All Things Digital

Amateur Radio for the 21st Century

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WSPR: THE WEAK SIGNAL PROPAGATION REPORTER—Part 1

Note: I would like to thank Jay Wilson, W5OLF, for his invaluable assistance with the technical details.

BACKGROUND

WSPR (pronounced "whisper") is both the name of a computer program and digital radio mode developed by Dr. Joe Taylor, K1JT, Nobel laureate (Physics, 1993) and he is also the author of other weak-signal programs/modes such as WJST and JT65. Digital "guru" Murray Greenman, ZL1BPU, asked Joe about adding a new, optimized mode for manned experimental propagation tests (MEPT) to WSJT, and two weeks later (13 March 2008), Joe announced the "birth" of WSPR!

WSPR adds to the rapidly growing list of [free] digital radio modes that can do amazing things [today] that were impossible or very difficult/expensive to do 10 years ago. Hundreds of automated WSPR QRPp and QRP (low and extremely low power) stations transmit and/or receive signals on established, world-wide "channelized" frequencies. An free-access Internet webserver called "WSPRnet" was created for Hams (transceive) and radio hobbyists (receive only) and the WSPR program automatically uploads received data to the webserver for sharing with others (Figures 1 and 2, next page).

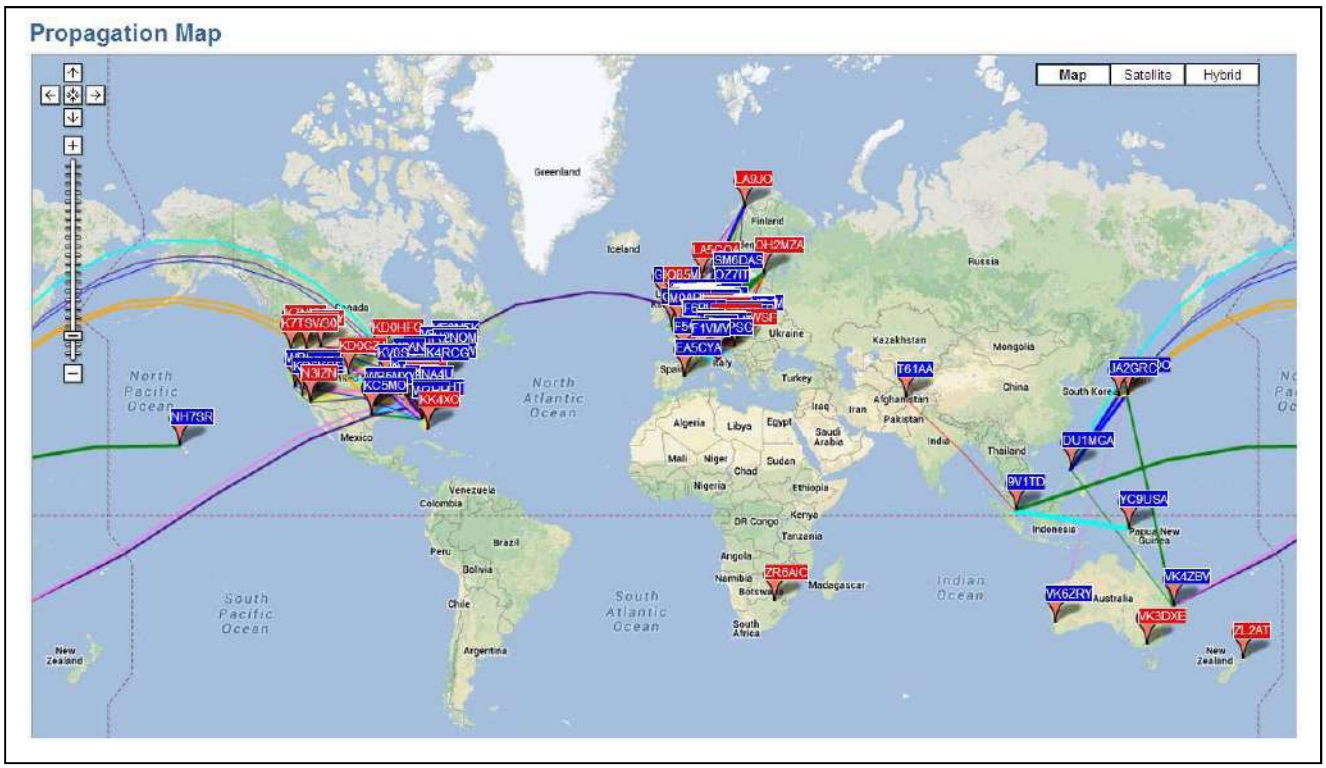


FIGURE 1: SAMPLE WSPRNET 30M WSPR SIGNALS PROGATION MAP

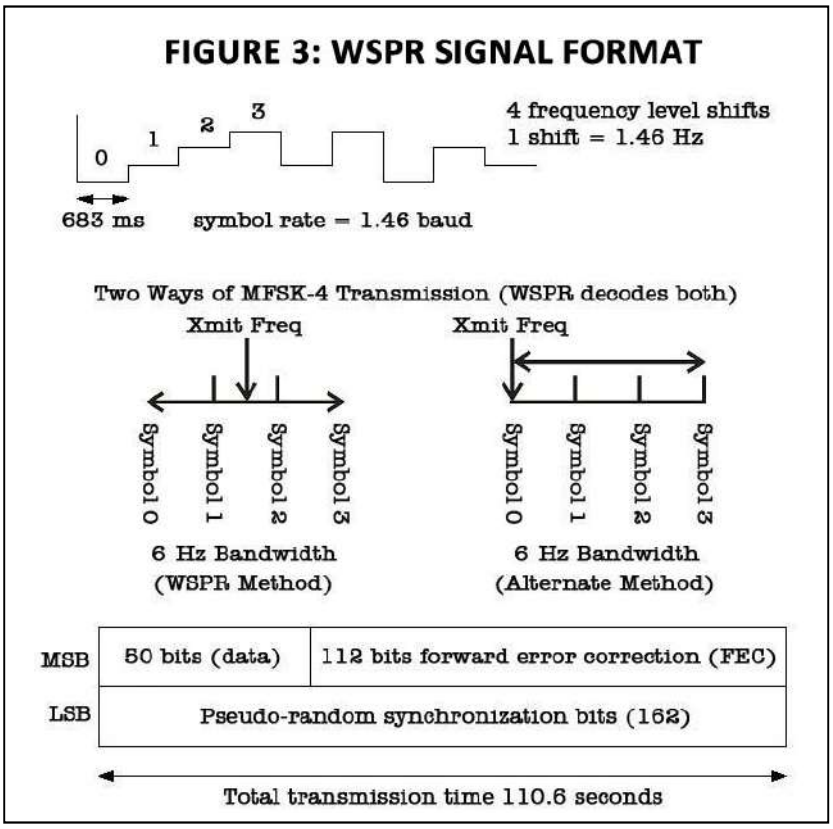
FIGURE 2: WSPR USB HF DIAL FREQS

Band	USB Dial	WSPR 200 Hz Window
160m	1.836600	1.838000 - 1.838200
80m	3.592600	3.594000 - 3.594200
60m	5.287200	5.288600 - 5.288800
40m	7.038600	7.040000 - 7.040200
30m	10.138700	10.140100 - 10.140300
20m	14.095600	14.097000 - 14.097200
17m	18.104600	18.106000 - 18.106200
15m	21.094600	21.096000 - 21.096200
12m	24.924600	24.926000 - 24.926200
10m	28.124600	28.126000 - 28.126200
6m	50.293000	50.294400 - 50.294600
2m	144.488500	144.489900 - 144.490100

You download the free WSPR program from the Princeton University website and configure the program just like any other [soundcard] digital radio mode, but, and it's a big but, you don't use it for two-way, chit-chat type exchanges. However, if you are "into" QRPp/QRP, experimentation, research, statistics, propagation studies, testing transmitters, receivers and antennas or developing MCU (microcontroller) radio projects then WSPR will definitely appeal to you!

