All Things Digital

Amateur Radio for the 21st Century

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QRSS CW—SENDING SLOW CONTINUOUS WAVE: PART 3

INTRODUCTION

This is a very general short list of a few that you can do with and use the analog weak-signal QRSS CW modes for besides one or two-way communications. The weak signal propagation reporter (WSPR) is included because it's a modern weak-signal, four frequency shift keying (4-FSK) digital variant (of sorts). I'm only touching lightly on each item because this list can go on and on and on:

1. Testing and calibrating.
2. Mode comparisons.
3. Propagation experiments.
4. "Spooky" stuff.

SUPPORT SOFTWARE AND WEBSERVERS

Once you start transmitting weak-signal, narrow band CW beacons (analog or digital) or use two-way communication data modes (like FT8 or PSK31 et al), any radio hobbyist receiving them can also upload signal "grabs" or "spots", along with any associated telemetry, to various world-wide web servers such as: WSPRnet, Reverse Beacon Network (RBN), PSKReporter, and QRSS Plus. Digital signal processing (DSP) "grabber" programs like Argo, Spectran, and Spectrum Laboratory can save captured data as analog images (frames), which can be enhanced by using image stacking/averaging techniques (part 1 refers). Our eye/brain fuzzy logic processor analyses and interprets what these images "mean" and/or what information they contain (if any).

Grabs uploaded to the QRSS Plus server aren't stored for very long because of the physical sizes of cumulative images, so up-streaming stations usually keep them separately on their hard drives to search for and save anything interesting—then delete the rest. But WSPR spots are all digital (just numbers), so they are much easier to store on its central web server, and it has online archives going back to March 2008. Anyone can download them and analyze the data contained therein. There also a new website called "DXplorer" that allows anyone to easily create real-time graphs and maps of transmitted WSPR spots uploaded to the WSPRnet (yours and/or others).

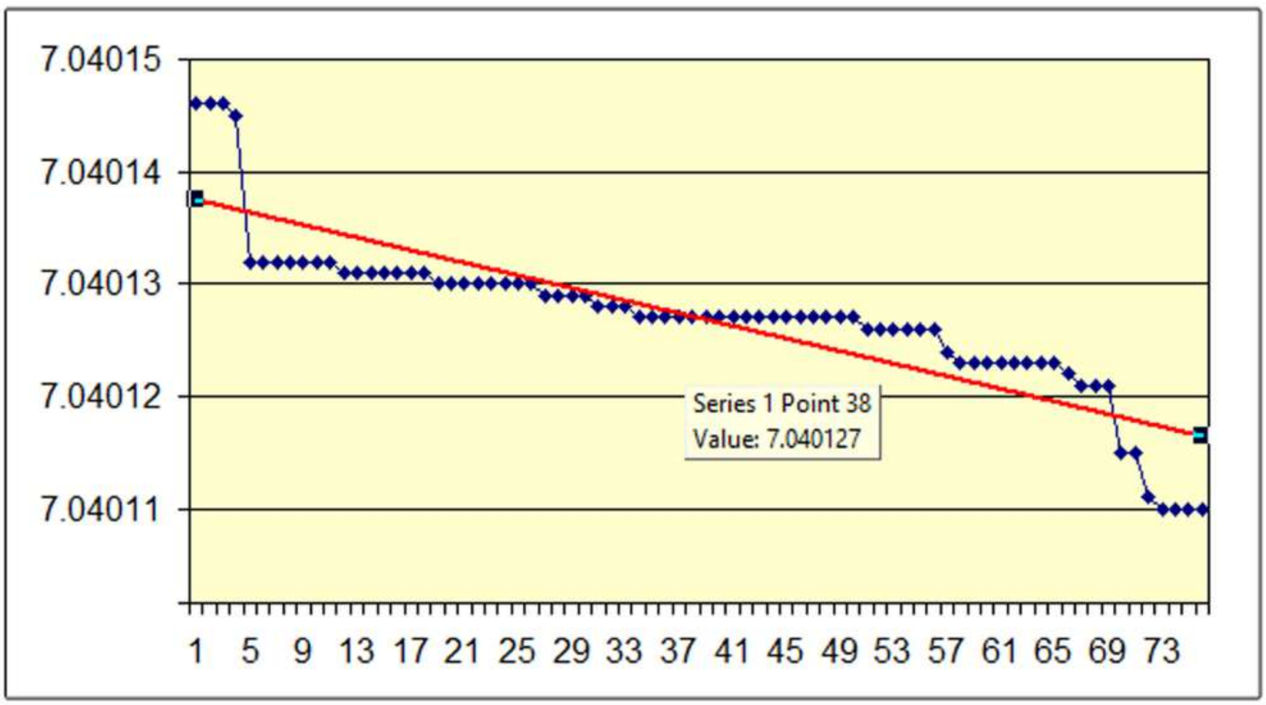

FIGURE 1: FREQUENCY TESTING

EQUIPMENT TESTING

How frequency accurate and stable is your radio for transmit and/or receive, and how can you test for this using analog and/or digital data modes? WSPR seems to be the one to use because you get absolute number values, so it should be all you really need, right? Well, let's see how my transmitter performed based on a collection of spots of my 30 decibels-per-milliwatt (dBm) or 1 watt, 40 metre (m) band WSPR beacon, transmitted every 10 minutes for one hour (see Figure 1):

a. Highest frequency reported was 7040.146 kilohertz (kHz).
b. Lowest frequency reported was 7040.110 kHz.
c. Average frequency was 7040.128 kHz based on above values.
d. Average frequency drift was -0.0395 hertz (Hz) per hour. Only the same three stations reported any drift so it's not me who's drifting.

