

Introduction to Ham Radio Digital Mode* FT8



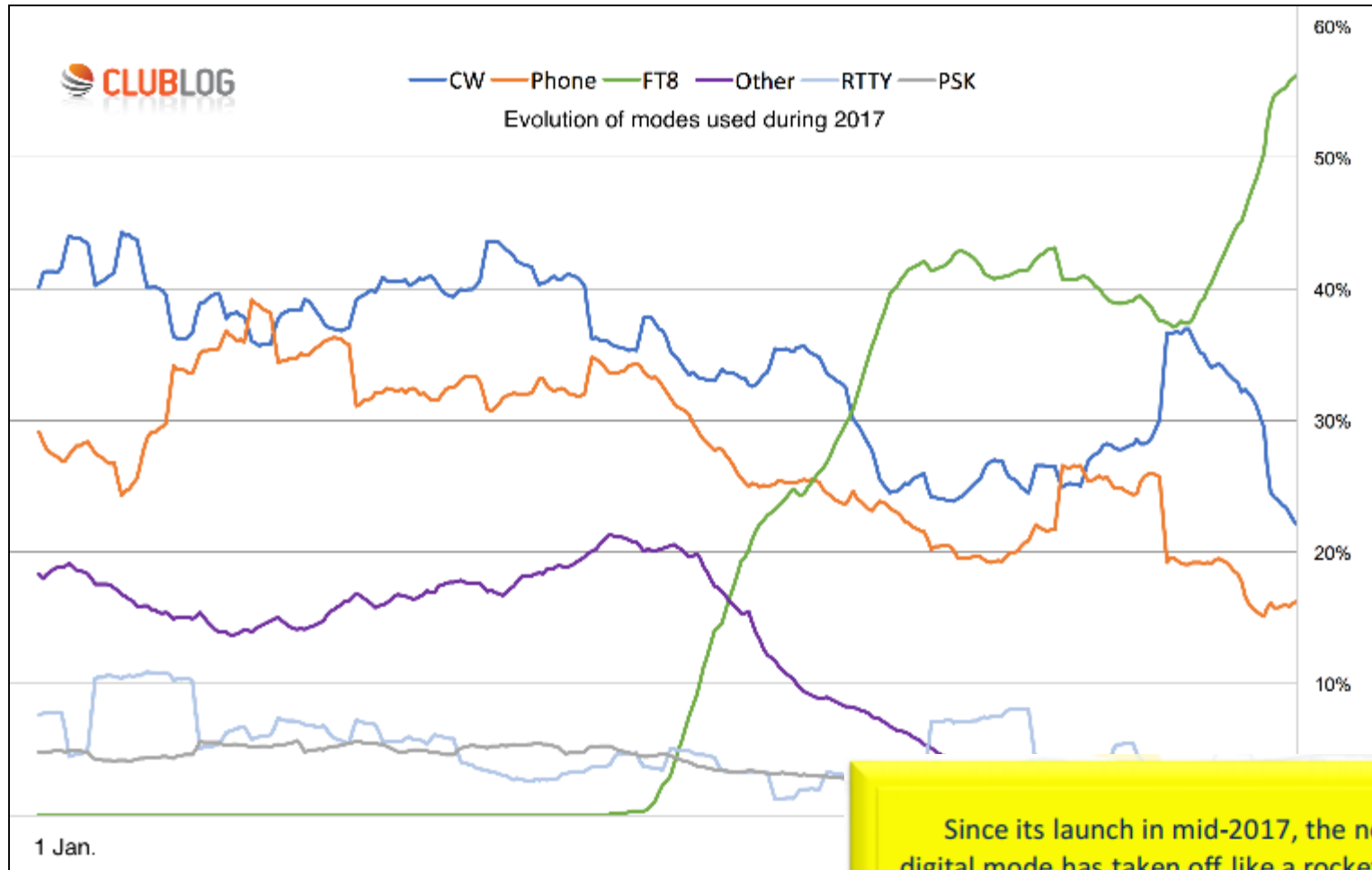
Dave LeVasseur, N0DL
March, 2018

* But in reality, *everything* is analog

Summary of FT8

- FT8 is named after its developers, Steven Franke, K9AN, and Joe Taylor, K1JT.
- The “8” denotes mode's 8-frequency shift keying format.
- Tones are spaced at 6.25 Hz, and an FT8 signal occupies just 50 Hz.
- Unlike JT65 or JT9, transmit and receive cycles in FT8 each last about 15 seconds.
- Contacts are four times faster than with JT65 or JT9, and an entire FT8 contact can take place in about 1 minute.