THE TECHNICAL (BORING) "STUFF" (Figure 3)

a. Message format: callsign, grid square locator, and [transmitter] power (in dBm).
b. Message bit allocation (50 bits): callsign (28), locator (15), and power (7).
c. Forward error correction (FEC): long-constraint convolution code (112 bits).
d. Total transmitted bits: 162 (values range from 0 to 3). These are the most significant bits (MSB) of a "channel symbol" packed with least significant bits (LSB) generated by a pseudo-random number sequence to provide accurate time and frequency synchronization.
e. Modulation: WSPR uses a 200 Hz wide passband "window". With soundcard based WSPR, the RF carrier is shifted up (or offset) by a continuous, user-selected, single tone between 1400-1599 Hz. This new RF product is then modulated by continuous phase (all signals stay in phase with no breaks between), 4-tone [multiple] frequency shift keying (FSK) or MFSK-4. The level shifts (or symbols) have 1.465 Hz tone separation: symbol 0 = 0 Hz, symbol 1 = 1.465 Hz, symbol 2 = 2.93 Hz, and symbol 3 = 4.395 Hz.



f. Symbol rate: 1.465 baud (each symbol transmitted for 683 milliseconds).
g. Synchronization: 162-bit pseudo-random. One data bit (MSB) and one sync bit (LSB) are packed together and transmitted. The symbols are "unpacked" and converted back to data and sync bits at the receiving end.
h. Transmission duration: 110.6 seconds (transmission must begin within 1 second and usually no later than 2 seconds of the start of any even [UTC] minute). *Note: In actual use, I've seen beacons start well later and still get decoded, so it appears the WSPR software has a wider tolerance.*
i. Bandwidth used: approximately 6 Hz.
j. Minimum reception level signal to noise ratio (SNR or S/N): about -28 dB (give or take 1 dB) with reference to a 2500 Hz (noise) bandwidth. A 5 watt WSPR signal is equivalent to a 25 kilowatt SSB signal—believe it or not!

With WSPR's 200 Hz wide window, 33 stations (spaced at 6 Hz intervals) can simultaneously transmit while infinity + 1 stations can simultaneously receive. Normally, most stations transmit 20% and listen 80% of the time (transmit for 2, listen for 8 minutes) using the WSPR software's randomized time-sharing method allowing 165 stations to share any WSPR window in any given 10-minute period.

Note: I've rounded all values and omitted the equations, but George Smart, M1GEO, has an easy to follow mathematical analysis of WSPR on his blog.

"WSPR'ING" ON THE AIR

Dr. Taylor has written a concise WSPR user guide so I'm not going to repeat it here. If you are already digital radio modes operator you know how to setup the software and hardware, but it doesn't hurt to skim the documentation! It's preferred that you run your transceiver (or receiver) without using any built-in filters so even a simple DCR (direct conversion receiver) will suffice because it's the WSPR program that does all the work with razor-sharp 1.5 Hz wide software filters! Any dual-duo core XP (and later) or Linux computer with an accurate clock (periodically adjusted by an Internet time server, if possible) will work just fine.

The 30 metre all-digital band is very popular because no contesting or high-power operation is allowed; it's also great for digital modes experimenting but 20 metres still seems to be the popular "work-horse" band.

I've been "hooked" by the SDR (software defined radio) craze and my little FLEX-1500 QRP SDR transceiver is getting a lot of use. An SDR lets you look at a small "slice" of the radio spectrum and you can see (and hunt for) signals you may not be able to hear (analog or digital). Figure 4 shows the PowerSDR software and FLEX-1500 tuned to the 20m WSPR frequency with the WSPR software decoding the received signals.

