All Things Digital

Amateur Radio for the 21st Century

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How do you solve a "problem" like FT8?

Introduction

"How do you catch a cloud and pin it down? How do you solve a problem like Maria?"—The Sound of Music. There's no doubt about it, high frequency (HF) or shortwave radio "doomsday" is upon us as lack of solar activity continues to steadily decline towards a solar cycle minimum in 2020, and it may last for years longer than normal according to a few Nostradamus-like "fatalistic" predictions. Some consider this to be the worst of radio times, and are heading down the bands, going lower and lower; some are heading up to the satellite bands, going higher and higher; some are renting time on internet remote controlled "super" stations with their towering towers, multi-element beams, and kilowatt transmitters; some are selling off all their equipment and taking up a less frustrating hobby—like golf. But some consider this to be the best of radio times because necessity leads to inspiration and invention—"Sunspots? We don't need no silly sunspots!" The "big three" classic Amateur Radio modes: Morse code (CW), radio teletype (RTTY) and single sideband (SSB) work and have worked very well when there was even a modicum of solar activity with Sol's sunspots "juicing" up the upper atmosphere (ionosphere), but high HF band propagation has almost disappeared and won't be back again for possibly a very long time.

Fortunately, we also live in “interesting times” of rapid technological (and societal) change; what was impossible last year is very possible this year, and unless you’ve been living inside a Faraday cage, you’ve probably heard about “Franke-Taylor Eight” or FT8 (see Figure 1). It’s the hottest new digital data mode on planet Earth, co-created in mid-2017 by the dynamic digital duo of Steve Franke, K9AN and Joe Taylor, K1JT. FT8 has been alternatively called “that blasted new mode that’s destroying Amateur radio!”, and “that awesome new mode that’s saving Amateur Radio!” I think of it as the latter.

Transmission duration: 13.48 seconds (s)
Transmit/receive sequence length: 15 s including lead-in/out-out times to enable transmitter to turn on/off under computer control. Entire 2-way QSO takes less than 60 seconds.
Modulation: 8 tone frequency shift keying (8-FSK)
Keying rate/tone spacing: 5.86 hertz (Hz)
Waveform: continuous phase, constant envelope
Bandwidth used: 47 Hz
Decoding threshold: -24 dB signal-to-noise ratio (SNR) in a 2500 Hz passband. WSJT-X software detects/decodes all FT8 signals in the passband.

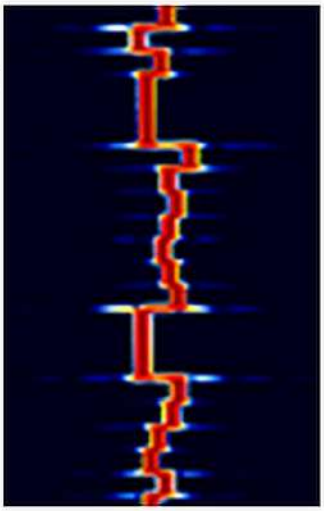

Figure 1: FT8 Fast Facts. While there are several other digital modes that have lower signal detection levels (like WSPR), they don’t have the two-way contact (QSO) speed of FT8.

Blame it all on PSK31

There have been several extremely popular Amateur Radio digital modes long before FT8, but what really started a paradigm shift (IMHO), at the tail-end of the 20th century, was when Peter Martinez, G3PLX created a variant of RTTY called “phase shift keying, 31 baud” (PSK31). With just a few watts of power, basic radio equipment, a computer/soundcard combination and digital signal processing (DSP) software you could work other PSK stations world-wide well below the signal-to-noise (SNR or S/N) levels of the conventional Amateur Radio modes.

