

All Things Digital

Amateur Radio for the 21st Century
O27

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QRSS CW—SENDING SLOW CONTINUOUS WAVE: PART 1

INTRODUCTION

Slow continuous wave (CW) first appeared in the mid 1990's when Amateurs with experimental licenses began attempting two-way communications on the low and very low frequency (LF/VLF) bands. They coined the new term "QRSS", which is derived from the international Q-code "QRS" for "Send more slowly." With high atmospheric noise levels, narrow bandwidths, and transmitter power restrictions (1 watt or less), on/off carrier keying (OOC/OOK) Morse code was the only viable method (at the time) to use in combination with digital signal processing (DSP) programs and computer soundcards to display any received signals (see Figure 1, next page). Because of the incredibly slow signal transmission speeds (data rates) involved, where one "dit" was usually keyed for 60 seconds or longer, sending QRSS CW manually and/or decoding it aurally was/is next to impossible to do.

Fast forward 20 years; the software, hardware, and some very new and novel techniques have improved things tremendously. The original mode is called QRSS CW, but it's no longer the only game in town because variants include dual-frequency shift keying CW (DFCW or DFSK CW) and frequency shift keying (FSCW or FSK CW). Other "graphical" CW versions consisting of ramps, slants, waves, triangles, and many other symbols/shapes are also used, along with a variant of Hellschreiber (slow Hell). Most CW modes (Morse code is but one of many) are called "pseudo-digital" or "fuzzy logic" because they are decoded using the human senses (sight, sound, touch, etc.), and they don't require/need or have start/stop, control, synchronization, and/or error correcting bits and bytes, which are required by "true" digital data modes.

