WSPR TESTING MY AUTOTUNED SMALL MAGNETIC LOOP ANTENNA
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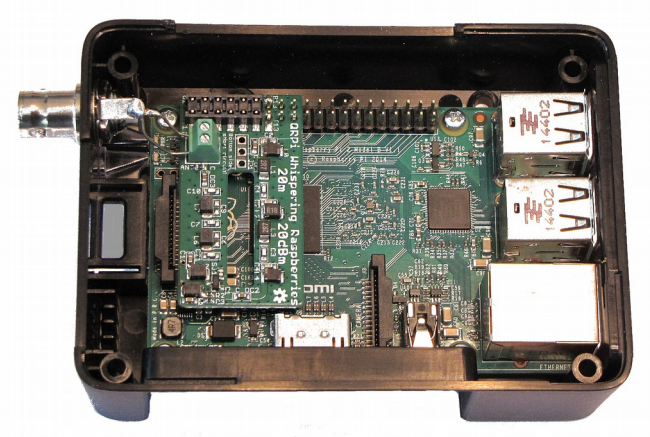
My interest in WSPR, Weak Signal Propagation Reporter, is to gain an understanding of the capability of my autotuned small magnetic loop HF antenna. If you are a member of the Radio Amateurs of Canada you may refer to Bill Karle's column "Making Waves ... Taking Measure" in the September/October 2017 issue of *The Canadian Amateur,* where Bill described WSPRNet as one way to measure the transmitting effectiveness and propagation environment of an amateur radio signal. A primary source for information about WSPR on the Internet is WSPRNet.org. The small magnetic loop antenna and its autotuner (the latter my design) is described on my website: acornwall.ca .

A special low power radio transmission with the WSPR format is received by WSPR monitoring stations all over the globe and on most amateur bands through UHF. Signal content consists of call sign, maidenhead location, and transmitter power. The transmission is precisely timed, and at a precise frequency; it takes about 1 minute and 50 seconds to be sent. WSPRNet aggregates, catalogues, and displays reception reports in real time. As an indication of signal success, the more receptions, especially from far away, the better.

For $29 US I obtained from TAPR (https://www.tapr.org/) a 'QRP TX Shield for WSPR on 20 Meters' module (commonly referred to as QRPi Shield), comprising an integrated 100 mW 20 metre band transmitter and low pass filter on a small circuit board. The QRPi Shield plugs into the port pins of a Raspberry Pi computer running WSPR software (with the Debian Raspbain OS). In my installation the Pi is a model 2. The picture below shows the QRPi Shield installed on the left in the Pi.

RASPBERRY PI 2 WITH QRPi SHIELD INSTALLED (on left)



I live in a dense forest of trees with a hill to the East. With summer foliage in bloom the direction of propagation is selective. I normally use a Hustler 6-BTV (7.3 metres tall) trapped vertical antenna, in the yard about 30 metres away from the house, that can kind of push through or over these obstacles. Under these conditions, however, a small magnetic loop antenna elevated only 2 metres off the ground would be even more handicapped. To give this antenna a clearer view of the world I wanted to conduct a trial from an open field at the back of my property. There is no mains electricity nor Internet available in the field.

To satisfy WSPR's requirement of starting a transmission within about 1 second of the beginning of each even numbered minute, and to be within a few cycles of the given frequency, the Raspberry Pi routinely receives over the Internet highly accurate NTP (Network Time Protocol server) time data to correct its on-board clock and to measure and correct transmitter frequency deviation. My conundrum was how to use the QRPi Shield where there is no Internet to access NTP. Indeed, NTP is not needed if, once started on time, the on-board clock remains accurate, and the Pi oscillator controlled frequency is stable. This is a lot to ask of an ostensibly hobbiest-educational computer but it might be possible.

At home, in my cool, constant temperature radio-electronics-computer workshop, I connected the Pi to a regulated 5 V power supply and started the WSPR program, allowing it continuous access to NTP via WiFi. I periodically connected the QRPi Shield to the transmission line supplying the Hustler vertical for about ten minute periods. Throughout there was a satisfactory number of WSPR reception reports to tell me that, as set up, the QRPi Shield was working properly. Over a period of 2 hours and 40 minutes the Pi automatically adjusted the 20 metre band WSPR transmitting frequency, initially at the rate of -5.61679 PPM (parts per million), then -4.181103 PPM, and at the end -3.82719 PPM The adjustment was settling down the longer the Pi operated. In the absence of an Internet NTP connection to automatically adjust the transmitting frequency, a PPM frequency offset can be entered as a constant parameter into the WSPR computer program.