And it probably was more responsible for the rapid adoption and evolution of all the digital modes that would follow over the years, and PSK31 became the number one digital mode by the end of the 2000's. User-programmable "macro" keys allow for the use a single key press to transmit a general "All Stations" (CQ) call, and/or a reply, or send the usual back-and-forth contact (QSO) exchanges, or transmit a text file about you, your equipment, hobbies, pets, job, family, et al. Text can be easily converted to computer speech and human speech can be converted to text using ancillary hardware and/or software. So PKS31 and its variants are a great two-way chit-chat mode especially for anyone with a disability of some kind ("Handihams" especially) to enjoy the hobby that we able bodied Amateurs all take for granted. It also became part of the new "social media" terse texting trend that created another paradigm shift for better or worse. Quite naturally, Amateurs began to emulate this behaviour and started to send only the basic information required to make a valid two-way QSO in order to get in as many contacts as possible and as quickly as possible. For the most part, long and leisurely radio conversations have sadly become the exception rather than the rule for most digital mode operators. But, I digress…

Blame it all on JT65

A few years later, K1JT's WSJT-X (weak signal Joe Taylor experimental) software debuted with his new "JT" digital modes that could go deeper into the noise and dig out signals even better than PSK31, but the price for this ability was much, much slower messaging speed (Shannon's law refers). The most widely used variant on the HF bands is JT65 (65 discrete audio tones), and like PKS31 it also uses a series of manual macro key presses except there's no two-way texting what-so-ever because it takes nearly 4 minutes just to complete a valid two-way QSO, which is the exchange of the station's call signs, Maidenhead grid squares and SNR (calculated by the software). It's often called the "watching the grass grow" digital mode because it's so, so painfully slow.

Blame it all on WSPR

In early 2008, Joe released WSPR (weak signal propagation reporter), based an idea from another famous digital modes designer Murray Greenman, ZL1BPU to create a “manned experimental propagation transmitter” (MEPT). WSPR is an MEPT and/or telemetry weak signal digital mode that sends most of the same information as JT65, except it transmits power in decibel-milliwatts (dBm) instead of SNR, all in just under two minutes (it’s a beacon only digital mode). But its signals can be detected even deeper into the noise than JT65. Many radio hobbyists who fly party foil (“pico”) balloons or high altitude balloons (HAB) transmit various combinations of WSPR, JT65 and now FT8 beacons with alternating telemetry packets using solar/battery power with specially modified software, a microcontroller (Arduino type), plus a very low power (QRPp) transmitter connected to various sensors.

Blame it all on FT8

What the majority of digital Amateurs really wanted was a reliable and fast digital basic two-way QSO mode with the weak signal capabilities of JT65 or WSPR and the speed of PSK31, but it would take another decade for that to happen. Meanwhile, by 2015, JT65 had slowly and quietly surpassed PSK31 in popular use. Then, in June 2017, FT8 was released upon an unsuspecting Amateur Radio world, and in less than a year it had literally “destroyed” the digital “competition” and it became number one! It’s an awesome digital mode with lightning fast 15 second back-and-forth basic QSO exchanges wherein a computer-to-computer contact usually takes less than 60 seconds to complete; then you move on to the next and the next and the next. Albeit the only information exchanged are the calls, grids and SNRs. While you can manually press the required macro keys in the proper sequence ala JT65, most Amateurs prefer to use the fully automatic computer-to-computer exchanges. So only a “CQ” is sent manually, and everything else is fully automatic when another station answers your call. FT8 can detect signals down to an SNR of about -24 decibels (dB), which is 14 dB lower than PSK31, about 23 dB lower than Morse and a staggering 34 dB lower than SSB!