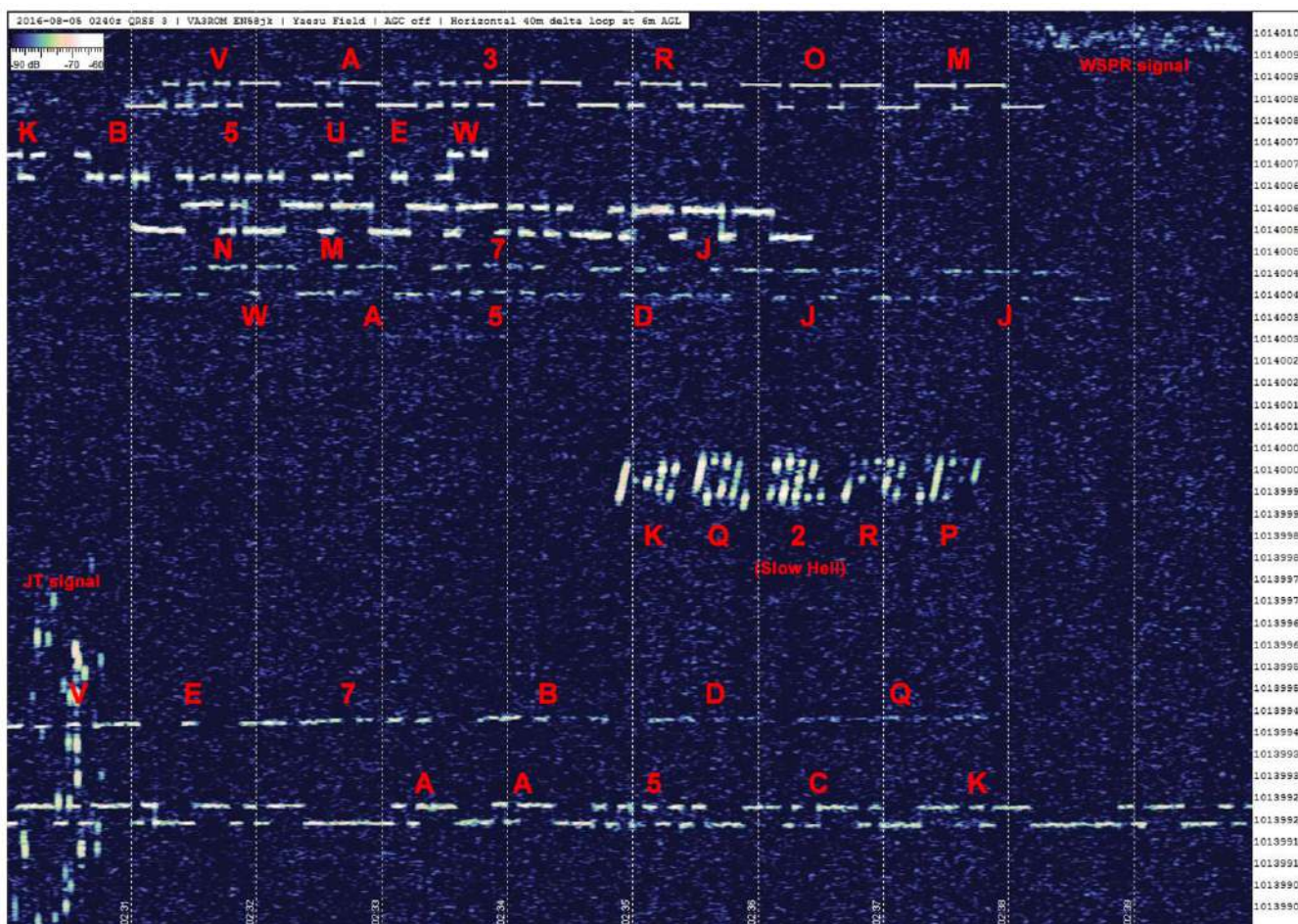


FIGURE 1: SAMPLE SIGNALS

Thirty metres is a great data modes band because no high power stations or voice are allowed.

MORSE DEFINED

The Morse code has five parameters or possible states: short on, medium on, short off, medium off and long off. Proper timing/spacing is everything when it comes to correctly sending and/or receiving the code. Its smallest symbol (unit) is the “dit” (dot), and it’s defined as having a value of one time length measured in seconds, milliseconds or microseconds, etc., and everything else is derived from it (see Table 1, next page).

Note: There is a commonly used sixth but unofficial parameter called the “long dah” representing the number zero (normally five dahs). This abbreviated or cut form is transmitted as one noticeable longer single dah when using a hand key, or as three dahs when using an electronic keyer.

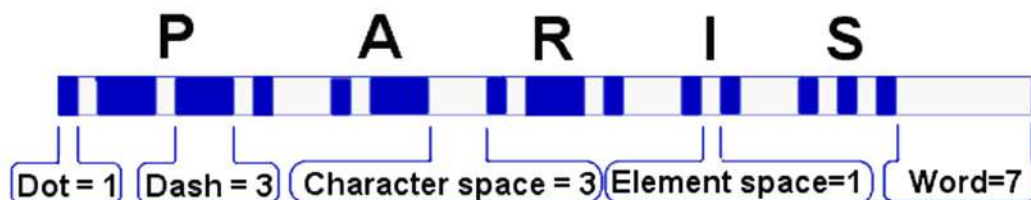
TABLE 1: MORSE CODE DEFINED

The basic Morse code element is the dot (dit) and all other elements are defined in multiples of the dot length.

Dot (dit) length	1 time unit
Dash (dah) length	Dot length x 3
Pause between character elements	Dot length x 1
Pause between characters	Dot length x 3
Pause between words	Dot length x 7

Character speed in words-per-minute (WPM) is related to the dot length (T) in milliseconds (ms) by the following equation: **$WPM = 1200 / T$**

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If the cypher group "PARIS" is sent ten times in one minute then transmission speed equals 10 words-per-minute and the dot length equals 120 milliseconds.

"PARIS" image courtesy www.nu-ware.com

LAYING DOWN THE "LAW"

Now, why would we want to use any QRSS and/or similar weak signal analog/digital data modes in the first place? Well, because of a quirk of physics, when the transmission speed (data rate) slows down the bandwidth used and transmitter power needed is also reduced, and the signal-to-noise ratio (SNR or S/N) is increased. This was brilliantly proven by C. E. Shannon [Shannon-Hartley theorem or "Shannon's law"] A *Mathematical Theory of Communication* (1948). It states that any communication system, no matter how complex it may be, is only defined by two things: the signal bandwidth used and the noise (anything interfering with the signal is considered "noise"). Shannon also introduced the concepts of a communication "channel" with a channel "limit". Think of it as different types of roads with various speed restrictions; you can't go faster than the road will allow for or else you will crash.