Figure 1 is the resulting dot plot of the WSPR spots obtained over the test hour, with the graph's trend line plus its midpoint value added. Most "agreed" with K9AN (the reference station), but others were well above or below the line. So, what's going on? Isn't digital supposed to be 100% accurate? No. All electronics, even the latest software defined radio (SDR), has built-in parts-per-million (ppm) or parts-per-billion (ppb) frequency errors in their master clock oscillator (MCO) which needs to be corrected as the electronics "ages", and any deviation from the trend line indicates a problem with the spotting stations' receivers being off frequency and not properly "dial calibrated". We may only be talking about 20 to 25 Hz frequency error (usually), but in the data mode world that's a huge error, and it easily exceeds some data mode bandwidths. If the frequency drifts it can "crash" into nearby signals, which isn't a good thing.

My transmitter frequency was exactly on 7040.127 kHz with exactly zero frequency drift during the test period. How do I know "exactly"? Well, Steven Frankes, K9AN, has a GPS controlled, multi-band WSPR receiving system and his spots of any WSPR signal tell you what's what with extreme decimal point accuracy. If your receiver or transmitter can get to within +/- 1 Hz of what his station reports it to be, then you are doing very well, indeed. But what if we converted from digital to the analog world? Perhaps we can see if there's some kind of recognizable and/or repeating pattern hidden in all the digital data. A jumble of numbers can't do this for us because they only give an absolute value at a specific time, while analog can show rates of change (slow or fast), direction of change (positive or negative), and create curves or lines so we can analyze and determine if the digital data is "good" or "bad": "Lies, damned lies, and statistics."—Mark Twain.

We can also “see” what a radio signal looks like in the ether (Argo is great for beginners) to look for any problems. Figure 2 (top part) shows two different strength WSPR beacons with noticeable problems (to the trained eye): both are below the 30 m WSPR sub-band; the timing is off for the top signal (it starts too late), while the second has noticeable positive frequency drift and could interfere with nearby signals. Figure 2 (middle part) is a QRSS FSK CW beacon missing its carrier lead-in signal (the lead-out was present, not shown here), plus it has a very slight negative frequency drift. Figure 2 (bottom part) is a QRSS CW beacon whose transmitter has very distinctive startup characteristics going positive, arcing up, dropping down then leveling out for the rest of the transmission. All these visual patterns are specifically unique to each transmitter allowing them to be “fingerprinted”, cataloged, and used for later identification. This “quick and dirty” method can identify common radio technical problems right across the radio spectrum, or can be used to search for and identify a particular transmitter.