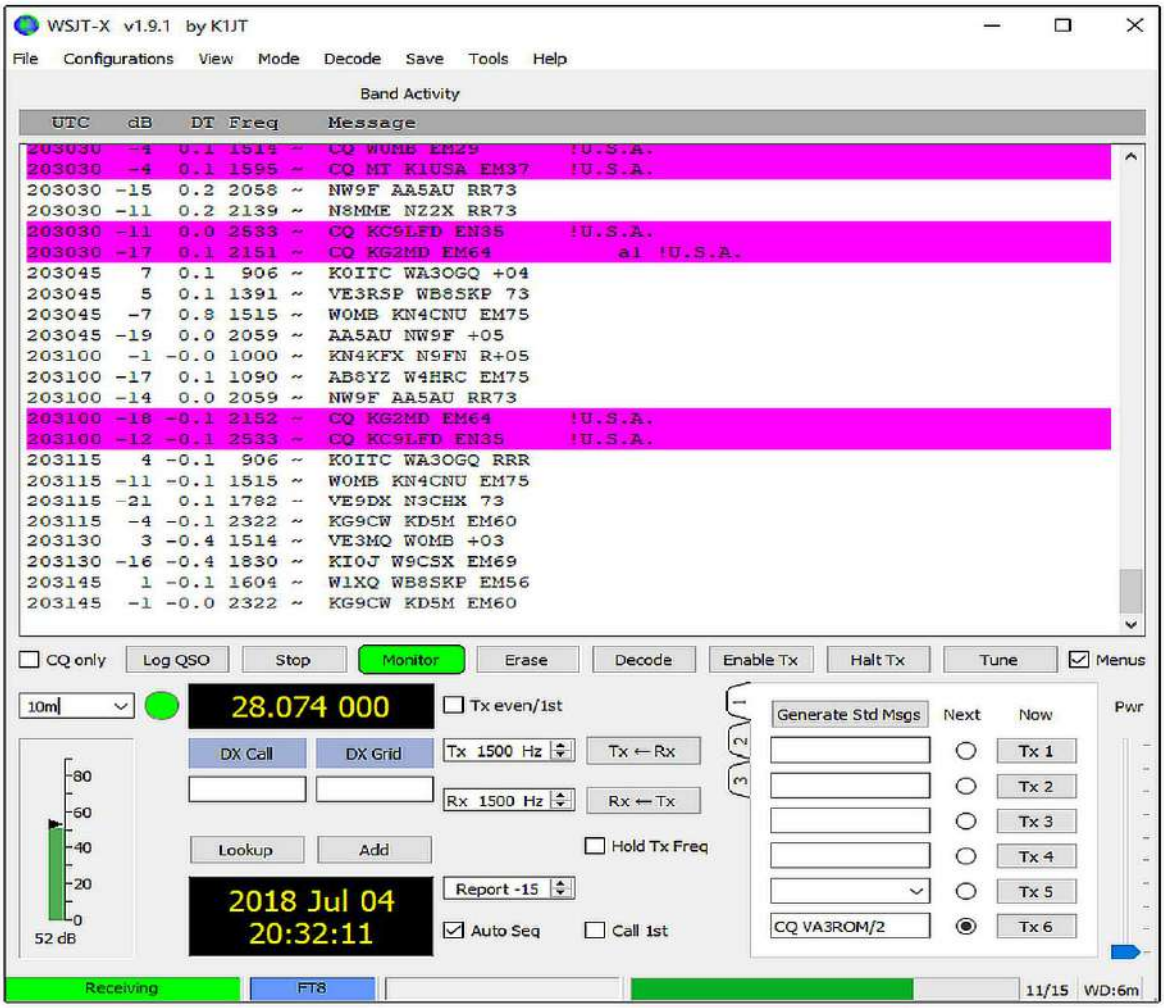

Figure 2: WSJT-X main display showing FT8 contacts on 10 m when we had some sunspots!

The latest version of WSJT-X (see Figure 2) supports WSPR and JT65 plus several other specialized weak-signal digital modes. It pushes the SNR limits down a few more dB with improved and optimized algorithms (as if that was even possible!). FT8 is now nearly on par with JT65's weak-signal performance but is four times faster in QSO exchanges! There's the new FT8 DXpedition feature that creates a "fox and hounds" scenario allowing up to 100 QSOs per hour between one station (the fox) and the rest of the "pack" (the hounds). But wait, there's even more! DXpedition mode also allows a fox to transmit, when required, up to five simultaneous responses to the hounds increasing the contact rate up to 500 per hour! The mode has become really popular with the die-hard radio contesters.

For better or for worse, FT8 is here to stay—at least until the next “best digital mode since sliced bread” shows up. Right now, it’s flooding the ether with rapid fire digital signals with reports (“spots”) being streamed automatically and continuously 24/7 to the Reverse Beacon Network (RBN) and PSKReporter global web servers. The RBN added a separate server port just to handle the “problem” of FT8 (it also collects all world-wide RTTY and CW spots) overloading the system. In one day in May, the total number of RBN spots for all digital modes was 30681: RTTY with 69 (0.22% of the total), CW at 4294 (14%) and FT8 with 26318 (86%).