Continuous wave is a simplified form of amplitude modulation (AM), so it radiates “sidebands” (harmonics) that travel above and below the keyed carrier frequency. If not properly contained these produce “hard keying” or “key clicks”. This is very problematic at as Morse code sending speeds increase because (in severe situations) the rapid carrier on/off states can produce key clicks heard hundreds or thousands of hertz (or even more) above/below the carrier (see Figure 2). To reduce them, we can slow down transmission speed, reduce carrier power, shape the on/off keying so that it’s “softer”, use “sharper” RF filters, or any combinations of these.

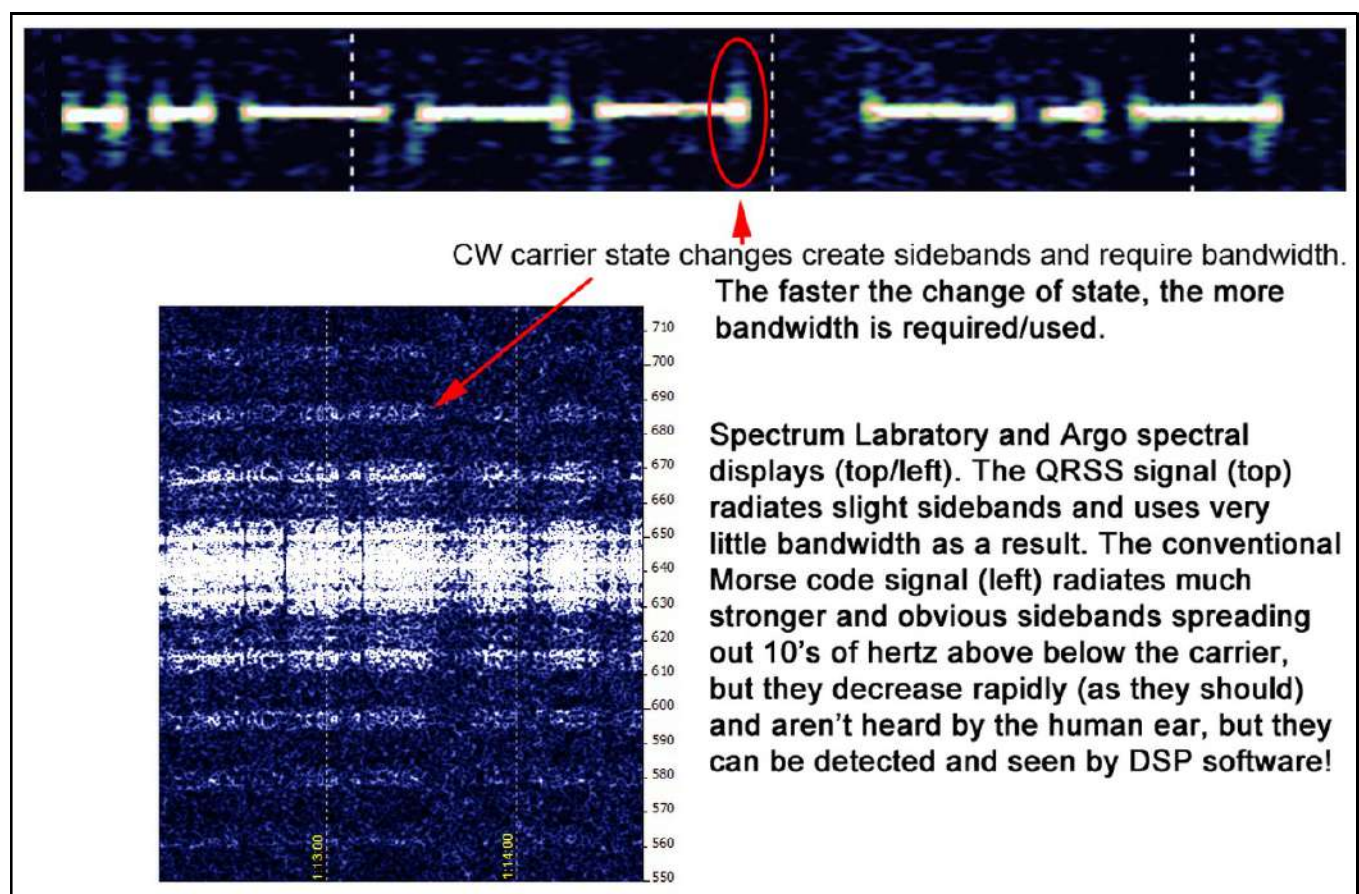


FIGURE 2: HARD KEYING AND SIDEBANDS

The CW bandwidth is solely dependent on the carrier keying speed (data rate), and its “shape factor” or “K” (see Table 2). This is how fast the leading/trailing edges of the wave changes states or the rise/fall (attack/decay) of each on/off cycle. For conventional speed Morse, the recommended K is just under five milliseconds (ms), and this minimizes hard keying but also avoids “soft keying” (which is just as bad), and prevents unnecessary bandwidth use caused by sidebands. Many simple QRSS transmitters are hard keying (where K = 1), generating square waves rich in harmonics, and therefore they rely heavily on their very slow keying and RF filters to soften and shape the signal.

TABLE 2: CW BANDWIDTH VS. KEYING SPEED

Bandwidth (BW) in hertz (Hz) used by an unshaped carrier is approximately: $BW\ (Hz) = 0.833 \times WPM \times K$ (where $K = 1$) $WPM = 1200 / T$ and $T = 1200 / WPM$ <i>‘WPM’ is transmission speed in words-per-minute.</i> <i>‘T’ is dot length in milliseconds (ms). I.E. 10 sec/dot = 10000 ms.</i> <i>The value ‘0.833’ gives an approximate conversion to the bits-per-second (bps) channel symbol rate.</i>		
Speed	Optimum BW	SNR v. 12 WPM
12 WPM	10 Hz	0 dB
8 WPM	6.67 Hz	+1.8 dB
4 WPM	3.33 Hz	+4.8 dB
1 sec/dot	1 Hz	+10 dB
3 sec/dot	0.33 Hz	+14.8 dB
10 sec/dot	0.1 Hz	+20 dB

Table courtesy Rik Strobbe, ON7YD

QRSS MODES

Figure 3 depicts the commonly used modes. Current practice is to transmit using the upper sideband (USB) regardless of the band (all frequency shifts are up). Most other data modes have also adopted this except for a few legacy mode exceptions.