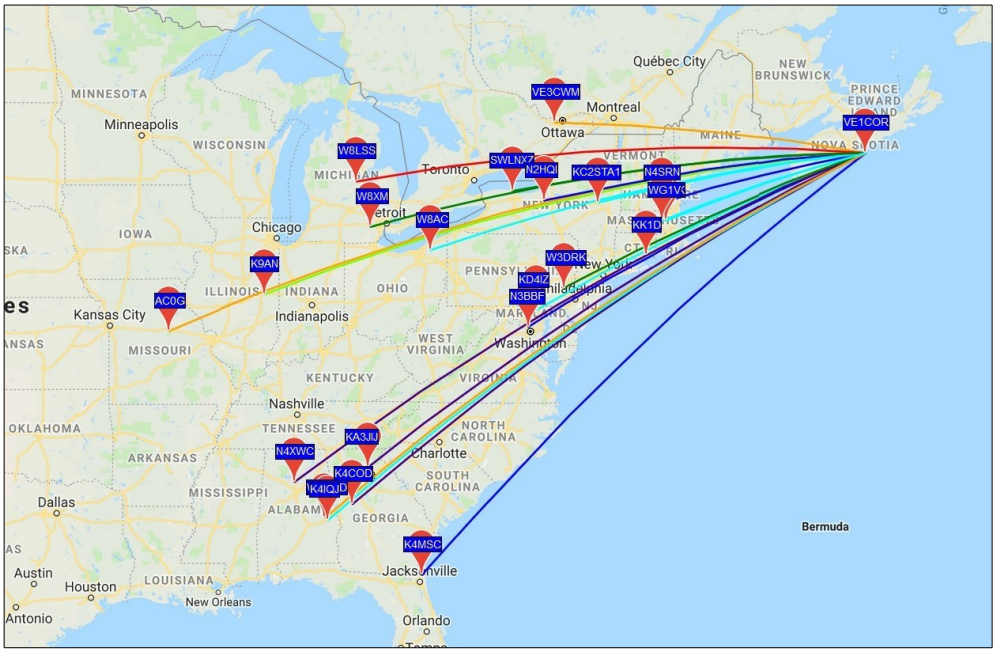
Next I checked the continued accuracy of my Pi's on-board clock when NTP is not available to make corrections. Running the WSPR program I let the Pi synchronize its clock with the NTP then I disabled WiFi on the Pi for the next 49 hours and 12 minutes. During this time I periodically connected the QRPi Shield to the Hustler vertical for ten to twenty minutes then checked WSPRNet for the 'last 10 minute' reception reports. There were numerous monitoring station reports throughout the trial period, and no degradation in the number of reports was evident. This indicated satisfactorily consistent time-keeping accuracy. I stopped the trial after two days because the process was becoming tedious. Two days of workability was longer than I needed.

There was one other condition that required investigation: would the QRPi Shield's 100 mW output be sufficient to be detected by the small magnetic loop antenna autotuner. During tuning the autotuner senses the power being radiated from the small magnetic loop antenna with the objective of achieving the maximum output (at the transmission frequency). Usual tuning wattage is in the range of one to five watts (once tuned higher wattage can be transmitted) with a signal-detecting 'sampling antenna' about 15 cm long (times two - it's a dipole). The sensitivity of the autotuner can be changed by reducing or lengthening the sampling antenna. To detect the 100 mW power of the QRPi Shield I arbitrarily increased the sampling antenna length to about 70 cm (times two). With this modification the autotuner worked normally. (An autotuner generated computer report during automatic tuning with the

QRPi Shield transmitting 100 mW indicated that a sampling antenna somewhat shorter than 70 cms would suffice.)