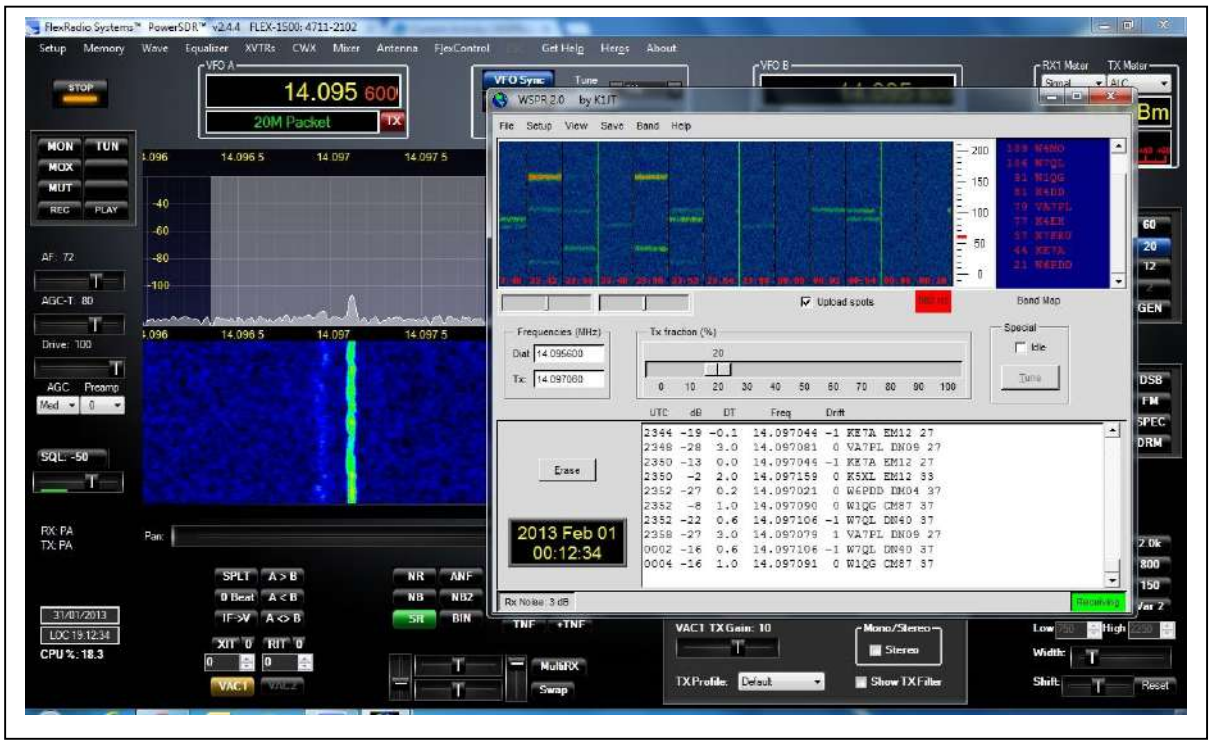
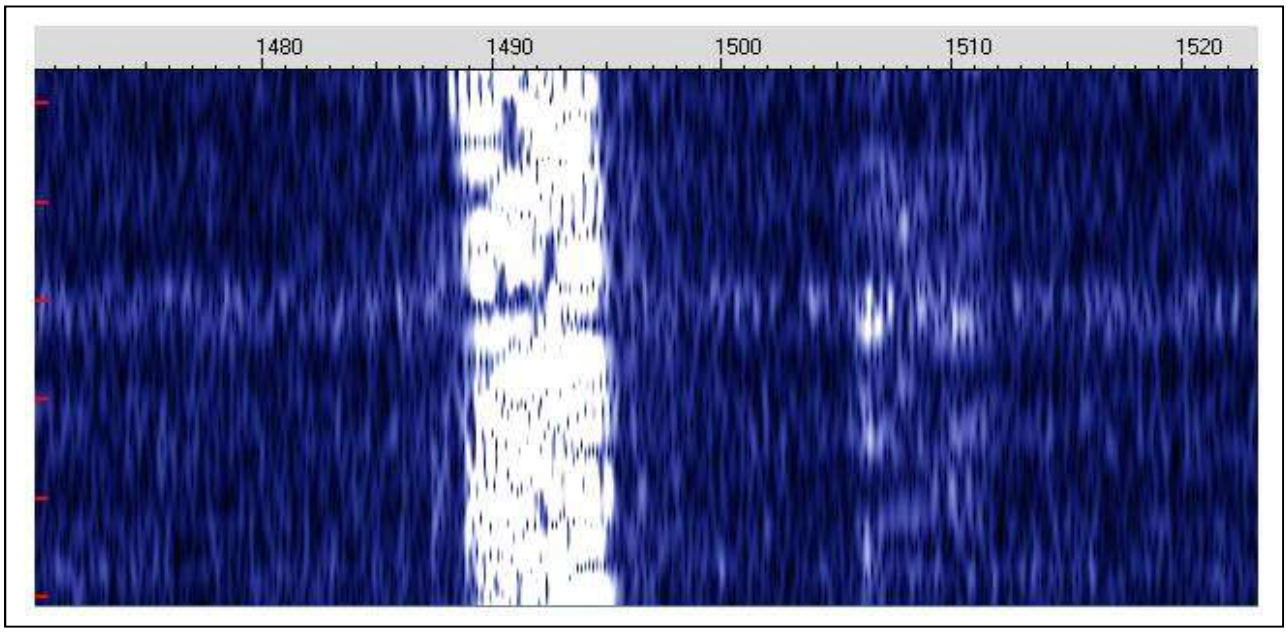