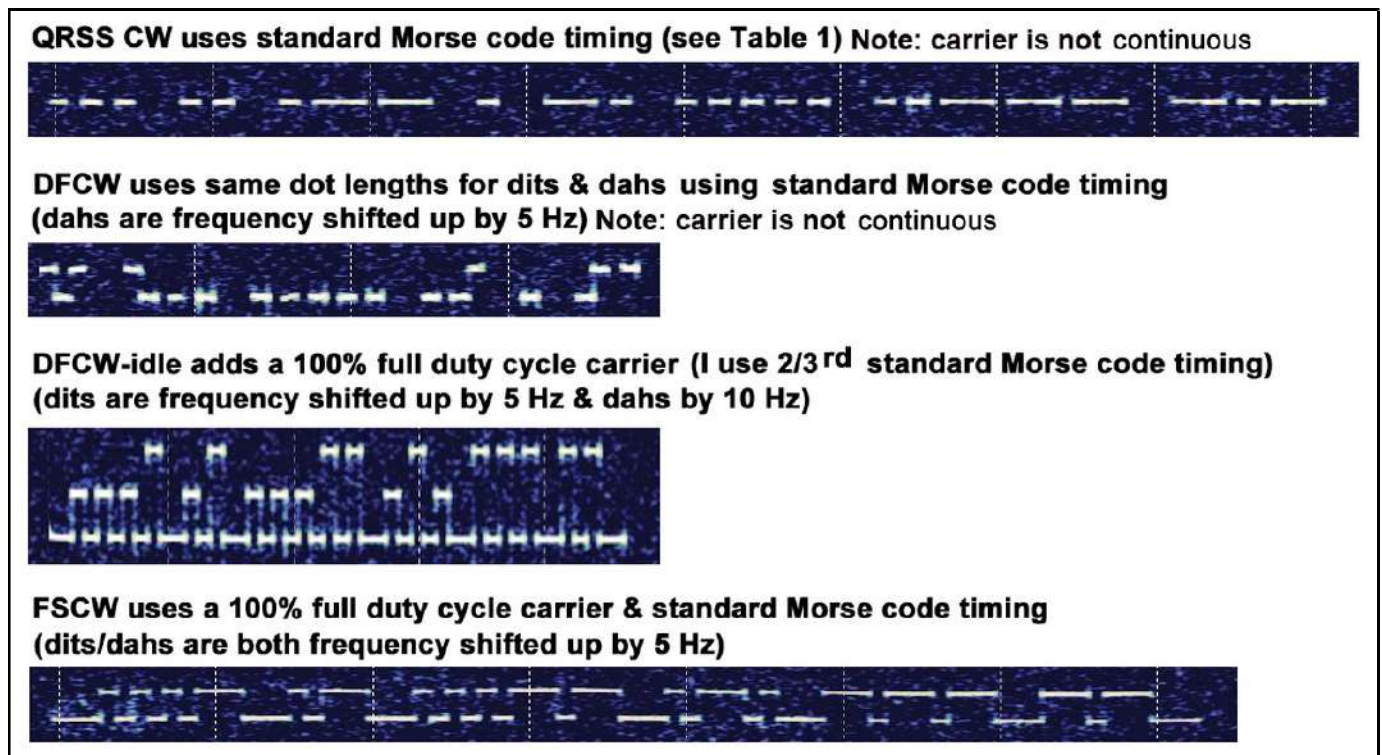


FIGURE 3: COMMON QRSS MODES

TRANSMITTING

QRSS signals are easily transmitted using any old Windows XP/Linux/Apple computer/tablet/notebook, or the latest Android smartphone combined with DSP software, a soundcard-to-radio interface, plus a frequency stable single sideband (SSB) or CW radio (see Figure 4, next page). Audio frequency shift keying (AFSK) is normally used with SSB radios, but you can easily convert the audio to OOK to key CW only radios. For reception, you just connect an audio patch cord to your radio's audio out and computing device's soundcard line or microphone input.

FIGURE 4: EASY QRSS HARDWARE AND SOFTWARE



Free DSP software lets you view and “grab” (screen capture) QRSS and/or other radio signals using analog radios (frequency stability is required), or newer software defined radios (SDRs). Screen grabs can be automatically saved on your computer and uploaded to personal and/or world-wide web servers for sharing your data with others worldwide.

EVOLUTION

In early 2010's, new very low-power (QRPp) FSK digital modes called the “weak signal propagation reporter” (WSPR) along with “JT9” and “JT65”, all invented by Joe Taylor, W1JT, pretty much superseded conventional QRSS CW for use as propagation beacons and two-way weak-signal communications. And that should have been that, but the maxim “adapt or die” for a biological species also applies to intellectual concepts/ideas.

The brilliant idea of applying an astrophotography enhancement technique called “stacking” (image noise averaging) came to the rescue, and we can now digitally “dig” extremely weak QRSS signals out from the random background atmospheric noise far better than any current Amateur Radio data mode can. What makes stacking even more effective was another novel concept of using time synchronized ten minute transmission windows or frames, adopted because our call signs easily “fit” inside a frame using 6 second dot lengths (“QRSS 6” or “QRSS 3 slow”). And because these QRSS signals are unchanging patterns repeating every ten minutes (not random), stacking multiple frames enhances weak signals and reduces random atmospheric noise (their patterns change from frame to frame). Unlike a digital data mode signal, any missing bits here and there (pun intended) won’t affect our analog brain’s fuzzy logic decoding ability because it usually can make sense out of repeated patterns (see Figure 5).