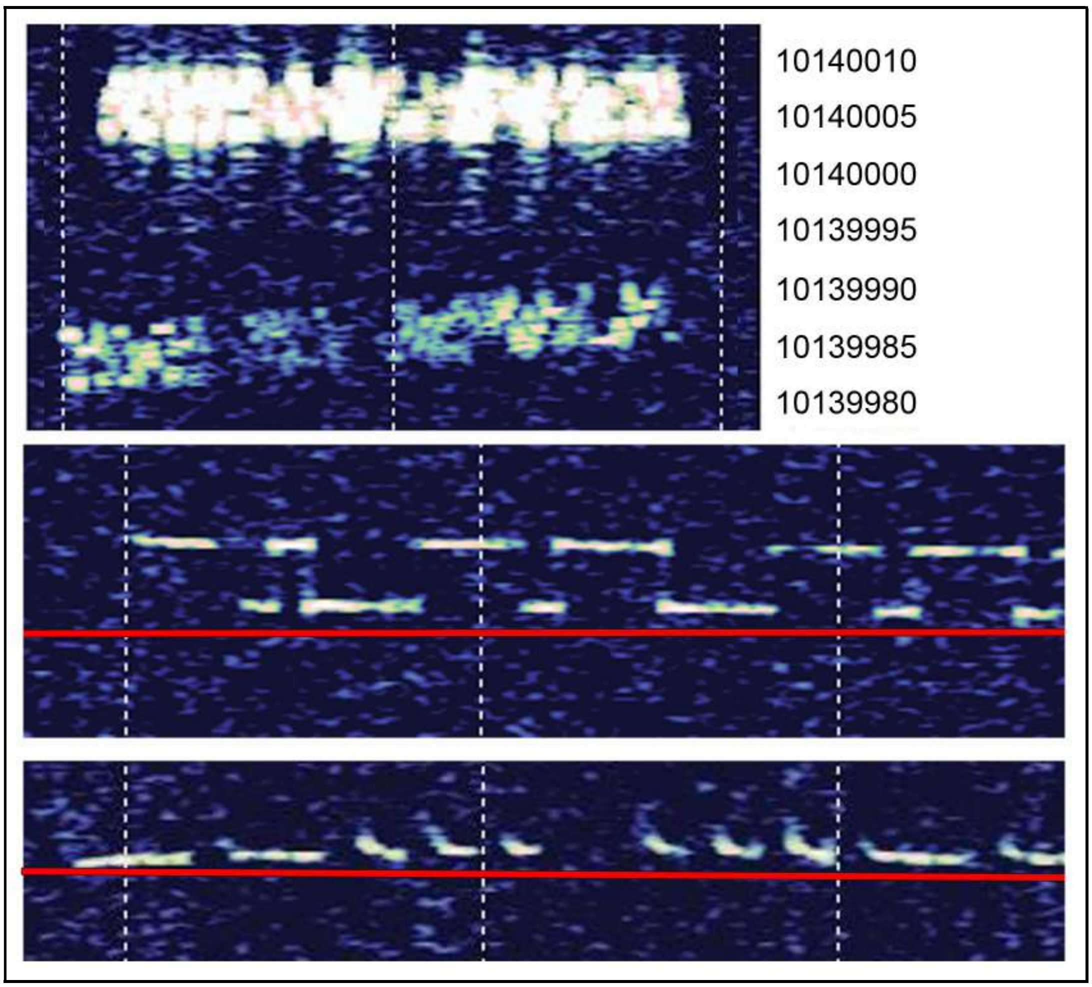

FIGURE 2: IDENTIFYING PROBLEMS

DIGGING DEEP

One use of QRSS beacons is to compare different types of antennas to see which perform better for short and/or long distance (DX) reception, or to see how one receiver stacks up against another, or we can compare how well one data mode stacks up against others. Because of the adoption of image stacking/averaging and 10 minute time synchronized transmissions (since mid-2010), QRSS analog transmissions sent using simple CW transmitters can outperform even WSPR— if you don't mind the extremely slow data rates involved. Look closely at Figure 3A, a single raw (unprocessed) frame grab of various 40 m QRSS beacons. Can you spot either my graphical CW signal or G6NU's slow Hell beacon in the background noise? Well, prior to year 2010, no one would have seen them for the noise. Figure 3B (see next page) is a sequential 9 frame stack of the same QRSS signals received over 90 minutes. Can you see me now?