FIGURE 4: FLEX-1500 SDR DISPLAY USING WSPR ON 20 METRES

Figure 5 (next page) is a close-up "waterfall" display of two WSPR signals created by an audio spectrum analyzer program called "Spectran"; it's a very handy and free tool that also provides the waterfall display that's missing from the WSPR program for those who use "regular" analog radios. The very strong (vertical) signal centred on 1492 Hz with the slight (1 Hz) drift is a Texas station using a 5 watt transmitter is received with a 0 dB SNR (signal-to-noise ratio).

FIGURE 5: SPECTRAN WATERFALL DISPLAY OF WSPR SIGNALS



The "ghostly" vertical image (centred on 1508 Hz) belongs to a Dutch station with 0 Hz drift, running 5 watts and received with a -22 dB SNR—it's more than a 100 times weaker but was still detected and decoded by the WSPR software!

Note: Frequency calibration of your transceiver (or receiver) and soundcard combination is explained in the WSPR documentation.

LIES, DAMNED LIES AND STATISTICS!

All transmissions heard by other WSPR stations are normally uploaded to the WSPRnet Internet database (created and maintained by Bruce Walker, W1BW) and stored for retrieval by anyone interested in using the data. You can analyze the information collected on your transmissions or that of others, and you can perform any kind of statistical analysis you can possibly think of doing!

You can check out the weak-signal propagation on any WSPR band, any date and time from your location to/from other parts of the world; perhaps you want to test a new antenna design, or determine the frequency stability of your transceiver (or receiver), or see who's hearing you and vice versa, etc.

The WSPR "collective" can help you determine many things based on what you and others feed into the "hive"— resistance is futile! In Figure 5, I am "crunching" the numbers to test my transceiver/soundcard combo calibration and not looking at propagation or antenna effectiveness. The data was collected from WSPRnet using an Excel spreadsheet developed specifically for the WSPR community.

You will often see wide ranges of your spotted frequency even if you are properly calibrated because others may or may not know how-to or bother to do this, but if you collect a large enough sample of reports then perform simple statistical analysis, the results will converge near your transmit frequency. George Smart, M1GEO, has posted detailed information on analyzing the collected WSPR data with links to his YouTube time-lapse WSPR videos.

FOR THE STATISTICALLY CHALLENGED

Dave Tiller, K4DET, created an Internet based Java app called "WSPRmap Generator" that "pulls" data from the WSPRnet and creates an animated world-map display. It plots whom you spotted or who spotted you and it should be fascinating enough to easily "assimilate" you. WSPRmap can help you spot a DX station (you don't stare at your computer screen 24/7, do you?). There's also a new trend for WSPR stations to exchange eQSL "cards" based on these types of automated after the fact "contacts".