FT8 has become EXTREMELY popular



Since its launch in mid-2017, the new digital mode has taken off like a rocket, with more than *half* of today's HF QSOs being on FT8.

Mode Usage Evaluation: 2017 was “the Year When Digital Modes Changed Forever” – QRZ NOW.com, January 22, 2017

Data courtesy of *Club Log*
Tnx Michael G7VJR

What FT8 Can Do

- FT8 is an excellent mode for HF DXing and for situations like multi-hop Es on 6 meters, where deep QSB may make fast and reliable completion of QSOs desirable.
- Works well for EME (“moonbounce”), meteor scatter and other modes where Doppler shift would otherwise render communications difficult or impossible

SWOT Analysis¹

Strengths	Weaknesses
<ul style="list-style-type: none">• Good for weak signals <i>e.g.</i> marginal paths, QRP, stealth antennas, poor conditions• Efficient use of bandwidth: signals are just 50 Hz wide, and can often be decoded if they overlap more or less entirely with others• Minimal QSO information is passed reliably• Popular, with <i>lots</i> of HF activity at present	<ul style="list-style-type: none">• Mechanized, without the personal touch that comes from legacy-mode human-to-human contacts and conversation• Slow communication speed equivalent to about 5 wpm• Complex and confusing for beginners• Problems with non-standard calls including CEPT travelers and special event calls
Opportunities	Threats
<ul style="list-style-type: none">• User interface improvements, addressing software design flaws and programming bugs• Enhanced functionality <i>e.g.</i> better logging and statistics• Further innovation <i>e.g.</i> multi-transmit capability for DXpeditions	<ul style="list-style-type: none">• Fragmentation of digital modes if too many variants develop• Automating ourselves out of the game• Marginalization of legacy modes and low-tech hobbyists• Increasing dependence on technology

¹Lifted from “FT8 Operating Guide” by Gary Hinson ZL2IFB, February 2018. See references at end for link.

How FT8 Works

- All QSOs consist of data blocks sent and received in synchronized 15-second intervals.
- The software uses your computer's soundcard to decode and display multiple received signals and also to encode your transmitted CQ or response
- Uses lots of overhead error correction in the message To reach down into and below the noise floor. The effective data rate is about 5 WPM.
- FT8 encodes three Costas Arrays, one at the start, one in the middle and one at the end of each transmission to help receiving end identify and decode the message payload.

A sidetrip into the FT8 Costas Array

- In addition to Forward Error Correction FT8 uses 7x7 Costas arrays, originally developed to provide better SONAR and RADAR pings by tagging each transmission with unambiguous combinations of frequency hops and time intervals.
- There are 200 unique frequency and time combinations in a 7x7 Costas Array.
- For background visit the Ted Talk “[The World’s Ugliest Music²](#)” created using a Costas Array, guaranteed NOT to be running through your brain all day long once you hear it.

Correspondence With K1JT

-----Original Message-----

From: Joe Taylor [mailto:joe@princeton.edu]
Sent: Tuesday, March 27, 2018 12:19 PM
To: Dave LeVasseur
Subject: Re: Costas Array function in FT8

Hi Dave,

- > I hadn't heard of Costas arrays
- > before reading up on FT8 but I see their first use was to create
- > unambiguous sonar pings. I guess this makes sense knowing that FT8 is
- > well-suited for EME where Doppler shift comes into play but does the use
- > of the three arrays also improve HF communications as well?