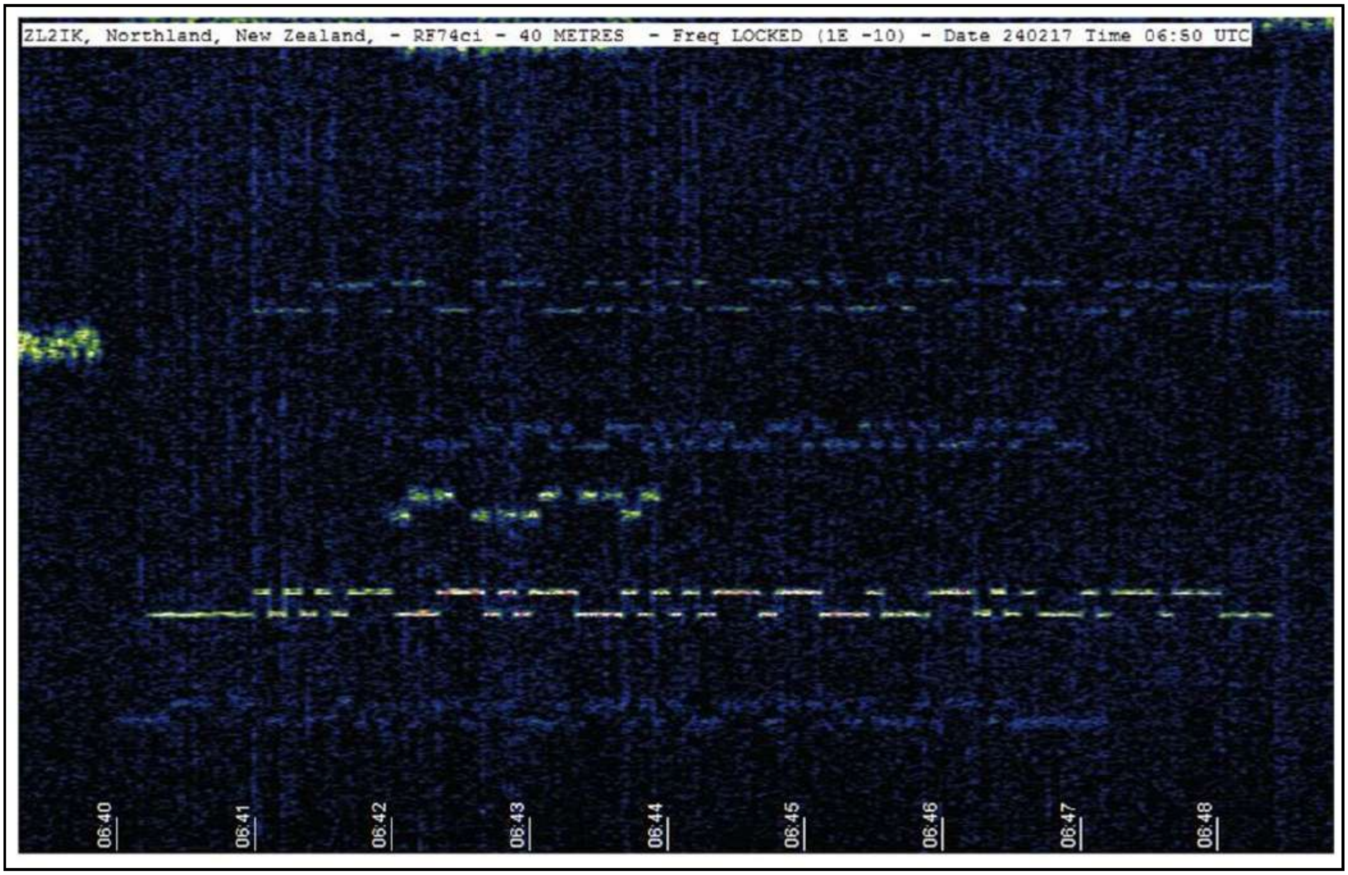

FIGURE 3A: SINGLE FRAME/GRAB 40 M QRSS SIGNALS

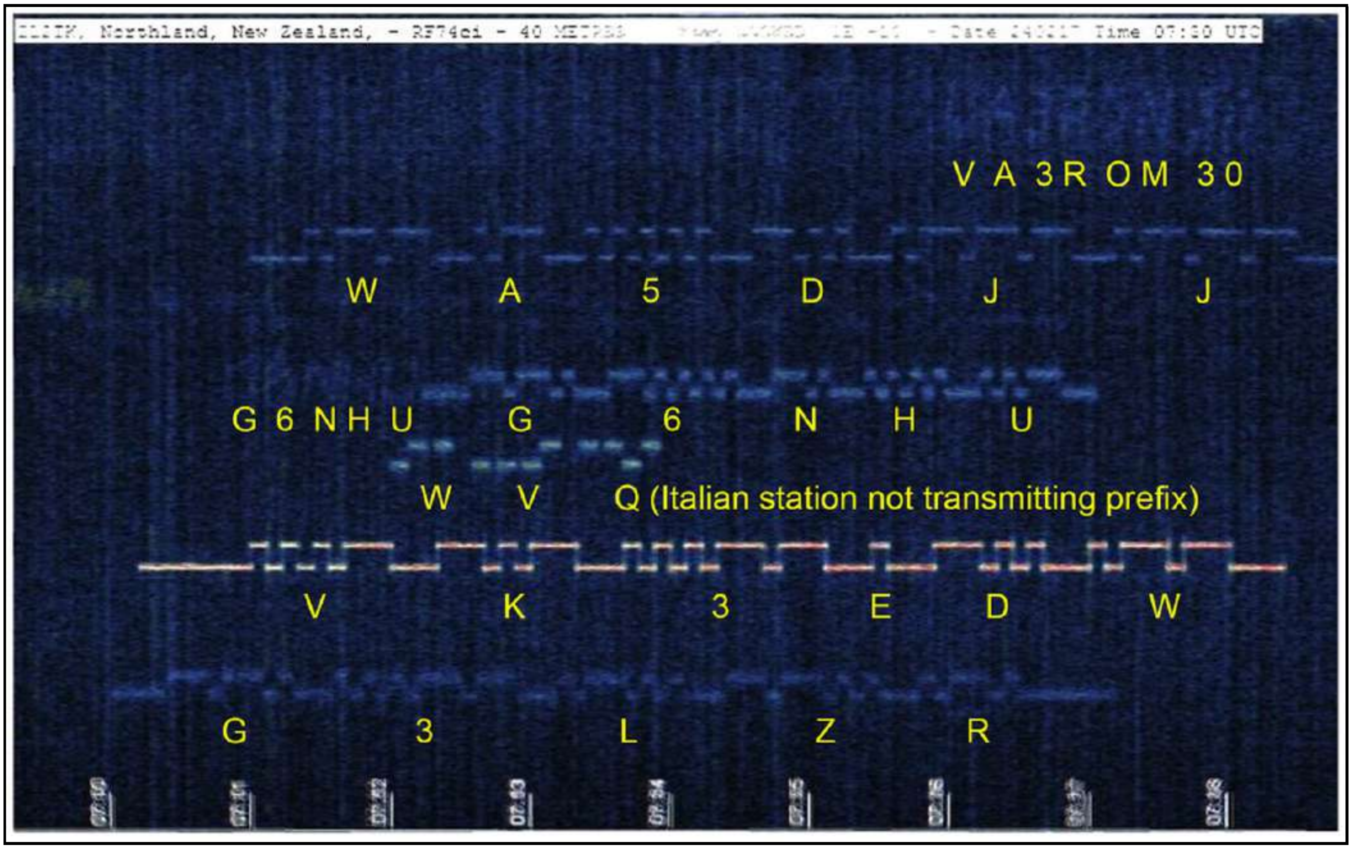

FIGURE 3B: NINE FRAME STACK OF 40 M QRSS SIGNALS

PROPAGATION EXPERIMENTS

Radio beacons are commonly used to provide real-time propagation information. As the solar cycle continues to drop towards a year 2020 minimum they will become more important. The atmospheric layer responsible for all long range radio signal or sky wave propagation is called the “ionosphere”, which is actually made up of several other layers (“D” or “absorption”, “E” and “F/F1/F2”), which range in height from 60 to 150 km. The ionosphere extends up to 1000 km but the lower altitudes are where radio waves are mostly affected. It’s bombarded constantly by solar ultraviolet (UV) ionizing radiation, which is most intense on the daylight side of the Earth. Photons at UV wavelengths become bullet-like particles, literally blasting negatively charged electrons free from their atoms (turning atoms into positively charged “ions”). This creates a super heated gaseous “soup” or “plasma”, which is more intense when the solar cycle (about 22 years long) is on the upswing, alternating every 11 years or so between maximum and minimum solar activity.