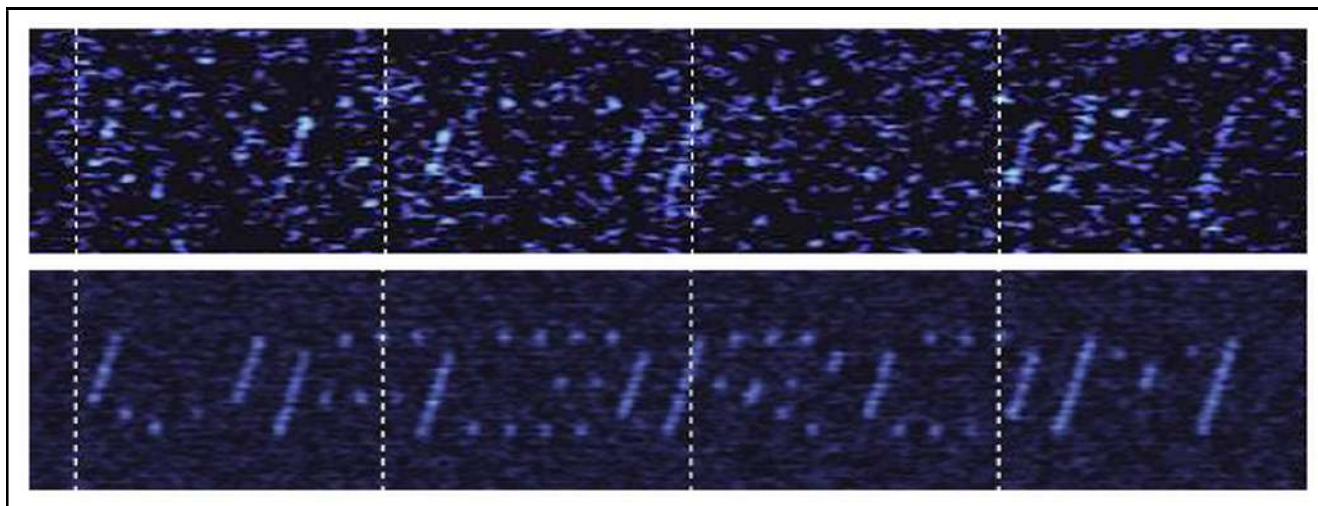


FIGURE 5: QRSS IMAGE STACKING

Can you see me now? Compare the SNR differences of my received QRSS beacon between the top (unprocessed) single frame and the bottom image (stack of ten frames). Gimp/Photoshop stacked Layers (Normal) opacity percentages used: 100, 50, 33, 25, 20, 17, 14, 13, 11 and 10. This is called the “harmonic mean”, and it produces much higher SNRs than the simpler arithmetic mean (average) can.

Another QRSS advantage is the fact you can collect and store hundreds of sequential images (grabs) on your hard drive, and then use a graphics program (like Irfanview) to rapidly flip through them and create the illusion of motion. All time frame synchronized QRSS beacons will appear frozen in frequency (space) and time, while everything else around them moves around and/or through them in the “movie”.

This is much like using an astrophotography blink comparator to search static background star fields looking for things that aren't part of the background (or noise), but changes or moves as time goes by.

SHARING

Amateur Radio data has become very, very important to professional and amateur scientists and researchers who have limited resources (staff, time and money). This didn't go unnoticed by doctoral student Nathaniel Frissell, W2NAF, who was the lead on a *Space Journal* research paper.

“Amateur radio reporting networks, such as the Reverse Beacon Network (RBN), PSK Reporter, and the Weak Signal Propagation Network, are powerful tools for remote sensing the ionosphere. These voluntarily constructed and operated networks provide real-time and archival data that could be used for space weather operations, forecasting, and research. The potential exists for the study of both global and localized effects. The capability of one such network to detect space weather disturbances is demonstrated by examining the impacts on RBN-observed HF propagation paths of an X2.9 class solar flare detected by the GOES 15 satellite. Prior to the solar flare, the RBN observed strong HF propagation conditions between multiple continents, primarily Europe, North America, and South America. Immediately following the GOES 15 detection of the solar flare, the number of reported global RBN propagation paths dropped to less than 35% that of prior observations. After the flare, the RBN showed the gradual recovery of HF propagation conditions.”

Can there be any better promotion of Amateur radio and a strong incentive to get involved? Most radio hobbyists don't use their equipment for more than a few hours a day, so why not receive signals and upload telemetry during the “down” hours? Badly needed and invaluable are data collected from “north/south of 60” stations either full or part time. While there may not be many active Amateurs in Canada's north and far north, there are a lot of shortwave radio listeners (SWLs) and schools who can participate as receive only stations, and share data with others via Internet servers.