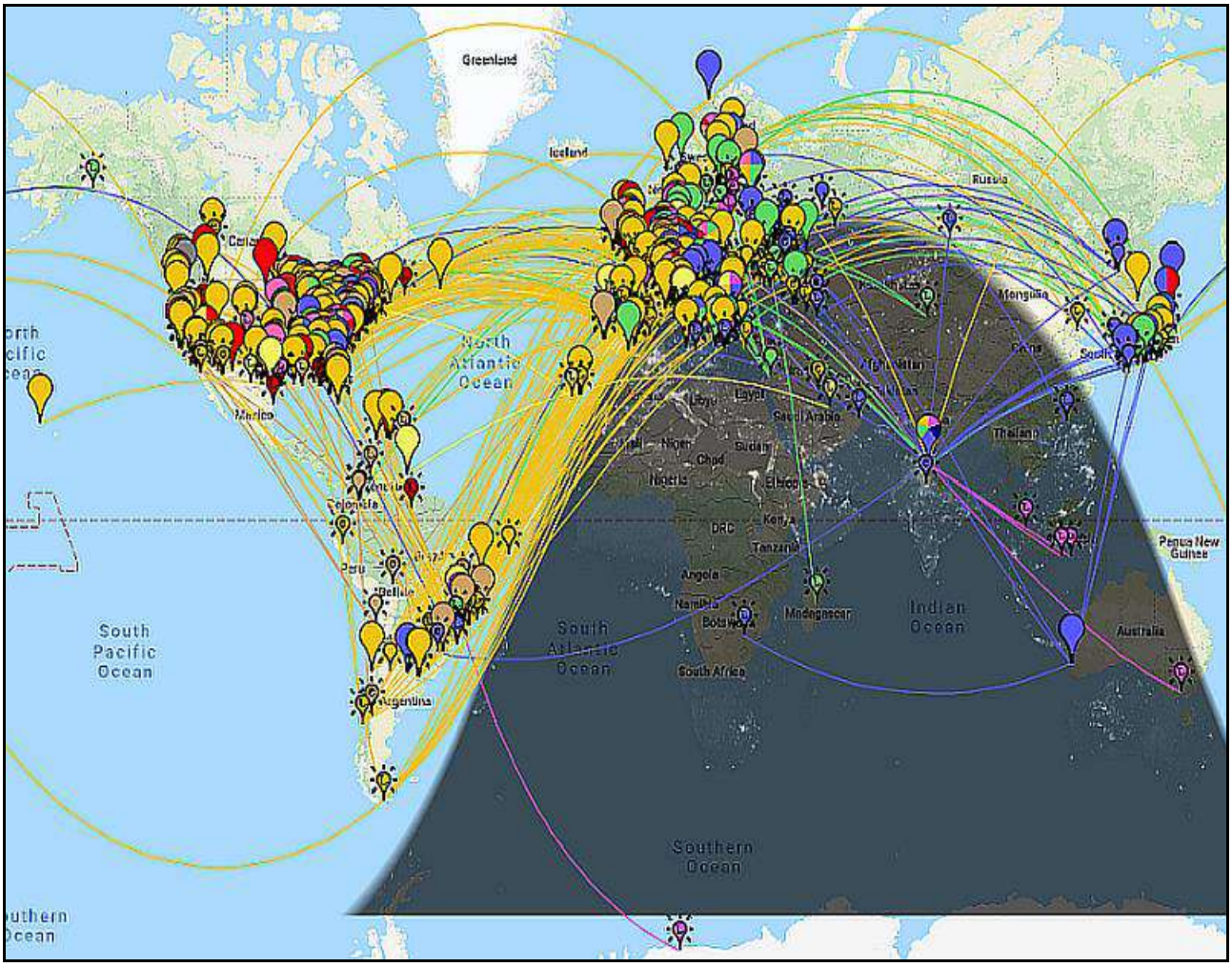

Figure 3: PSKReporter FT8 Map screen capture of one hour’s worth of combined FT8 activity (receive and transmit) for all bands on a mid-afternoon in early July (about 5000 stations).