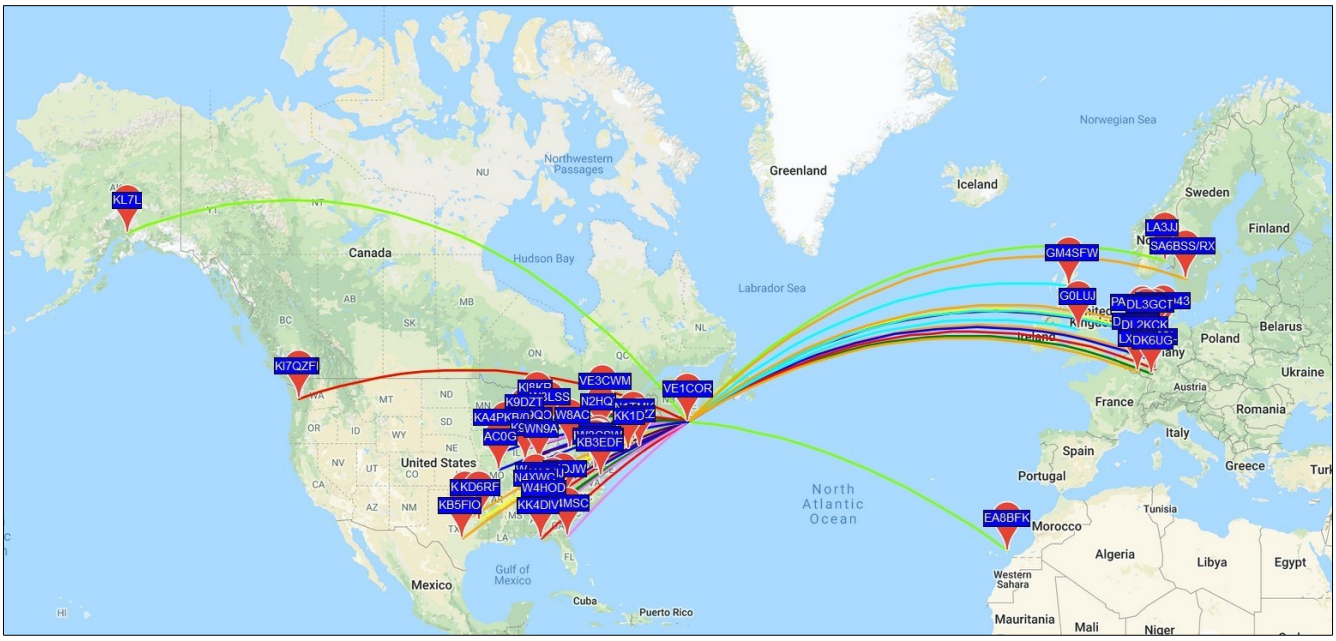
The initial field trial occurred on June 30, 2018 from 17:54 to 21:04 UTC. The antenna was pointed approximately east-west; it is directional. The trial stopped when the Pi ceased to function. It was an unusually hot, sunny day in Nova Scotia, Canada. The Pi and the 12 V gel cell powering it (through a 12V to 5V down-converted) were not adequately shaded from the sun and became very warm. I suspect that heat caused the Pi to quit prematurely. There were 285 WSPR reception reports from 20 monitoring stations during the 3 hours 8 minutes trial. Until overcome the Pi with QRPi Shield was functioning well. All of the spots were from the West or Southwest as can be seen in the map below, copied from WSPRNet.org. The closest monitoring station was N4SRN 703 kms away, and the farthest ACOG, 2477 kms.

WSPRNet MAP OF MONITORING STATIONS HEARING QRPi SHIELD 100 mW SIGNAL
3 HOURS 8 MINUTES JUNE 30



I repeated the field trial on July 2 and July 3, starting at 17:28 July 2, and ending at 3:03 UTC July 3; a total of 9 hours and 35 minutes. The Pi with QRPi Shield (and gel cell battery) would have continued transmitting for many more hours, but I turned it off. The time was getting late (midnight local time) and I wanted to take the antenna and WSPR transmitter in from the field before going to bed. As previously, the orientation of the antenna was approximately east-west. There were 672 reception reports from 47 monitoring stations, many from far away, demonstrating that the autotuned small magnetic loop antenna was doing a good job. The WSPRNet map on the next page shows the location of the monitoring stations hearing the antenna's signal. The closest station was FN41ro 688 kms away, and the farthest BP51ip, 5593 kms. It was heartening that many European monitoring stations, to the East, reported hearing the signal.

WSPRNet MAP OF MONITORING STATIONS HEARING QRPi SHIELD 100 mW SIGNAL
9 HOURS 35 MINUTES JULY 2 and 3



Two amazing things were occurring during these trials. First is that a 1/10 watt signal from my autotuned small magnetic loop antenna could be heard and decoded as far away as 5593 kms, and be consistently heard and decoded at distances more than 3000 kms distant (20% of the total spots in the July 2-3 trial). Second is that there is a myriad of hams and short wave listeners around the world who voluntarily provide reception reports to WSPRnet. Thank You all and Thank You WSPRNet!