Free electrons form negatively charged “swarms” or “clouds” varying, thicknesses, locations, energy levels, and tilt angles in the ionosphere, but they stay relatively close to ions. Things are complicated by the Earth’s magnetic field because it interacts to warp, twist and bend the Ionospheric soup. Generally, when solar activity is low, the higher in frequency (higher energy) radio waves travel up and out through the ionosphere—“to infinity and beyond”—while the lower in frequency (lower energy) radio waves can only travel up and in so far before they are refracted back to Earth (horizontally polarized waves refract easier than vertically polarized waves). Propagation programs calculate the highest frequency that will refract back, which is called “maximum useable frequency” (MUF).

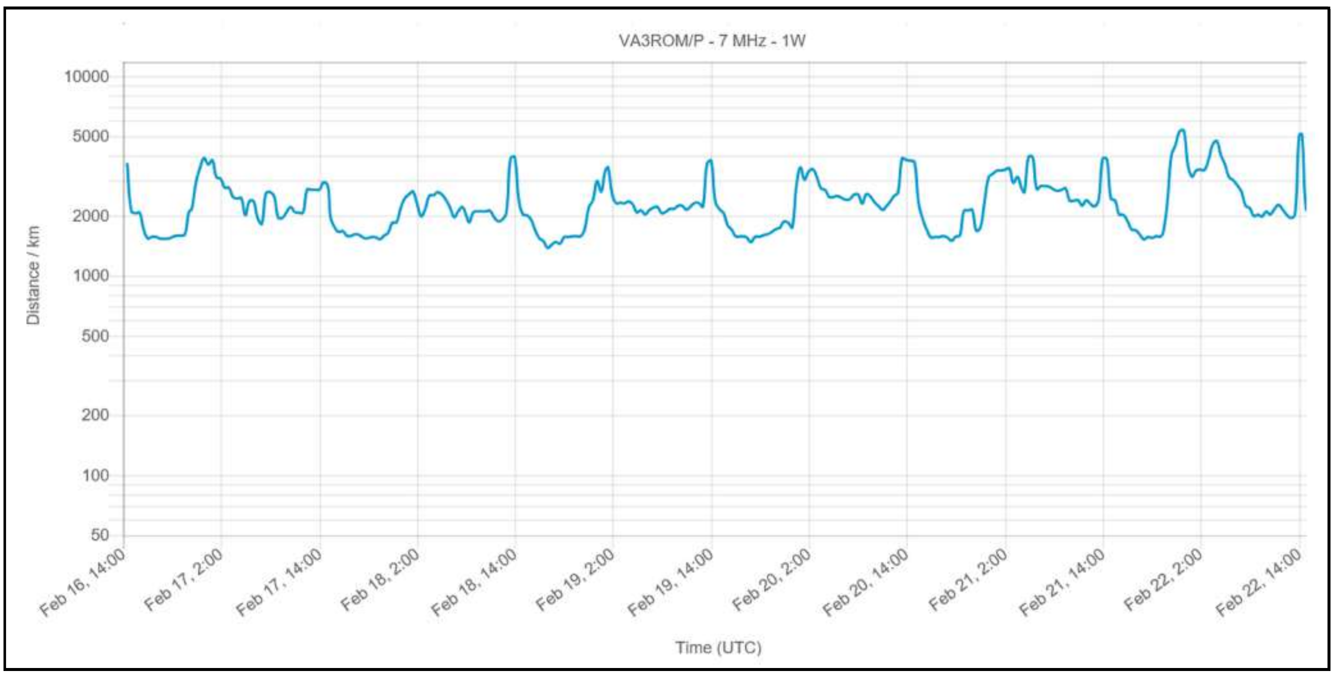

FIGURE 4A: DXPLORER 40 M WSPR 7-DAY PLOT

Figure 4A is the DXplorer plot of one week’s worth of my 40 m WSPR beacon spots showing the mean distances achieved. There appears to a repeating daily pattern related to my local sunrise, solar noon (by the sun not by the clock or time zone), and sunset times.

Figure 4B is an enlargement of one of the “dips” recorded earlier in the month; as the sun arcs up across the sky from east to west (its apparent motion is 15 degrees per hour), the ionosphere is bombarded by more and more UV radiation until about solar noon, when the sun is at its highest point in the sky and due south (in the northern hemisphere).