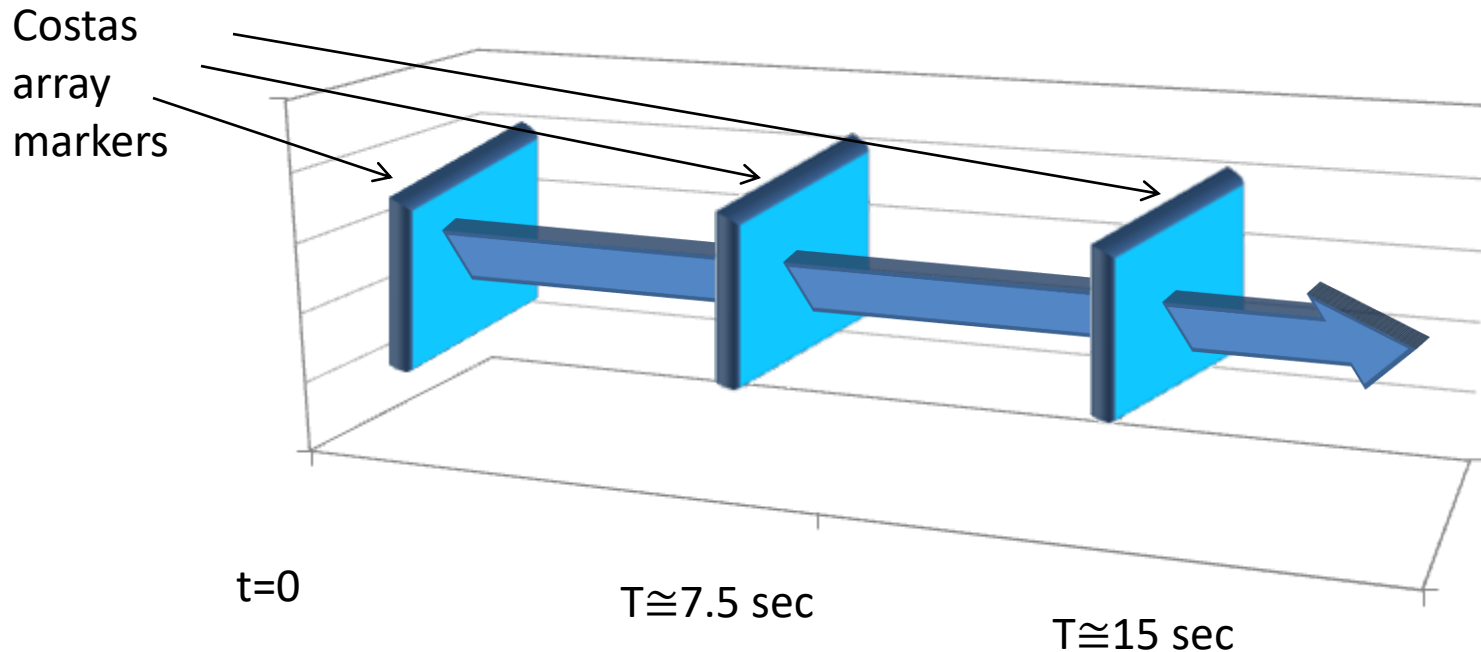
Costas arrays provide an effective mechanism for determining unknown offsets in both frequency and time. To decode an FT8 signal we need to determine its frequency to within ~1 Hz and its start time to within ~20 ms.

- > ...Does each person transmitting use a randomly assigned
- > member of the 200 that are available in a 7x7 array?

No. All Costas arrays in FT8 are the same, tone numbers 2 5 6 0 4 1 3.

-- 73, Joe, K1JT

N0DL's best attempt to understand and interpret K1JT's explanation



Special combinations of tone and time delays are inserted at the start, mid-point and end of each transmission. After the transmission has been recorded the software uses these markers to adjust for transmission time and frequency error, QSB, Doppler and other propagation-related frequency shifts

What You Need to use FT8

- An SSB transceiver, ideally with Digital mode capability built-in, although USB is a viable alternative
- A PC with a soundcard, ideally one separate from the one connected to your speakers (so you don't send Windows system "bonks" out onto the air). Must support 48kHz, 16-bit audio.
- Some form of rig T/R control such as CAT (VOX is an option but much less convenient)

What You Need to use FT8, cont.

- Computer with 1.5GHz or faster processor running Windows (XP and later), Linux or OSX
- Software such as WSJT-X³
- A means of synchronizing the computer to UTC within 1 second (Internet connection is handy but if you're quick with the mouse you could use WWV, CHU or an Atomic Time clock)

Typical Configuration



I tried using direct control of my Yaesu FT-897 from the WSJT-X software but found it issued CAT commands that messed with my auto-tuner. Using DX Lab Commander⁴ solved this problem for me.

