988	139	2	197600	93311	2.4.0

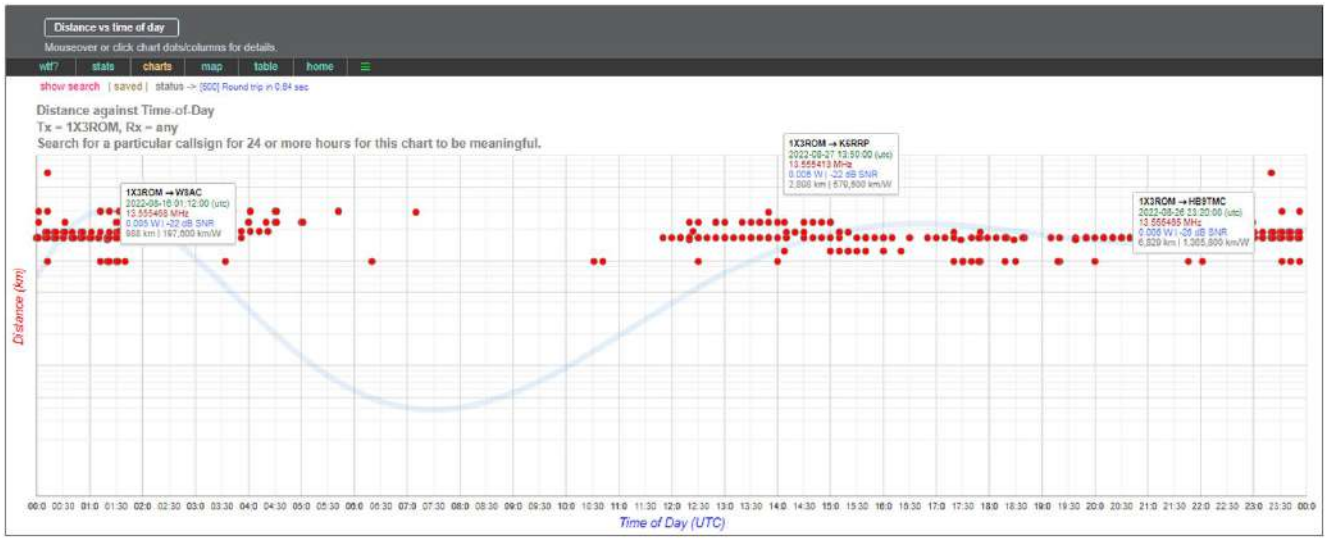


Figure 3B: WSPR Rocks! Sample Distance v. Time of Day Plot

You can clearly see the times of day when my 22 m WSPR signal goes long between local sunrise until a few hours after sunset when it goes short or disappears altogether. Image credit: WSPR Rocks!

During the course of our email exchanges, Phil mentioned that he also added decoding of QRP Labs' telemetry-over-WSPR pico balloon flight telemetry packets along with additional information (Figure 4).