Digital Modes and Ancillary Programs

Carol Milazzo, KP4MD has conducted extensive weak signal research comparing WSPR to other Amateur Radio modes, and has derived a simple equivalency equation. She has created a spreadsheet to extract spots from the WSPRnet and then scale the data up/down in power level and/or antenna gain to see how other digital modes would compare to each other (see Figure 4).

Date	Time	Frequency	Call	km	SNR	dBm	WSPR	JT65	FT8	PSK31	CW	RTTY	SSB
07-07-2018	05:52	10.140245	N7SCQ	2785	-23	30	23	19	18	1	-5	-11	-16
07-07-2018	05:46	10.140246	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	05:42	10.140245	N7SCQ	2785	-21	30	25	21	20	3	-3	-9	-14
07-07-2018	05:36	10.140246	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	05:32	10.140245	N7SCQ	2785	-18	30	28	24	23	6	0	-6	-11
07-07-2018	05:26	10.140246	N7SCQ	2785	-19	30	27	23	22	5	-1	-7	-12
07-07-2018	05:22	10.140245	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	05:16	10.140246	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	05:12	10.140245	N7SCQ	2785	-23	30	23	19	18	1	-5	-11	-16
07-07-2018	05:06	10.140246	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	04:56	10.140246	N7SCQ	2785	-19	30	27	23	22	5	-1	-7	-12
07-07-2018	04:52	10.140246	N7SCQ	2785	-22	30	24	20	19	2	-4	-10	-15
07-07-2018	04:46	10.140246	N7SCQ	2785	-13	30	33	29	28	11	5	-1	-6
07-07-2018	04:36	10.140246	N7SCQ	2785	-14	30	32	28	27	10	4	-2	-7
07-07-2018	04:32	10.140245	N7SCQ	2785	-14	30	32	28	27	10	4	-2	-7
07-07-2018	04:26	10.140245	N7SCQ	2785	-19	30	27	23	22	5	-1	-7	-12
07-07-2018	04:22	10.140245	N7SCQ	2785	-19	30	27	23	22	5	-1	-7	-12
07-07-2018	04:16	10.140245	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	04:06	10.140244	N7SCQ	2785	-18	30	28	24	23	6	0	-6	-11
07-07-2018	03:56	10.140243	N7SCQ	2785	-18	30	28	24	23	6	0	-6	-11
07-07-2018	03:52	10.140242	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	03:46	10.140242	N7SCQ	2785	-19	30	27	23	22	5	-1	-7	-12
07-07-2018	03:42	10.140241	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13
07-07-2018	03:36	10.140239	N7SCQ	2785	-18	30	28	24	23	6	0	-6	-11
07-07-2018	03:32	10.140239	N7SCQ	2785	-20	30	26	22	21	4	-2	-8	-13

Great Good Bad

Figure 4: Mode SNR Comparisons. KP4MD's nifty spreadsheet retrieved WSPRnet 30 m band records of my station spots for N7SCQ near Sacramento. His 30 dBm (1 watt) beacon with reported SNRs were scaled up to 50 watts (47 dBm) using a 0 dB gain antenna then compared to other modes. FT8 was the only fast, two-way QSO mode useable 100% of the time during the selected period (in UTC); JT65 was a tad better but is four times slower so FT8 will get you more contacts. Surprisingly, PSK31 did really well but Morse (CW) only had a few good openings.

An awesome new FT8 (and WSPR) ancillary program to add to our digital toolkit is called “GridTracker”, created by Stephen “Tag” Loomis, N0TTL and Henry Forte, N2VFL (see Figures 5A and 5B). It seamlessly communicates back-and-forth with WSJT-X plus several popular logging programs and a useful mode analysis tool.