Sync Your PC to UTC

- You need to sync your PC to ± 1 second of UTC
- <https://www.time.is> – to check your PC vs UTC
- The built-in Windows facility for time synchronization is usually not adequate. Try the program *Meinberg NTP* (see [Network Time Protocol Setup](#) for downloading and installation instructions)
- Or *Dimension 4* from [Thinking Man Software](#).

Setting up CAT (rig control)

Commander 13.2.0 [Yaesu FT897] @ 12:17:13 Z 7,073.30 RTTY

VFO A: 40M 11

7,073.30

0 999

A = B A x B XFC

Split

Ham bands only

Mode: RTTY

LSB FM USB AM CW RTTY CW-R PKT

Memory Bank 1

B1 B2 B3 B4 B5 B6 B7 B8 B9 B10

Sel	Frequency	Mode	Save
1	1,900.00	CW	1
2	3,330.00	CW	2
3	5,000.00	AM	3
4	7,850.00	AM	4
5	10,000.00	AM	5
6	14,670.00	AM	6
7	15,000.00	AM	7
8	20,000.00	AM	8
9	25,000.00	AM	9
10			10

Bandspread Msgs Config Scan Filters & Devices Help

WSJT-X Main Screen

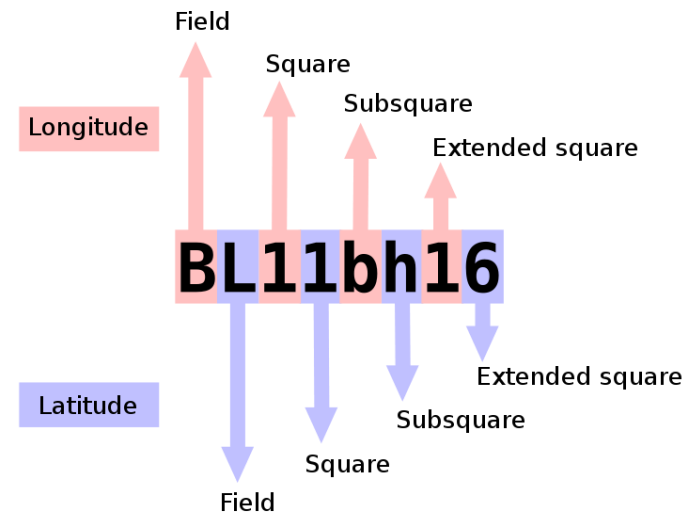
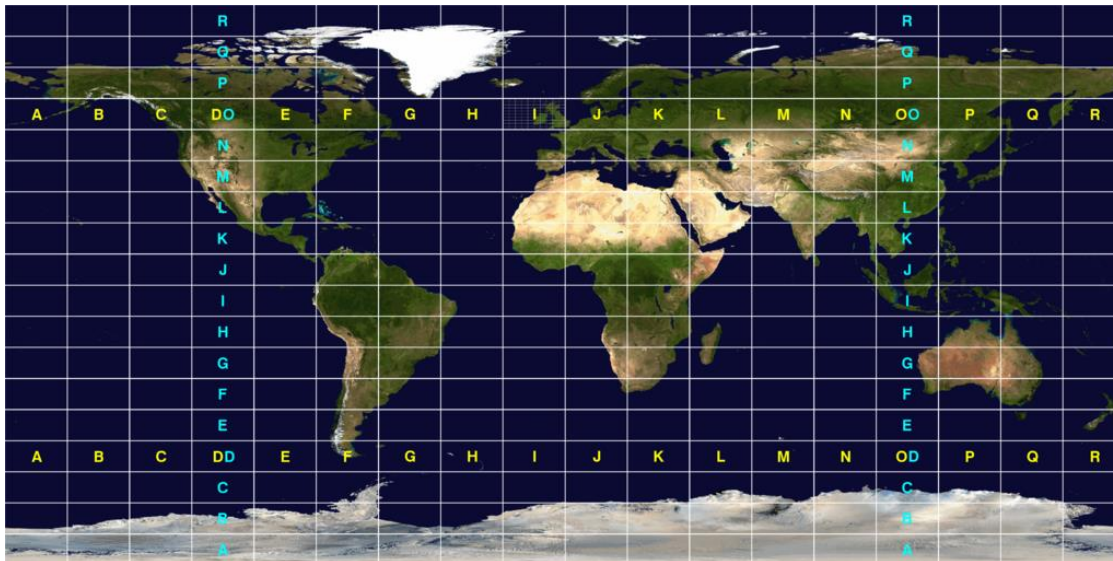
The screenshot shows the WSJT-X v1.8.0 by K1JT software interface. The 'Settings' window is open to the 'Station Details' tab, where 'My Call' is set to 'N0DL' and 'My Grid' is set to 'EN14'. A red box highlights these two fields. Below the settings, the main interface displays a list of stations with columns for UTC, dB, DT, Freq, and Message. The frequency display shows 7.073 300. The message generation panel is visible on the right, showing a list of messages to be transmitted, including 'KE6SCS N0DL EN14' and 'CQ N0DL EN14'. The status bar at the bottom indicates 'Receiving' and 'FT8' mode.

