All Things Digital

Amateur Radio for the 21st Century

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Article first published in the Nov-Dec 2013 issue of ***The Canadian Amateur***

WSPR: THE WEAK SIGNAL PROPAGATION REPORTER—Part 2

BUILD A WSPR KIT OR TWO (CONTINUATION)

Note: I've simplified the radio theory, mathematics and block diagrams.

WSPR-AXE TRANSMITTER (FIGURE 1)

Available for the 20 and 30 metre bands, this kit combines a PICAXE 08M2 MCU (microcontroller unit), 1PPS (pulse per second) clock, custom VCXO (voltage controlled crystal oscillator) with a 1 watt (class-E) transmitter. The MCU is preloaded with a [proprietary] PICAXE BASIC program along with your callsign, grid square and power (in dBm).

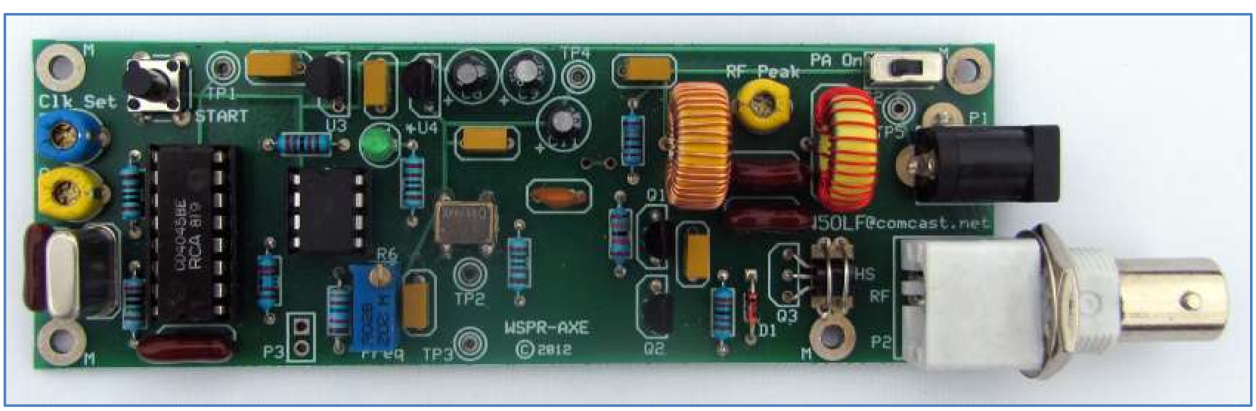
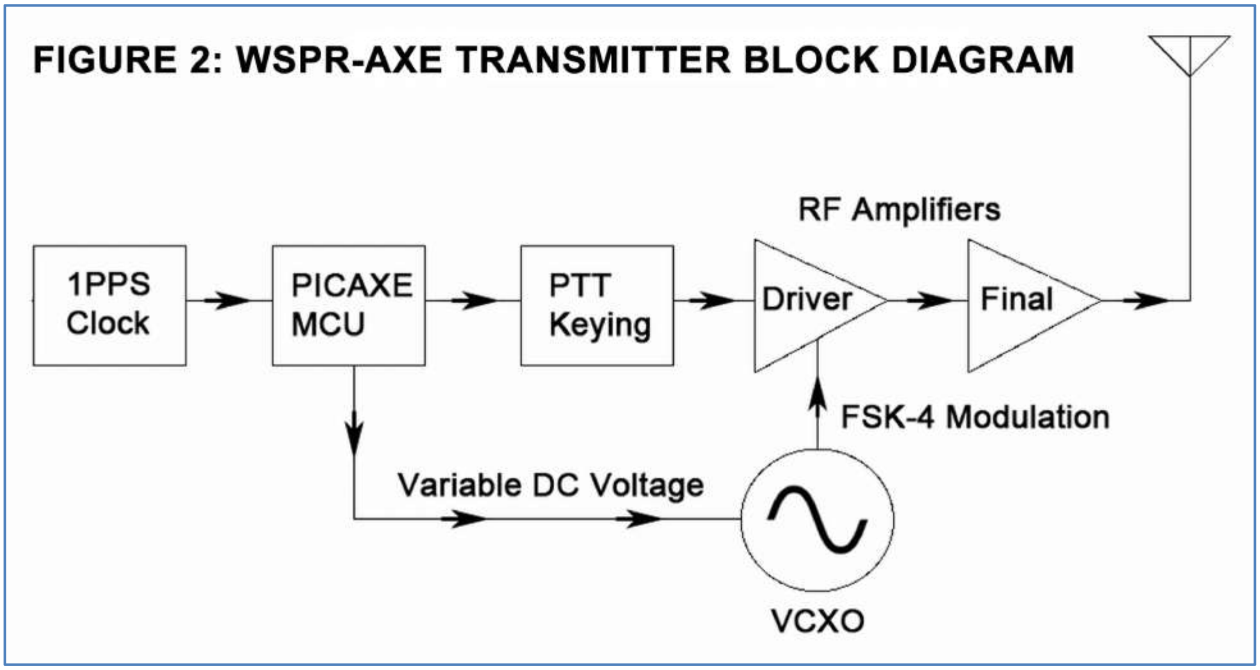