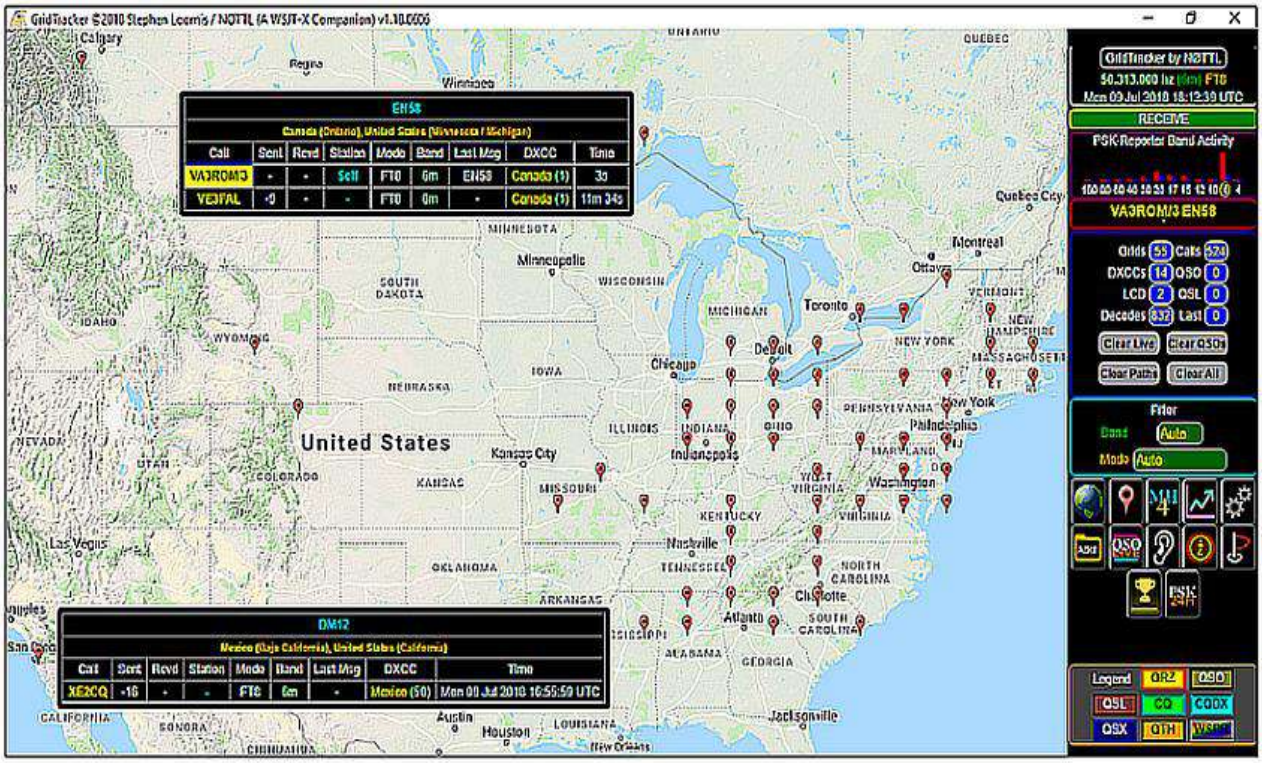

Figure 5A: Main Map Display. The program has a plethora of built-in features.