Make sure you enter your Call and Grid Square (under File | Settings) before using the software.

(If you don't you'll be sending anonymous transmissions that nobody can answer)

The “Maidenhead” Grid Squares

- Developed by Dr. John Morris G4ANB of Maidenhead, England in 1980
- Divides the earth into 324 fields



More info: https://en.wikipedia.org/wiki/Maidenhead_Locator_System

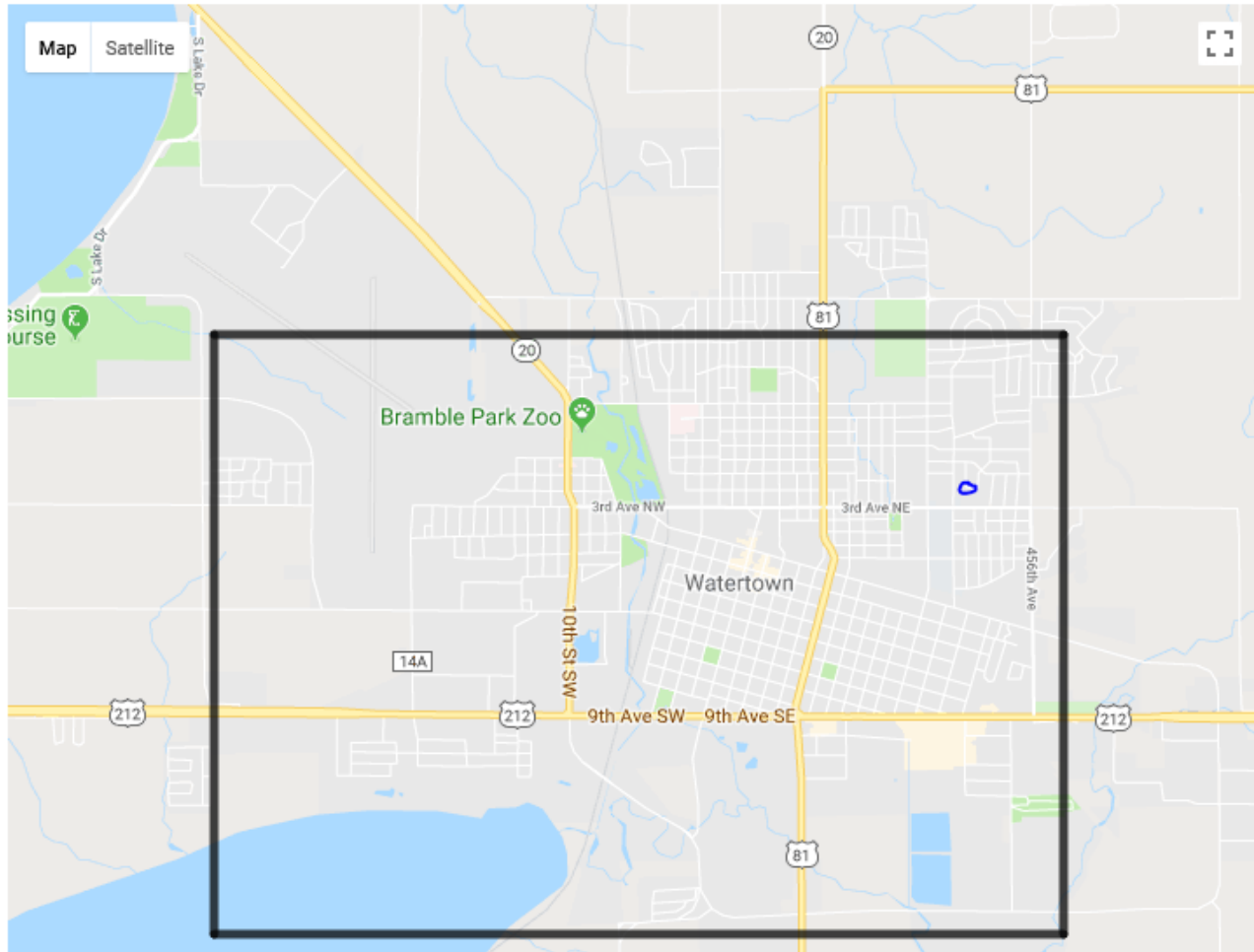
FT8 allows for four grid square characters