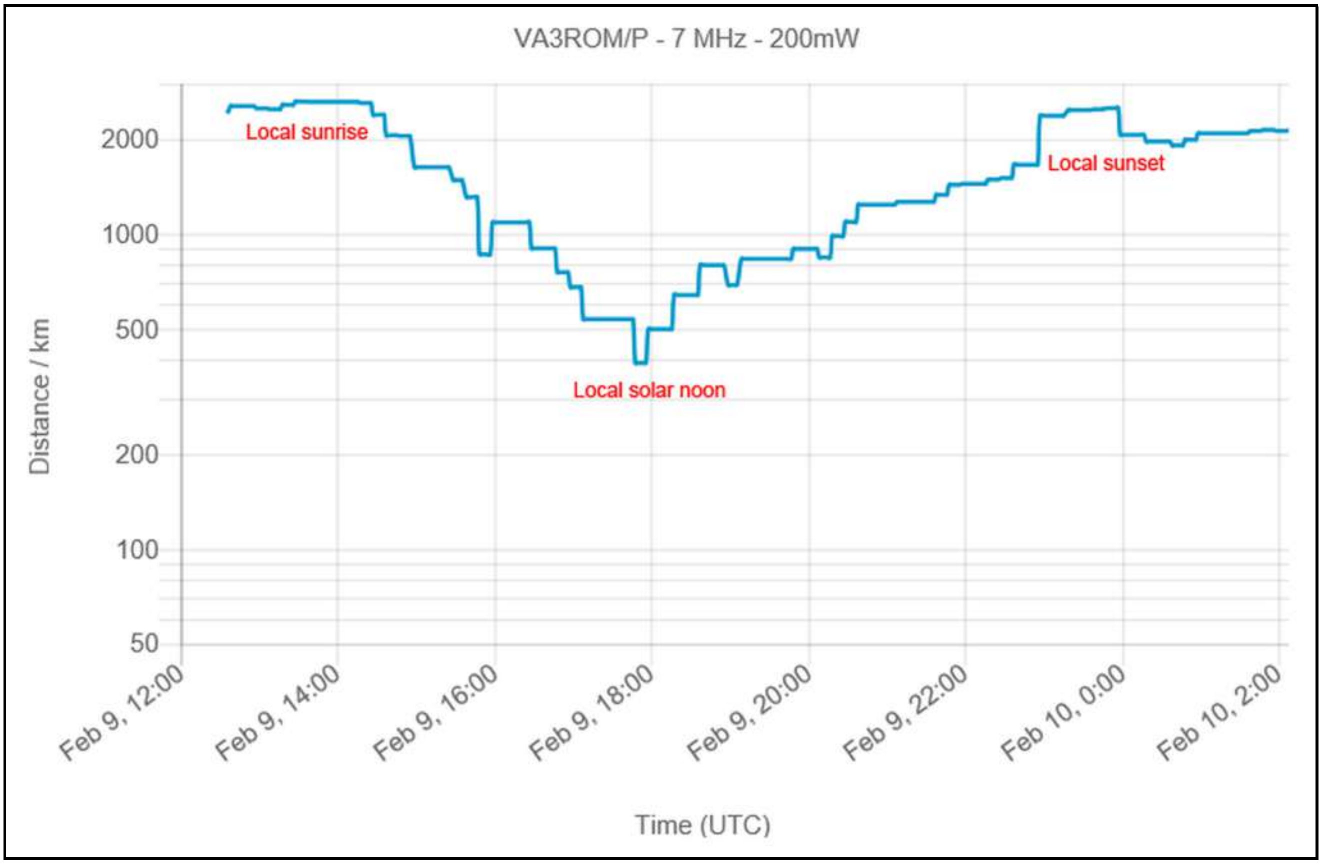

FIGURE 4B: DXPLORER 40 M WSPR DAWN TO DUSK IONOSPHERE PLOT

The 40 m band propagation (for area) is now reduced to a minimum at local solar noon because radio waves at that frequency just don’t have enough energy to penetrate as deeply into the ionosphere before they are refracted—the electron density is much too strong so the band goes “short”. But the higher frequency radio waves (up to the MUF), which had previously shot up and out or were weakly refracted will now refract back with a bit of “skip” or distance to go with, and those bands go “long”. The reverse process begins as the sun slowly sinks in the sky and the Ionospheric plasma starts to cool; ions can now grab and hold on to nearby free electrons and reform neutral atoms.

But Figure 4B suggests the process isn’t symmetrical; the ionosphere seems to heat up faster than it cools down, so some high band openings are still possible even as low band propagation improves and “opens”. DXplorer can extract WSPR beacon data for anywhere in the world if you use the WSPRnet to find a station in a specific “target” area. Then you can plot its real-time propagation profile to see if you fall within it’s DX reception pattern or not. No mathematics involved, it’s all visual!

A neat spreadsheet tool (courtesy KP4MD) compares WSPR performance to other modes (including voice). In Figure 5, I used it to import 2-1/2 hours of my 40 m WSPR beacon spots taken shortly before and shortly after local solar noon where no QRSS grabs or WSPR spots exceeded 1600 kilometres (km). My original spotted WSPR beacon signal-to-noise ratio (SNR) is in column H and power is in column I, and the columns to the right are what the SNR sensitivity thresholds would be, when scaled up and compared to the other modes using 50 dBm (100 watts), a 0 dB gain antenna, with a 2500 Hz bandwidth (power and antenna gain combinations can be varied). The table is color coded for easy visual reference: modes in light green and yellow are good and fair chances of making 40 m contacts while light purple is definitely “no way in Hades”.

Note: The new FT8 digital data mode would sit between Olivia and JT65, which is why it’s become so popular with its faster transceive turn-around speeds (15 seconds) over WSPR, JT65 and Olivia, and almost as good weak-signal performance.