FIGURE 1: COMPLETED WSPR-AXE 20M TRANSMITTER

The 1PPS clock keeps the timing accurate for long term use but can be replaced with a GPS (with 1PPS output) for even more stability and accuracy. The VCXO generates a user-adjustable frequency inside the 200 Hz wide WSPR transceive "window" centred on 14097.100 kHz (20m) or 10140.200 kHz (30 m).



When a WSPR beacon sequence starts (on an even UTC minute), the transmitter turns on and uses continuous-phase, FSK-4 (4-level frequency shift keying) modulation to transmit your information (for 110.6 seconds). The MCU retrieves each WSPR [character] symbol (total 162) from its EEPROM (electrically erasable programmable read only memory) and uses a variable DC voltage to make slight adjustments to the VCXO frequency. A stable 12-13.8V DC power supply is preferred because battery operation can cause a slight frequency drift (a few Hz).

Note: WSPR symbols have 1.465 Hz separation: Symbol 0 = 0 Hz (no shift), Symbol 1 = 1.465 Hz, Symbol 2 = 2.93 Hz, and Symbol 3 = 4.395 Hz (shift). Also, the WSPR software is extremely tolerant and whole number integer shifts (0, 2, 4 and 6 Hz) will work just as well.

STELLAR WSPR RECEIVER (FIGURE 3)

Note: The related article "The Radio Whisperer" by George Steber, WB9LVI, describes the original receiver design and operation.