Grid Square: EN14



NODL's QTH grid square in 6 characters

Grid Square: EN14kv



More info: http://www.levinecentral.com/ham/grid_square.php

Getting Started

Adjust slider until transmit power drops (half your rig's power or even 25 or 10% is a good place to start)

Set the band, tune up as normal

Use Tune to check power level

The screenshot shows a radio software interface with several key elements:

- Band and Frequency:** A dropdown menu is set to "40m". The main frequency display shows "7.073 300".
- Call and Grid:** The DX Call is "KE6SCS" and the DX Grid is "DM04". The distance is "2183 km".
- Time and Date:** A large display shows "2018 Mar 10 11:35:39".
- Buttons and Controls:** Buttons include "Log QSO", "Stop", "Monitor" (highlighted in green), "Erase", "Decode", "Enable Tx", "Halt Tx", "Tune", and "Menus".
- Message Queue:** A table on the right lists messages to be transmitted:

Generate Std Msgs	Next	Now
KE6SCS NODL EN14	<input type="radio"/>	Tx 1
KE6SCS NODL -14	<input type="radio"/>	Tx 2
KE6SCS NODL R-14	<input type="radio"/>	Tx 3
KE6SCS NODL RRR	<input type="radio"/>	Tx 4
KE6SCS NODL 73	<input type="radio"/>	Tx 5
CQ NODL EN14	<input checked="" type="radio"/>	Tx 6
- RF Gain:** A vertical slider on the left is set to "74 dB".
- Status Bar:** Shows "Receiving", "FT8", "Last Tx: KE6SCS NODL 73", "9/15", and "WD:6m".

Adjust RF gain to keep receive level below red, between 40 and 80 is ok

You will probably need to adjust your sound card's audio levels to get everything to play. This can take some time and a separate sound card is highly recommended (set and forget)