	A	H	I	J	K	L	M	N	O	P
1	Date/Time	SNR	dBm	WSPR	JT65	Olivia	PSK31	Morse	RTTY	SSB
2	03-02-2017 18:30	3	30	30	27	20	10	4	-2	-7
3	03-02-2017 18:20	1	30	28	25	18	8	2	-4	-9
4	03-02-2017 18:20	-3	30	24	21	14	4	-2	-8	-13
5	03-02-2017 18:10	-3	30	24	21	14	4	-2	-8	-13
6	03-02-2017 18:00	-3	30	24	21	14	4	-2	-8	-13
7	03-02-2017 17:44	-4	30	23	20	13	3	-3	-9	-14
8	03-02-2017 17:34	-1	30	26	23	16	6	0	-6	-11
9	03-02-2017 17:24	-2	30	25	22	15	5	-1	-7	-12
10	03-02-2017 17:14	-8	30	19	16	9	-1	-7	-13	-18
11	03-02-2017 17:04	-6	30	21	18	11	1	-5	-11	-16
12	03-02-2017 16:54	-2	30	25	22	15	5	-1	-7	-12
13	03-02-2017 16:44	3	30	30	27	20	10	4	-2	-7
14	03-02-2017 16:34	-4	30	23	20	13	3	-3	-9	-14
15	03-02-2017 16:24	1	30	28	25	18	8	2	-4	-9
16	03-02-2017 16:14	2	30	29	26	19	9	3	-3	-8
17	03-02-2017 16:04	3	30	30	27	20	10	4	-2	-7

FIGURE 5: WSPR COMPARISON TO OTHER DATA MODES

"SPOOKY" STUFF

There are extraterrestrial radio sources like our sun, the planet Jupiter, pulsars, black holes, or the universe in general (it's the source of noise we call "hiss"), etc. Radio waves not only refract off of the ionosphere, they can also refract off of the long and narrow ion trails created by meteors, the auroral curtain, or aluminum aircraft bodies, etc. We can use radio signals to image, catalog, and analyze refracted/reflected signals, which is an interesting QRSS offshoot. Figure 6 is a frame grab (converted to grayscale) that looks like a nighttime star field photograph, but it's actually the QRSS 30 m sub-band imaged in the early morning hours when it's "dead" to most terrestrial radio signals.

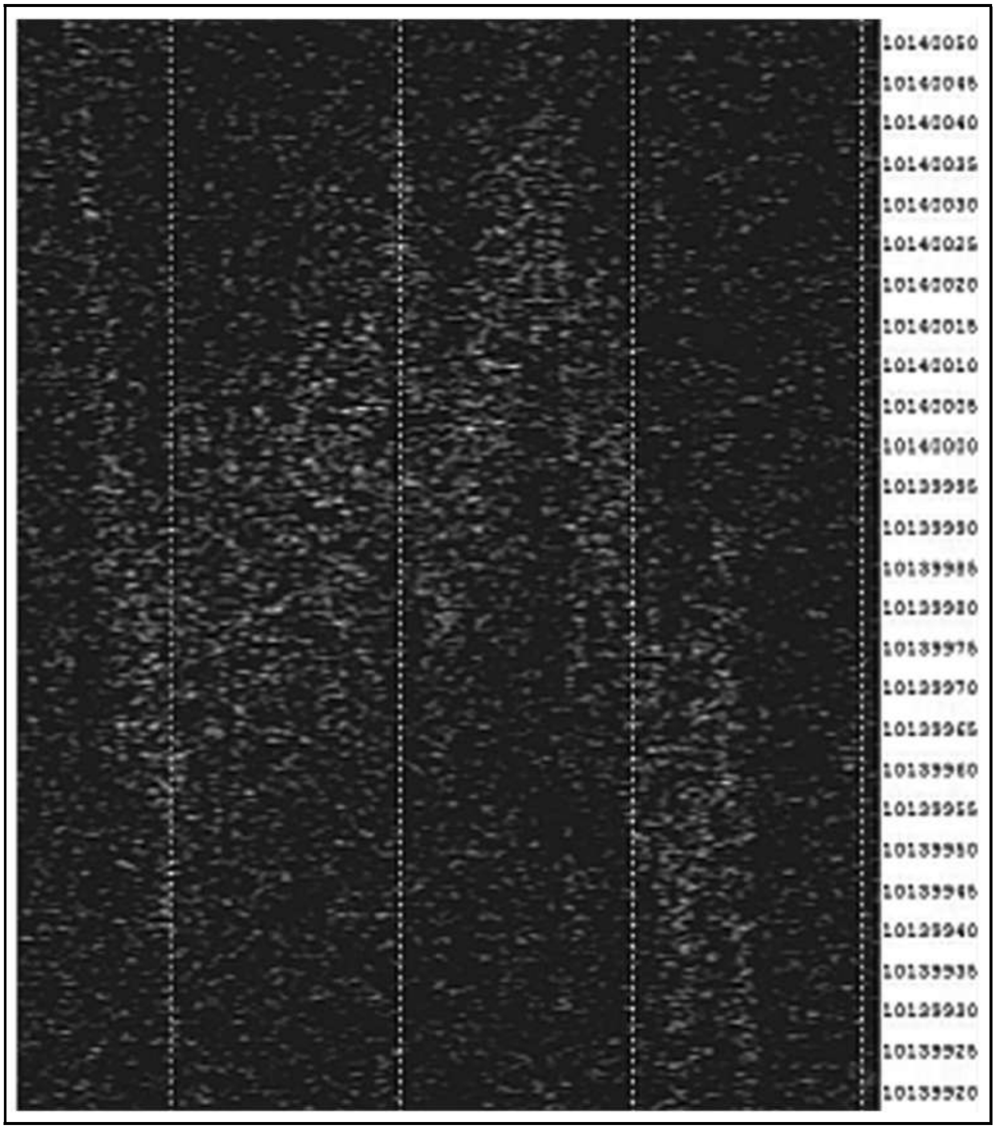

FIGURE 6: QRSS "SPOOKY" STUFF

My fuzzy logic processer "sees" it as either a Scottie terrier's head or a map of Australia, but your fuzzy logic processer may see it differently, or not see anything at all. This is called "pareidolia"—seeing recognizable patterns, faces, and shapes, etc., in random noise, clouds, shadows, burnt toast, et al. when none actually exist (it's literally all in your mind). Or, perhaps this is some ET's way of saying "Hello, world!"?