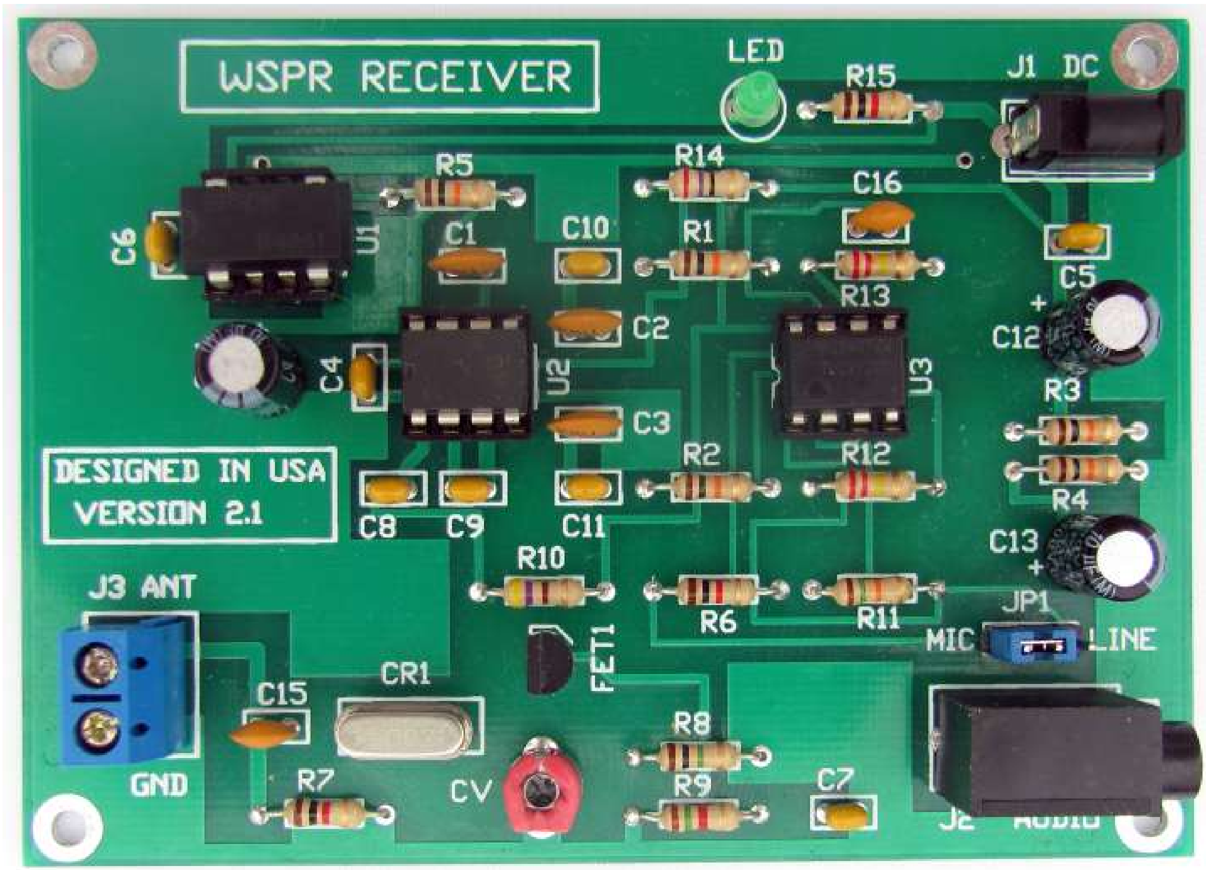
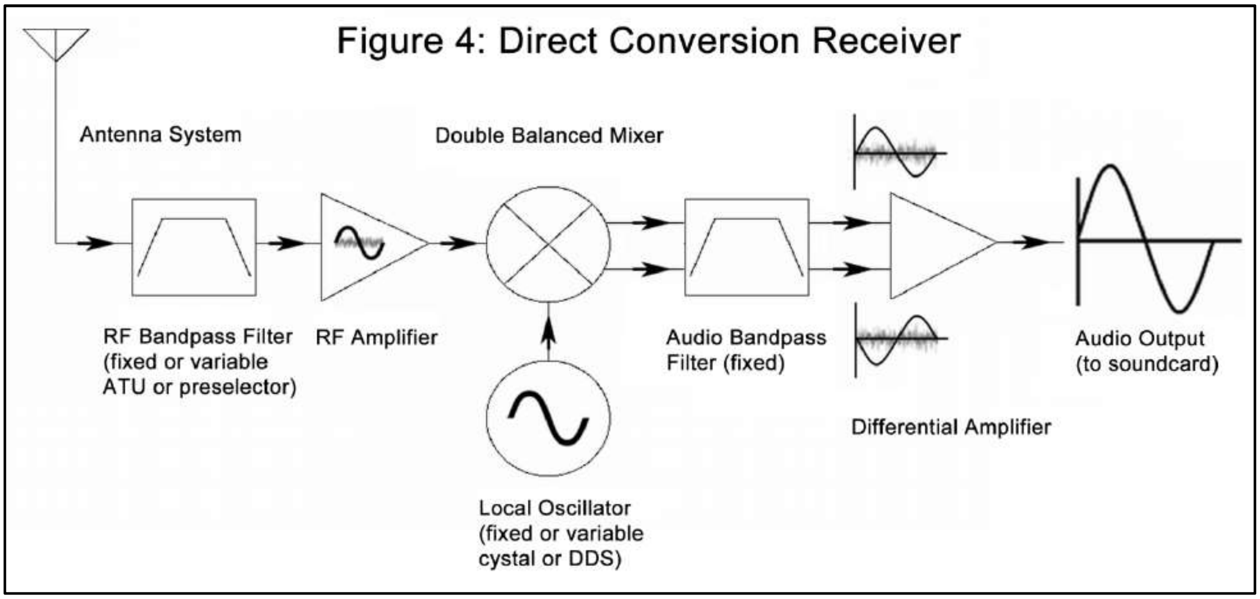


FIGURE 3: COMPLETED 20M WSPR DCR KIT

Available for the 20 and 30 metre bands, this is DCR (direct conversion receiver) or Zero-IF (0 Hz-intermediate frequency) receiver uses a custom VCXO called the LO (local oscillator). Because DCRs are very sensitive and broadband, and can easily demodulate all incoming AM/CW/SSB signals (but not FM), some method (hardware or software) is usually required to select/reject specific signals from the "crowd", and this receiver uses a custom-cut crystal to create a very narrow and frequency specific bandpass RF filter effectively blocking (for the most part) everything but the USB (upper sideband) WSPR signals.