WSJT-X Main Screen

All QSO activity in the receive spectrum

Stations calling "CQ" will be highlighted in green

Your call will show up highlighted in red

All activity shown on the Rx frequency

Your transmissions are highlighted in yellow

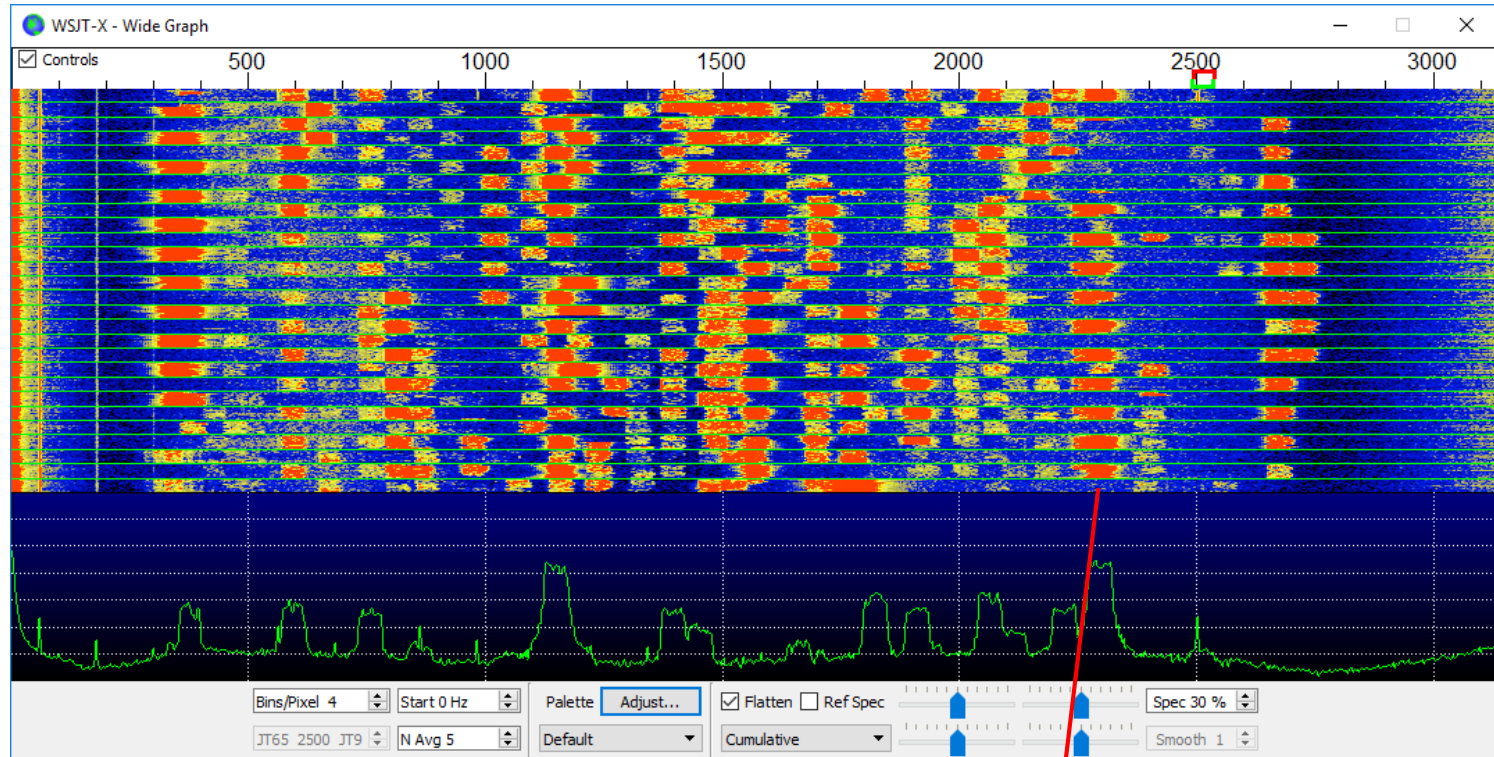
The message transmissions are generated automatically and sent in sequence

Your transmissions are sent in a 50 Hz-wide slot at the base frequency + the audio offset

The screenshot displays the WSJT-X v1.8.0 interface. At the top, there are menu options: File, Configurations, View, Mode, Decode, Save, Tools, Help. Below this is the 'Band Activity' section, which is split into two columns: 'Receive' (left) and 'Transmit' (right). Each column has a table with columns for UTC, dB, DT, Freq, and Message. The receive table shows various stations, with 'CQ' messages highlighted in green and the user's own call 'KE6SCS DM04' highlighted in red. The transmit table shows the user's transmissions, which are highlighted in yellow. Below the band activity is a control panel with buttons for Log QSO, Stop, Monitor, Erase, Decode, Engage Tx, Halt Tx, and Tune. A frequency display shows 7.073 300. Below that are fields for DX Call (KE6SCS), DX Grid (DM04), and Tx frequency (2010 Hz). There are also buttons for Lookup, Add, Report -14, and checkboxes for Auto Seq, Call 1st, and NA VHF Contest. At the bottom, there is a status bar showing 'Receiving', 'FT8', 'Last Tx: KE6SCS NODL 73', and '9/15 WD:6m'.