THE PRESENT

QRSS is mainly used for one-way “manned experimental propagation transmitters” (MEPTs) instead of for two-way communication. It has become the domain for those who like to build, tinker, learn, design, research and/or experiment. Ubiquitous and inexpensive microcontroller units (MCUs) such as the PICAXE, Raspberry Pi, and Arduino Uno, control frequency agile direct digital synthesis (DDS) modules in combination with simple QRPp transmitters (see Figure 6).

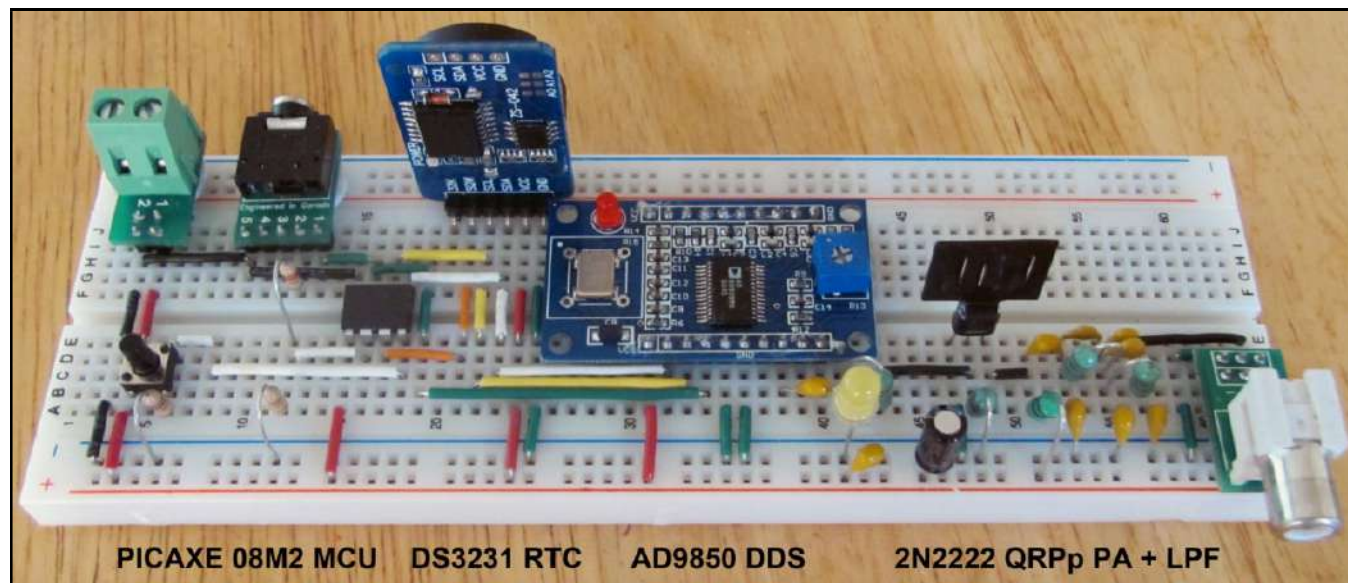


FIGURE 6: PICAXE MEPT

The Revolution Education PICAXE MCU platform is probably one the best for “newbies” to start with, yet it’s powerful and flexible enough for “experts”. A real-time clock (RTC) provides beacon timing control for a PICAXE 08M2, which controls the frequency output of the DDS chip that drives a simple single transistor power amplifier (PA).

Many Amateurs use MCU QRPp transmitters to send a FSK CW beacon followed by a WSPR beacon in the 17, 30 and 40 metre bands because their individual sub-bands are literally stacked on top of each other. Lastly, one huge advantage QRSS modes is the fact you can easily create new fuzzy modes or modify current ones.

MY FINAL

Part 2 will be about building and programming a simple MEPT, then looking at some of the things you can do with it, besides the obvious.—73

REFERENCES AND RESOURCES

A Mathematical Theory of Communication

C. E. Shannon

Extreme Narrowband Techniques

Rik Strobbe, ON7YD

Ionospheric Sounding Using Real-Time Amateur Radio Reporting Networks

N. A. Frissell, W2NAF, et al

Kits

QRP Labs <http://grp-labs.com>

QRSS: Very Slow Sending (Ham Radio for Arduino and PICAXE)

Hans Summers, G0UPL

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>