In this DCR (figure 4), the incoming WSPR signals mix with the base LO frequency of 14,095.600 kHz (20m) or 10,138.700 kHz (30m) to create two new signals: the sum (an RF signal) and the difference (an audio signal). This mixing or "heterodyning" method of RF (radio frequency) signals was discovered and developed by Canadian radio pioneer Reginald Fessenden in 1901.



Let's "freeze" an incoming 20m WSPR signal on 14097.150 kHz and mix it with an LO of 14095.600 kHz:

14097.150 + 14095.600 = 28192.750 kHz
14097.150 – 14095.600 = 1.55 kHz or 1550 Hz

The 1550 Hz audio is feed from both mixer outputs as balanced audio which is fed through the DCR's bandpass filter and differential audio amplifier where one signal is phased-shifted by 180 degrees (inverted or differential) to remove as much noise as possible, then on to the soundcard for further DSP (digital signal processing) and decoding by the WSPR software.

WSPR IN THE CLASSROOM

Amateur Radio is an excellent classroom tool to teach any subject using simple and practical real-life applications. You must have HF privileges to use a transmitter, but anyone can use a receiver and upload data to WSPRnet with the WSPR software using an alias (SWLTB1) instead of a callsign (VA3ABC). Anyone can access the WSPRnet website and access data online and/or download and process this with an Excel spreadsheet created by Mark Hughes, GM4ISM, with enhancements by Dr. Carol Milazzo, KP4MD.

FIGURE 5: WSPR-NET DATA & ANALYSIS OF WSPR-AXE KIT TRANSMITTER

	A	B	C	D	E	F	G
1			Macro to access WSPRnet databas GM4ISM with additional analysis by Ca				
2			Number of WSPR spots		1000		
3			reported Call filter		VA3ROM		
4			Spotter filter				
5			Band Filter (Dropdown List)		20m		
6	Get Web data						
7	Band List		Date UTC	Minute index	Time UTC	Call	Frequency
8	All		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097159
9	2190-600m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097141
10	160m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097140
11	80m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097151
12	60m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097153
13	40m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097145
14	30m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097143
15	20m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097143
16	17m		07/09/2013	59795548	4:28:00 PM	VA3ROM	14.097145

	Statistics							
17								46
18		Date UTC/T	Time U	Frequency	SNR	Drift	dBm	47
19	Mean	2013-09-07	12:44	14.097144	-13.7	-0.148	30	44
20	Median	2013-09-07	14:34	14.097144	-14	0	30	45
21	Mode	2013-09-07	15:38	14.097145	-19	0	30	45
22	Maximum	2013-09-07	23:58	14.097181	6	3	30	28
23	Minimum	2013-09-06	0:04	14.097085	-30	-3	30	45
24	Standard Deviation	1900-01-00	8:29	1.17909E-05	6.554	0.6173	0	61
25	Sample Variance	1900-01-00	3:00	1.39025E-10	42.955	0.381	0	56
26	Standard Error	1900-01-00	0:16	3.7455E-07	0.2082	0.0196	0	45

With reference to Figures 5: Note that not all stations are reporting my exact transmit frequency (or drift) but are equally above and below it.