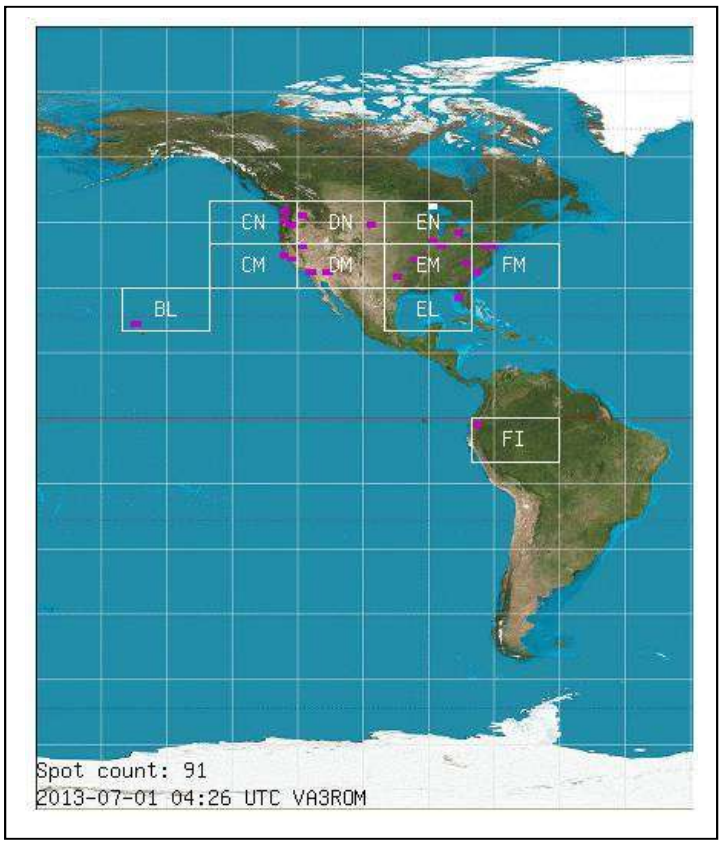


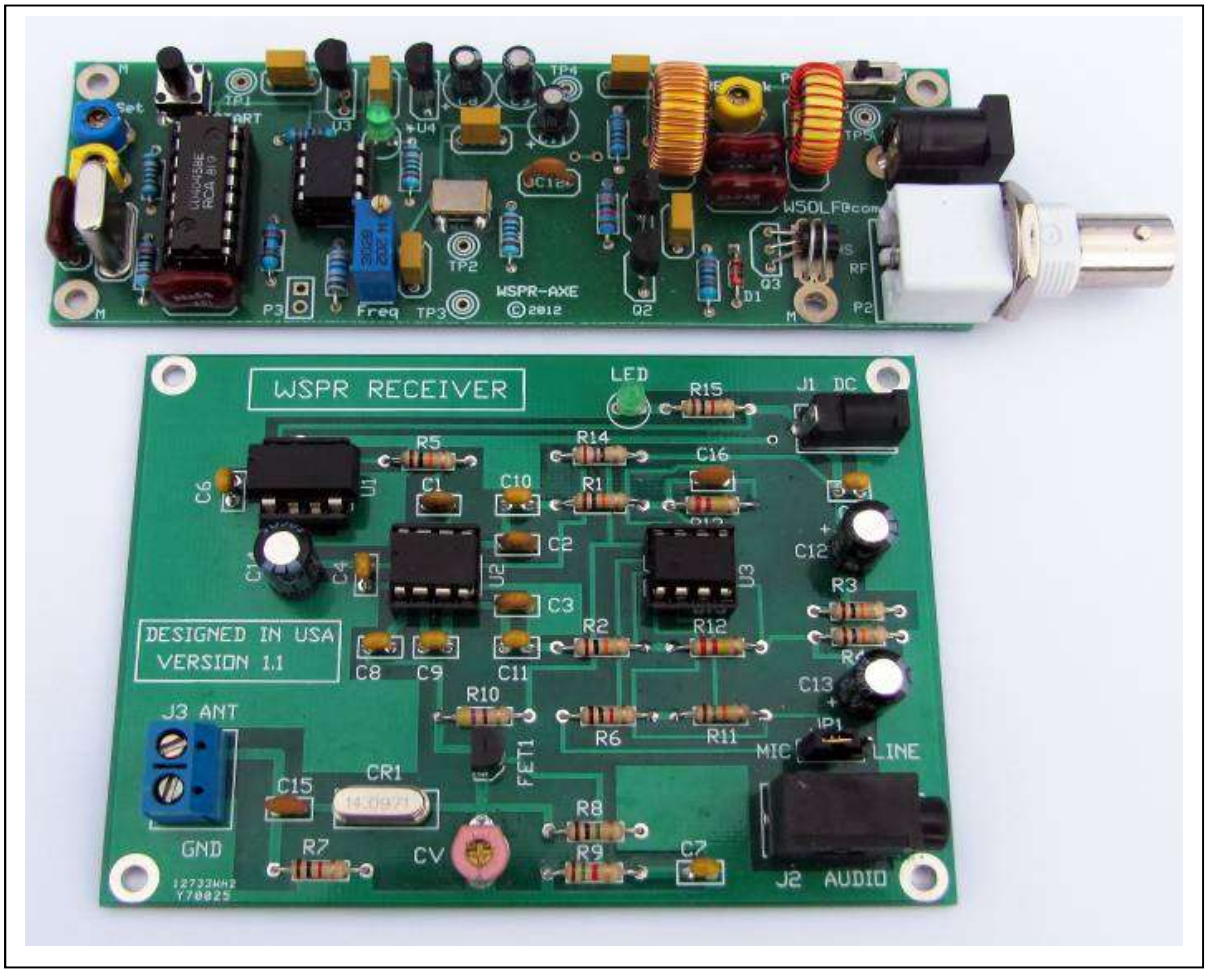
FIGURE 6: WSPRMAP DISPLAY

When I ran the map generator for the first week of July (Figure 6), a Hawaiian grid square flashed on the screen—who was it? The WSPRnet database extraction tool "said" it was a Hawaiian station transmitting at 2 watts with a -24 dB SNR (6689 km) and after looking closer at all the data, my station had also spotted a VK2 station (4 hours later) running 5 watts with a -19 dB SNR (14873 km).

BUILD A WSPR KIT OR TWO

Two single-band kits (Figure 7) are available: one is a self-contained, PICAXE MCU (8M2) controlled, QRP (1 watt) transmitter by Jay Wilson, W5OLF— no computer required. Stellar WSPR sells a receiver kit, a simple but custom DCR that plugs into any Windows/Linux computer soundcard running WSPR software. The Stellar WSPR website also has teacher/student WSPR educational lesson plans.

FIGURE 7: WSPR TRANSMITTER AND RECEIVER KITS



MY FINAL

In part 2, we'll go into more detail about the kits and also look at the experimental and educational WSPR.—73

REFERENCES AND RESOURCES

Audio Spectrum Analysis Software
http://www.weaksignals.com
http://www.qsl.net/dl4yhf/spectra1.html

George Smart, M1GEO
http://www.george-smart.co.uk/wiki/Arduino_WSPR
http://www.george-smart.co.uk/wiki/WSPR_Statistics

MEPT-JT
http://www.qsl.net/zl1bpu/MFSK/MEPT-JT.htm

Software (Apple iDevices)
WSPR Watch

Software (Windows and Linux)
http://physics.princeton.edu/pulsar/K1JT/wspr.html

WSPR Kits
http://w5olf.com
http://stellarwspr.com

WSPRmap
http://k4det.net/wsprmap

WSPRnet
http://wsprnet.org/drupal