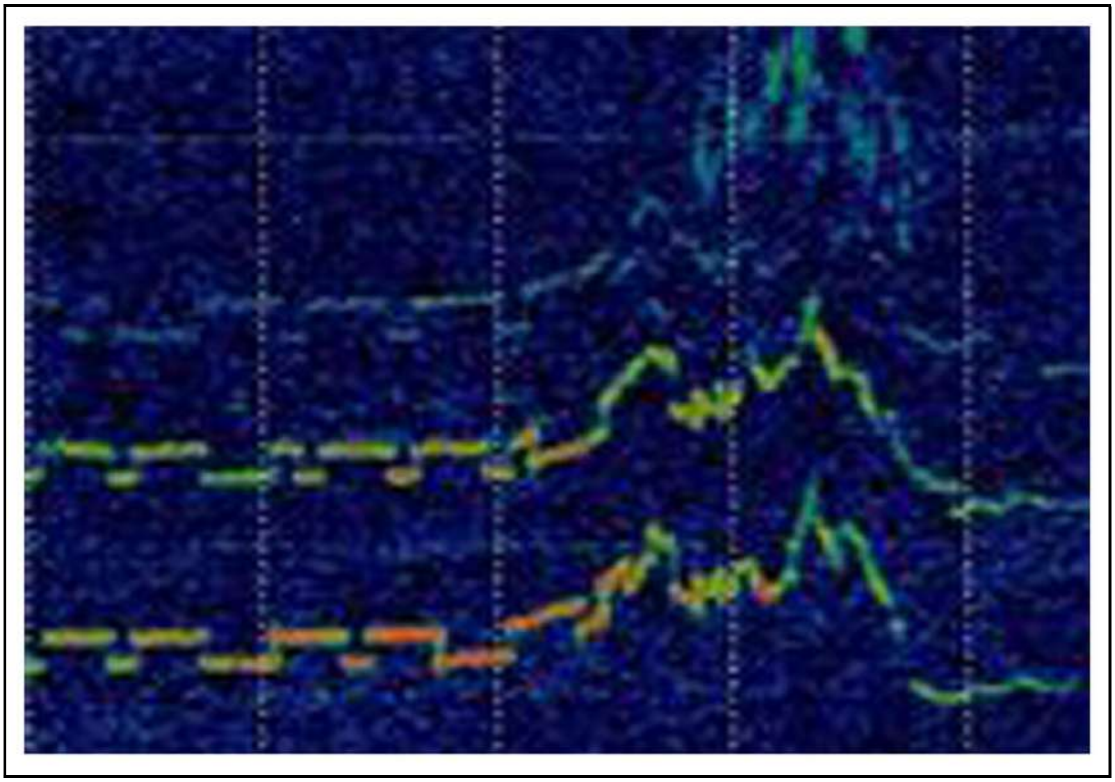

FIGURE 7: QRSS 10 M SOLAR FLARE DETECTION AND EFFECTS

Courtesy Euan McPherson, M0GBZ.

Figure 7 is a 10 m QRSS sub-band frame grab showing the effects of a solar flare recorded by Euan McPherson, M0GBZ. Notice how the QRSS FSK CW signals are literally ripped apart when the ionosphere was hit by extremely high energy photons ("X-rays"). No life would exist on this planet without the Earth's ionosphere and magnetic field (magnetosphere), and it also makes for really spectacular aurora. If you retrieve the WSPRnet archive for that day (28 October 2014), you can create mathematical models of the event right across the radio spectrum. Scientists and researchers are using various Amateur Radio web server data specifically for this purpose, and many other reasons.

MY FINAL

Radio propagation beacons using the various QRSS/WSPR modes are indispensible, inexpensive, and easy to setup (radio clubs take notice). Especially needed are stations above "north of 60" (or "south of 60" for the southern hemisphere) because their data (transmitted or received) is especially valuable. Don't turn your equipment off at night because it can be put to very good use while you sleep! *"Nobody made a greater mistake than he who did nothing because he could do only a little.—Edmund Burke"*

REFERENCES AND RESOURCES

Data Modes Web Servers
PSKReporter https://pskreporter.info
QRSS Plus (with tutorials) http://tinyurl.com/jcu6dsf
Reverse Beacon Network http://www.reversebeacon.net
WSPRnet http://wsprnet.org

DXplorer
http://dxplorer.net

G0FTD RADIO
https://sites.google.com/site/g0ftdradio/qrss-gallery

Interpreting WSPR Data for other Communication Modes
http://tinyurl.com/ou6m6jd

Software (Receiving/Grabbing)
Argo and Spectran http://tinyurl.com/m6m5qyk
Spectrum Laboratory http://tinyurl.com/nfakd

Software (Transmitting)
MEPT Tools http://tinyurl.com/zqpt6or
QRSS Beacon for Ham Radio (Google Play Store)
WSPR http://tinyurl.com/6vblqh

QRSS Web Server
QRSS Plus (with tutorials) http://www.swharden.com/qrss/plus/

VA3ROM QRSS 30 M BAND GRABBER
http://va3rom.com/QRSS/QRSS.html