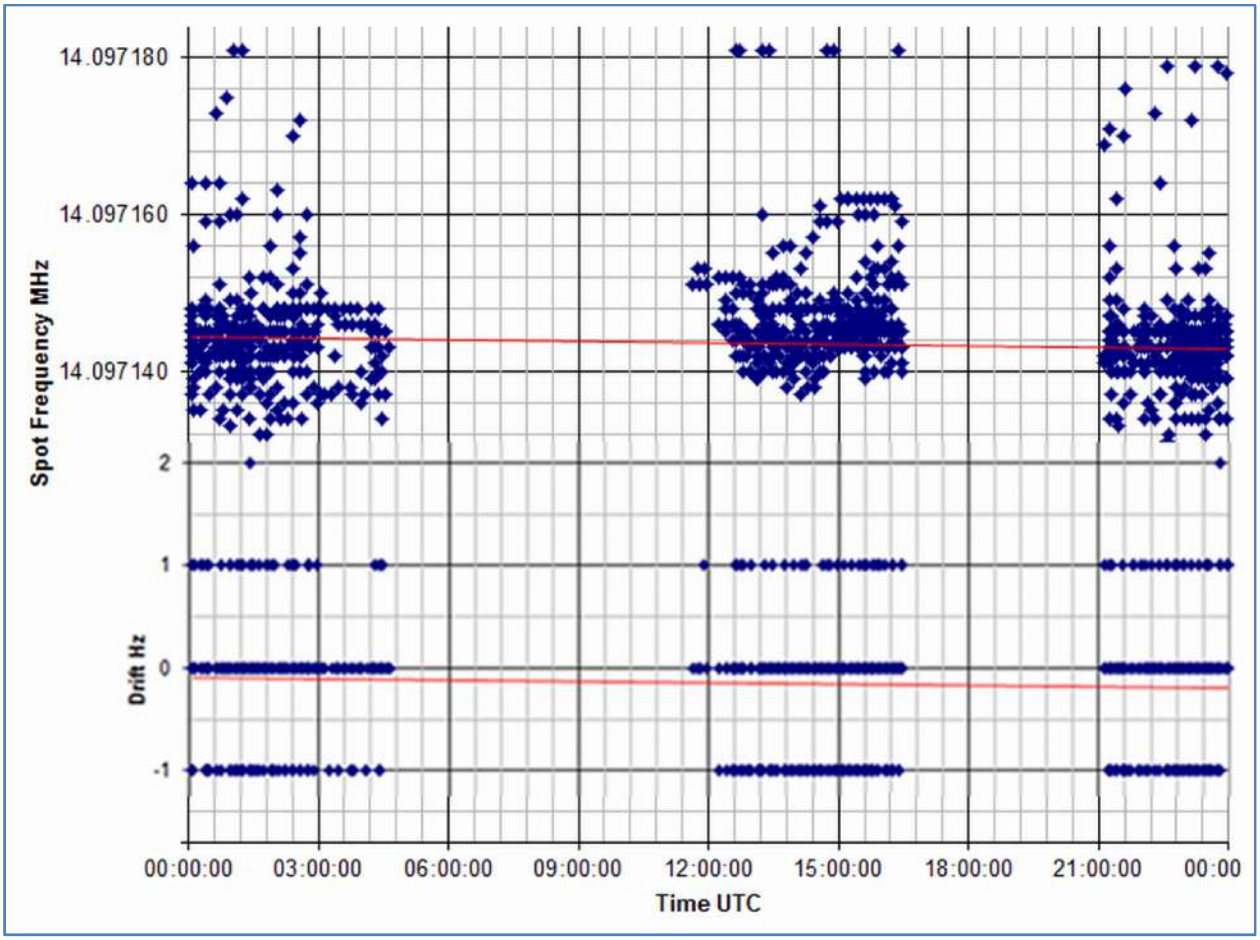


FIGURE 6: WSPR-AXE TRANSMITTER KIT REPORTED FREQUENCY AND DRIFT

Note: Frequency calibration of your transceiver (or receiver) and soundcard combination is explained in the WSPR documentation. In figure 6, the "public consensus" is that my transmitter frequency is around 14.144 MHz (which it was) with a slight drift of 0.15 Hz (this is very good) in the measured 24 hour period.