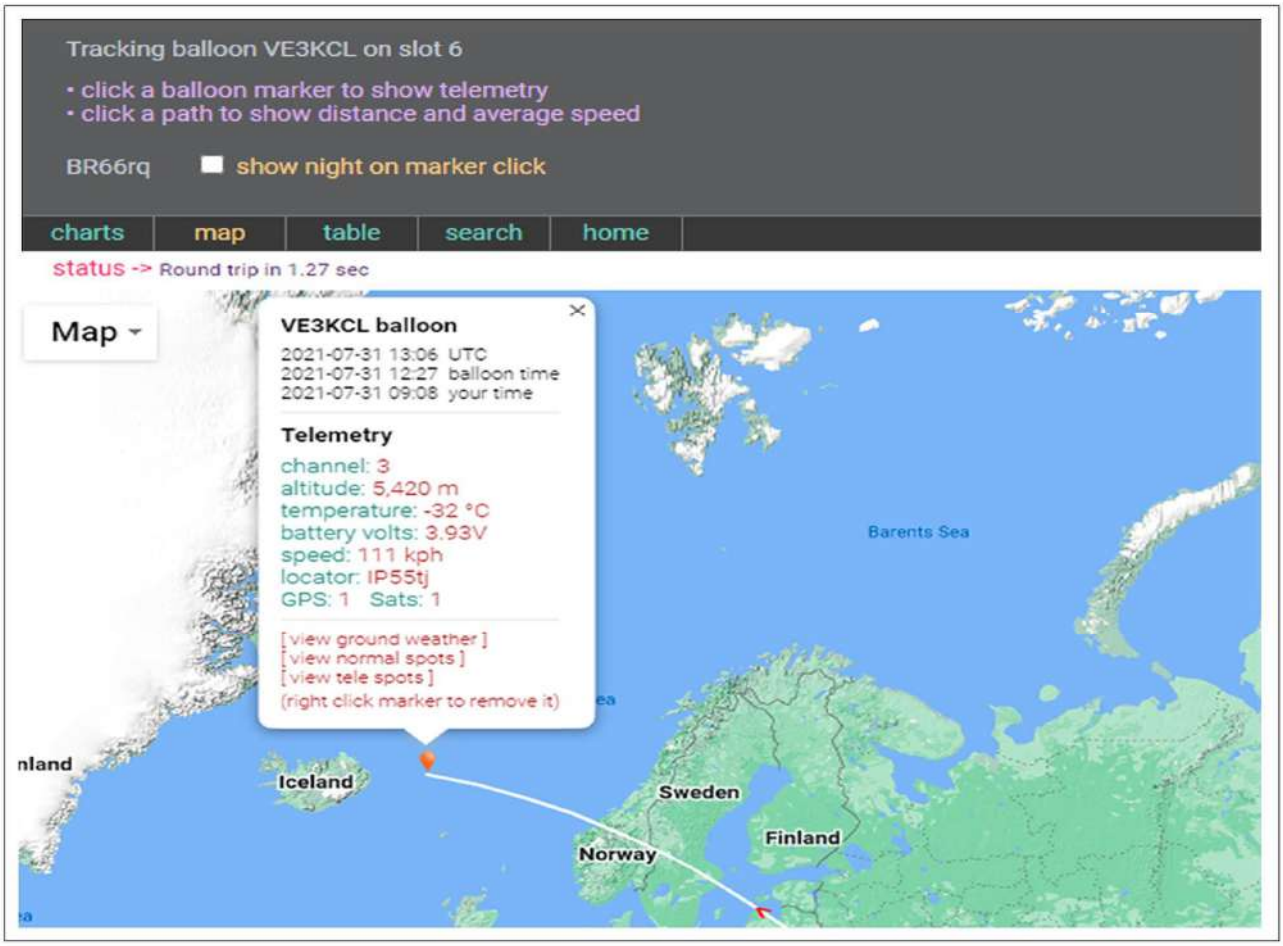


Figure 4: WSPR Rocks! Sample Decoding Balloon Telemetry
To avoid conflicts with other pico balloon flights (also called "floaters") the concept of WSPR sub-band "channels" along with fixed broadcast times ("slots") and unique encoded identifiers was devised. But WSPR Rocks! lets you extract much more than just flight information. Image credit: WSPR Rocks!

WSPR Rocks! "SpotQ"

WSPR has always lacked a way to make statistical analysis comparisons of signal data between spotting and spotted stations because we don't really know anything about a WSPR station's antenna gain and directivity except for our own receiving antenna or if we ask the other station(s) for their antenna information.

As a partial solution for this (even better if you ask for a transmitting station's antenna details), Phil determined a mathematical way to use the well-known kilometres per watt (km/W) measurement standard along with the SNR spots called "SpotQ", which along with km/W is automatically calculated and added to the extracted WSPR data table (Figure 3A refers). But I was having trouble understanding his concept of a radio signal's "Q" so Phil provided this excellent explanation: "…SpotQ is the relative quality or "Q" of a WSPR spot, i.e. how "good" it actually is. The best spot quality is the one received over the GREATEST distance, using the LOWEST power producing the HIGHEST SNR. The SpotQ equation is: km/W x (SNR + 36) / 36. Because -36 dB is the lowest mathematically possible decoded SNR for a regular WSPR mode 2 (two minute transmission times), we add 36 to the SNR and divide by 36 to ensure that the LOWEST NORMALIZED POSITIVE multiplier (0 to N) is always used…"

If any two WSPR stations are the same distance from you and your station spots them both with the same received SNR then the one using the lower transmitter power will always have the higher SpotQ. However, if both stations are equal in distance and transmitter power but the SpotQ isn't the same for both (their deviation is quite large) then "something" has affected the signal of the one on its way to you and it can get very interesting looking for the answer(s). It could be because one antenna has a higher gain than the other, the station's geographic orientation from you, time of day, your antenna's reception pattern, atmospheric factors, perhaps even a high flying, large body aircraft or even a skyquake. SpotQ makes it easier to do some serious citizen radio science and research because it has the fine resolution (it can generate really large integers!) needed to compare minute variations in received WSPR signals.

My Final

Perhaps future versions of WSJT-X will add the capability to transmit antenna gain plus directivity along with the ability encode/decode telemetry-over-WSPR packets, but this would probably require a new variant (type 4?) of the mode. Most dedicated WSPR websites have already added 22 m support plus more Amateurs and radio hobbyists are also monitoring. This world-wide allocated, license-free ISM band is fast becoming the place for members of various radio groups such as the LWCA and Ham Radio Science Citizen Investigation (HamSCI) to experiment within. It gets us back to our radio roots, IMHO.—73

Addendum

In mid September 2022, shortwave listening station “ZL2005SWL” located in Marahau (South Island), New Zealand, spotted my 22 m “flea power” transmissions just after his local midnight and my local sunrise (Figure 5). Chris uses a Wellbrook small receiving loop antenna (ALA-1530S) with built-in preamplifier mounted close to the ground. Perhaps it had something to do with being near the fall equinox and the radio reflective Pacific Ocean saltwater along the way? Not too shabby for a few milliwatt “arrows” shot up into the ether from a low “bow” dipole (inverted-V) antenna!

Figure 5: Electronic 22 m QSL (eQSL) Card Received from New Zealand

References and Resources

Development of Telemetry-over-WSPR https://tinyurl.com/bdfjahhh

DXplorer http://dxplorer.net

Earthquakes in the Sky https://tinyurl.com/4brxkztb and https://tinyurl.com/n747jmsk

Ham Radio Science Citizen Investigation (HamSCI) https://www.hamsci.org

ISM Bands https://tinyurl.com/bdevjfdm

Longwave Club of America https://www.lwca.net

Maidenhead Locator System https://tinyurl.com/2p83u4xj

QRP Labs https://qrp-labs.com

The Search for MH370 and WSPR https://tinyurl.com/4pjc8nt9

Total Electron Content https://tinyurl.com/mrz95shb

Warnings from the Ionosphere https://tinyurl.com/2bs54ms9

WSPRnet http://www.wsprnet.org

WSPR Rocks! http://www.wspr.rocks