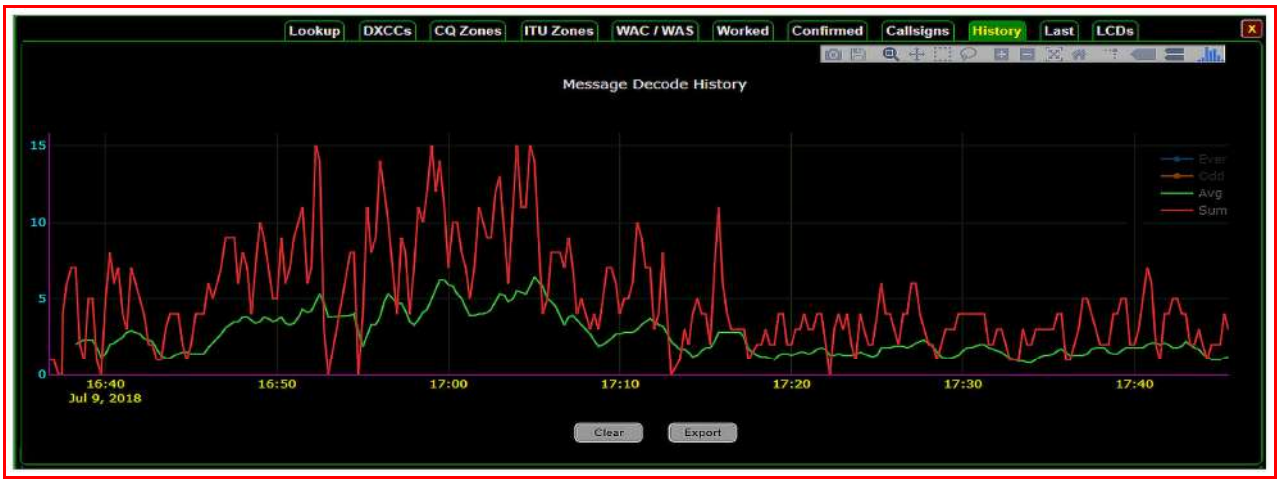

Figure 5B: Secondary Graph Display. You can export GridTracker data to a comma separated value (CSV) file for importing to database/spreadsheet programs and deeper data analysis.

Digital Modes and Phillips-Abel Theory

The study of the ionosphere and its affects on propagation is one very interesting aspect of Amateur Radio, and there's a fascinating article to read on this topic called "Understanding Propagation with JT65, JT9, and FT8" in the October 2017 issue of *QST*. Amateurs and other radio hobbyists are streaming massive amounts of invaluable data to the WPSRnet, RBN and PSKReporter servers, which is freely available for anyone to shift through and analyse. The article talks about how this data (especially FT8's because of its speed and amount of data you can collect very quickly for analysis) appears to confirm the Phillips-Abel theory (Phillips, 1963) and explain the phenomena of "above the basic maximum useable frequency (MUF) propagation" (see Figure 6).