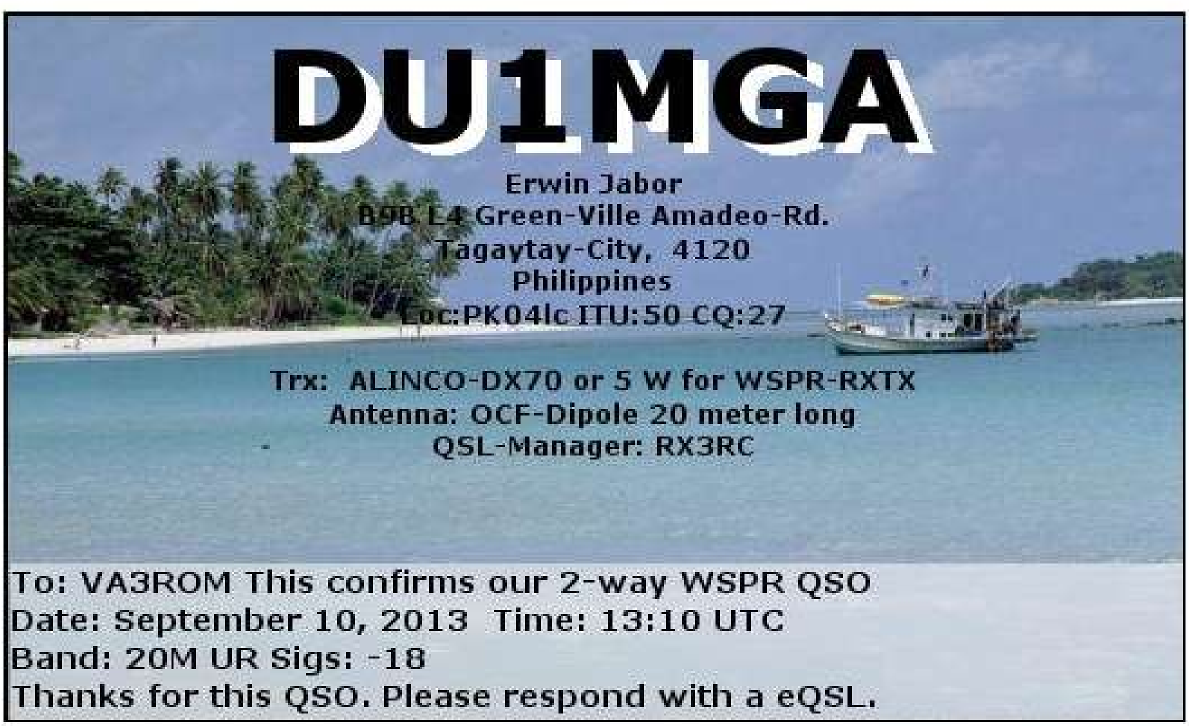
However, in regard to calibration, in the end it just doesn't matter because if enough data is received from the "hive-mind collective" (100 different station reports is a good sample size for this purpose), an amazing thing happens when you "crunch" the numbers—they will converge very close to your transmitter frequency (and any drift)! This is statistical "anomaly" is based on the well-known "guess the number of jelly beans in a jar paradox" and is used by pollsters to predict electron outcomes or to take the public's "pulse" on various topics.

You can try different antenna types and compare their effectiveness and reception patterns to determine if WSPR can “see” any difference (with its 1 dB resolution), or compare diurnal and seasonal VHF/UHF/HF propagation variations and how the sun, ionosphere and Earth interact to affect this. Or learn about the Maidenhead Locator System and how latitudes and longitudes are converted to alphanumeric groups (it’s more efficient and less error prone to use “EN58” or “EN58JK” with voice or digital signals).

The Stellar WSPR website has educational links and resources, plus sample lesson plans developed by Professor Lynne Reynolds, Ph.D., with suggested student projects and activities.

Many Hams and radio hobbyists also exchange WSPR QSL (acknowledgement of reception) cards (Figure 7) and these can make for interesting classroom topics of study and discussion. And less boring to look at than numbers and graphs ☺

FIGURE 7: SAMPLE WSPR QSL CARD



Timestamp	Call	MHz	SNR	Drift	Grid	Pwr	Reporter	RGrid	km	az
2013-09-10 13:10	DU1MGA	14.097088	-18	0	PK04lc	5	VA3ROM	EN58jk	12449	21

MY FINAL

Well, that's it for WSPR—for now. The next column will look at the "WebSDR" which is a combination of SDRs (software defined radios) with the resources of the Internet to allow many listeners at once to operate them.—73

REFERENCES AND RESOURCES

Amateur Radio in the Classroom
http://www.arrl.org/amateur-radio-in-the-classroom
http://www.nasa.gov/audience/foreducators/teachingfromspace/students/ariss.html#.VLxZRtLF-Sp

Dr. Carol Milazzo, KP4MD
http://www.qsl.net/kp4md/wspr.htm
http://www.qsl.net/kp4md/wsprmodes.htm
http://www.qsl.net/kp4md/wspr_analysis.xls

eQSL
http://eqsl.cc/qslcard/Index.cfm

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

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

The Radio Whisperer
www.kc4zvw.org/files/wspr-receiver.pdf

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

WSPRnet
http://wsprnet.org/drupal