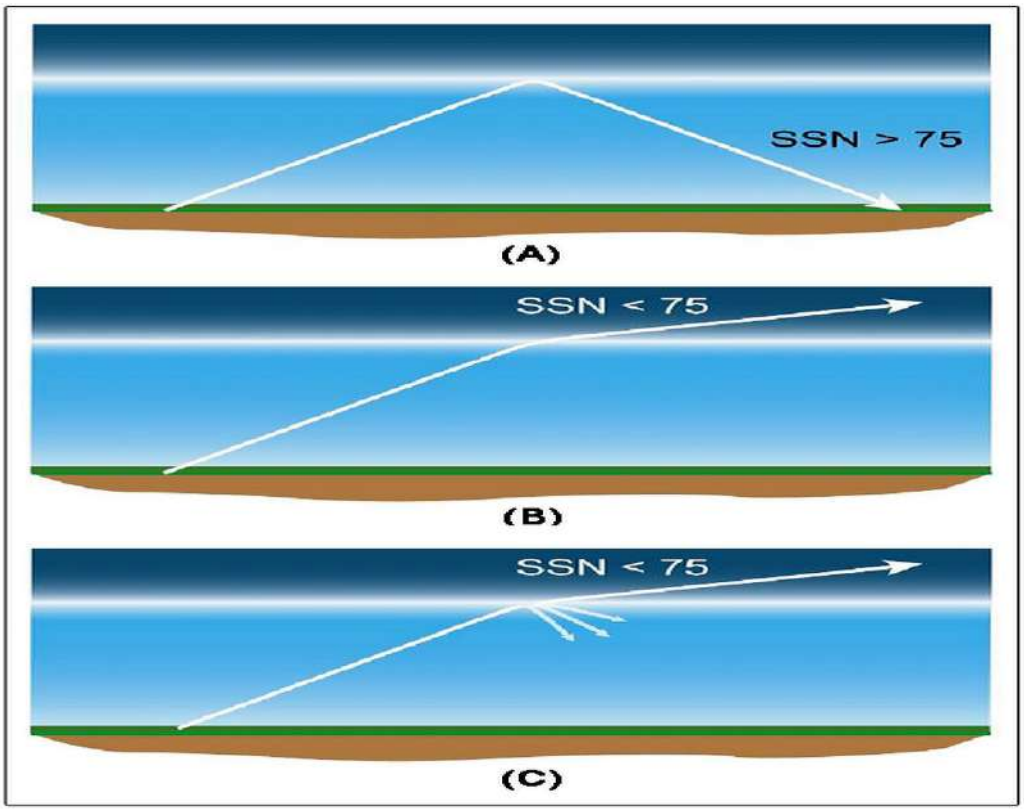

Figure 6: Phillips-Abel Theory (simplified). Imagine the ionosphere as a solid prism; below the MUF and when the smoothed sunspot number (SSN) is 75 or greater (A), high band HF radio wave waves refract back to Earth. Above the MUF and when the SSN is less than 75 (B), they travel up and out. However, according to Phillips-Abel theory, radio waves above the MUF (C) can partially refract or scatter weakly back to Earth (we aren't sure which it is) and be detected. Used with permission, October 2017 *QST*; copyright ARRL.

The theory is that while weak signal digital modes DSP software literally pull signals out of the background noise on the lower bands (below 20 m), with above the MUF propagation they can actually detect signals down to a typical receiver's noise floor, it's minimum discernible signal (MDS) that are just too weak and/or fleeting for conventional modes to do so. It's somewhat analogous to visible light photons streaming down to Earth from some distant star that can't be seen with the naked eye, but is clearly visible when viewed with a telescope.. FT8 was specifically designed for situations when radio waves (photons) are weak, and/or fading, and/or high radio band openings are of a short/sudden duration. So it's a great tool to use for Amateur Radio research, in my opinion.

Figure 7: MFJ-933 small loop tuner using LMR coax. A hula hoop and soft copper tubing also works well.

Digital Modes Antenna Test Results

KP4MD's spreadsheet and GridTracker can be used to create and analyze propagation profiles for FT8 and WSPR modes to/from specific target areas, or use to compare different antenna types, modes, and/or radios looking for best performance combinations, and so on. My tests indicate that two different types of antennas are needed in these times of reduced high band HF propagation. For transmitting, propagation favours vertical polarity because the ionosphere refracts vertical waves more easily, while small transmitting loops (STL's) offer higher SNR reception (less noise) over verticals. Or a vertically polarized STL for both purposes if can't use two antennas for various reasons (see Figure 7).

Verticals and STL's don't need to be very high above ground, and don't take up much space so they can easily fit inside most small city lots as compared to wire dipole antennas, plus they can be made to be portable for grab and go travel and/or field work. Those living in antenna restricted areas or apartment dwellers can install various clandestine versions: flagpoles make for great "patriotic" verticals, while small loops (on a balcony) are easily camouflaged with green plastic vines, etc. Small birds use my STL for a roosting ring and the transmitted RF doesn't seem to both them! Combining antennas into one dual-purpose transceive system was only done for convenience and less cost—not for the best performance. Quoting from Amateur Radio author and researcher Eric Nichols, KL7AJ, "…the fact that we ever have anything resembling reciprocal propagation is nearly miraculous! It's only due to the fact that the average HF antenna is so bad that we can use it for both transmitting and receiving..." Reference: "Propagation and Radio Science, Exploring the Magic of Wireless Communication").

On the other hand, today's "all-in-wonder" transceivers are more than adequate for both purposes, even more so if they also have DSP capabilities. Plus many have multiple antenna ports for dedicated transceive and receive (dual or diversity reception) so it's very easy to optimize separate transmit and receive antenna systems, which also includes the feedline and an important thing to consider, too. If you don't have a dedicated receive only antenna port, you can add an automatic transmit/receive (T/R) switch for this purpose to automatically between one antenna system and another.

My Final

The August 2018 issue of *QST* reports that more than 2.3 million FT8 contacts were uploaded to the "Logbook of the World" (LoTW) in one month, for a net gain of 1.2 million reports *over all other modes combined* for the same month from last year! While PSK31, JT65 and RTTY overall activity has decreased dramatically because of FT8 "fever", the use of Morse code and SSB voice modes has only dropped slightly (about 10%), which is what statistically occurs during any solar minimum according to data. And perhaps it's the perception of the "problem" that's more of the problem to solve than the reality. Blame it all on Sol!—73