Band Activity					Rx Frequency				
UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
113130	-4	0.2	1805	CQ W41EE EL82	112616	Tx	0.2	1005	N4BP NODL EN14
113130	-13	-0.6	1814	CQ CO3NR EL82	112630	-2	0.1	2053	W3DWJ N4BP -17
113130	-8	0.0	2010	CQ KE6SCS DM04	112645	Tx	0.1	1005	N4BP NODL EN14
113145	-18	0.2	1227	CQ HK7JA FJ35	112700	-2	0.1	2054	W3DWJ N4BP RRR
113145	-8	-0.0	1409	JAI8JI KM6NAP -08	112715	Tx	0.1	1005	N4BP NODL EN14
113145	-6	0.1	1792	DS1AAK LUSVV FE48	112730	-2	0.2	2054	W3DWJ N4BP 73
113145	2	0.1	2133	BD7OXR WD6DBM -19	112730	-12	-0.6	1816	CQ CO3NR EL82
113200	-17	-0.6	1814	CQ CO3NR EL82	112747	Tx	0.1	2053	CO3NR NODL EN14
113200	-12	0.0	2011	CQ KE6SCS DM04	112815	Tx	0.1	2053	CO3NR NODL EN14
113230	-16	0.0	1469	KD2DXJ YV1GIY -07	112830	-12	-0.6	1815	CQ CO3NR EL82
113230	-9	-0.6	1814	CQ CO3NR EL82	112845	Tx	0.1	1450	CO3NR NODL EN14
113300	-10	-0.0	2010	CQ KE6SCS DM04	112900	-14	-0.1	1815	CQ CO3NR EL82
113300	-9	-0.6	1066	KB1ODO CO3NR -08	112915	Tx	0.1	1450	CO3NR NODL EN14
113315	-8	0.1	1363	K1VWQ W2DEN 73	112930	-12	-0.6	1815	CQ CO3NR EL82
113315	-5	0.1	1728	BI4TGY LUSVV FE48	113000	-13	-0.6	1815	CQ CO3NR EL82
113315	-3	0.0	2054	N4BP K4ADR EL96	113030	-9	0.1	2054	CQ N4BP EL96
113315	-2	0.1	2133	BD7OXR WD6DBM -19	113048	Tx	0.1	1450	N4BP NODL EN14
113330	-12	-0.0	2011	CQ KE6SCS DM04	113100	-9	0.2	2054	CQ N4BP EL96
113330	-11	-0.6	1066	KB1ODO CO3NR RRR	113115	Tx	0.1	1450	N4BP NODL EN14
113330	-10	0.0	1469	KD2DXJ YV1GIY 73	113130	-6	0.2	2054	CQ N4BP EL96
113400	-9	-0.0	2010	NODL KE6SCS -11	113200	-12	0.0	2011	CQ KE6SCS DM04
113430	-14	0.0	2010	NODL KE6SCS RRR	113217	Tx	0.1	2054	KE6SCS NODL EN14
113430	-9	0.0	1469	W2DEN YV1GIY -06	113245	Tx	0.1	2054	KE6SCS NODL EN14
113430	-14	-0.6	1660	CQ CO3NR EL82	113300	-10	-0.0	2010	CQ KE6SCS DM04
113500	-9	-0.0	2011	NODL KE6SCS 73	113330	-12	-0.0	2011	CQ KE6SCS DM04
113500	-11	0.0	1469	W2DEN YV1GIY RRR	113348	Tx	0.1	2011	KE6SCS NODL EN14
113500	-12	-0.6	1660	CQ CO3NR EL82	113400	-9	-0.0	2010	NODL KE6SCS -11
113515	-13	0.2	1235	CQ HK7JA FJ35	113415	Tx	0.1	2011	KE6SCS NODL R-09
113515	-11	0.0	1414	DS4GKA N07E -11	113430	-14	0.0	2010	NODL KE6SCS RRR
113515	-5	0.1	1468	YV1GIY W2DEN 73	113445	Tx	0.1	2011	KE6SCS NODL 73
113515	5	0.1	2133	BD7OXR WD6DBM -19	113500	-9	-0.0	2011	NODL KE6SCS 73

What FT8 Looks and Sounds Like



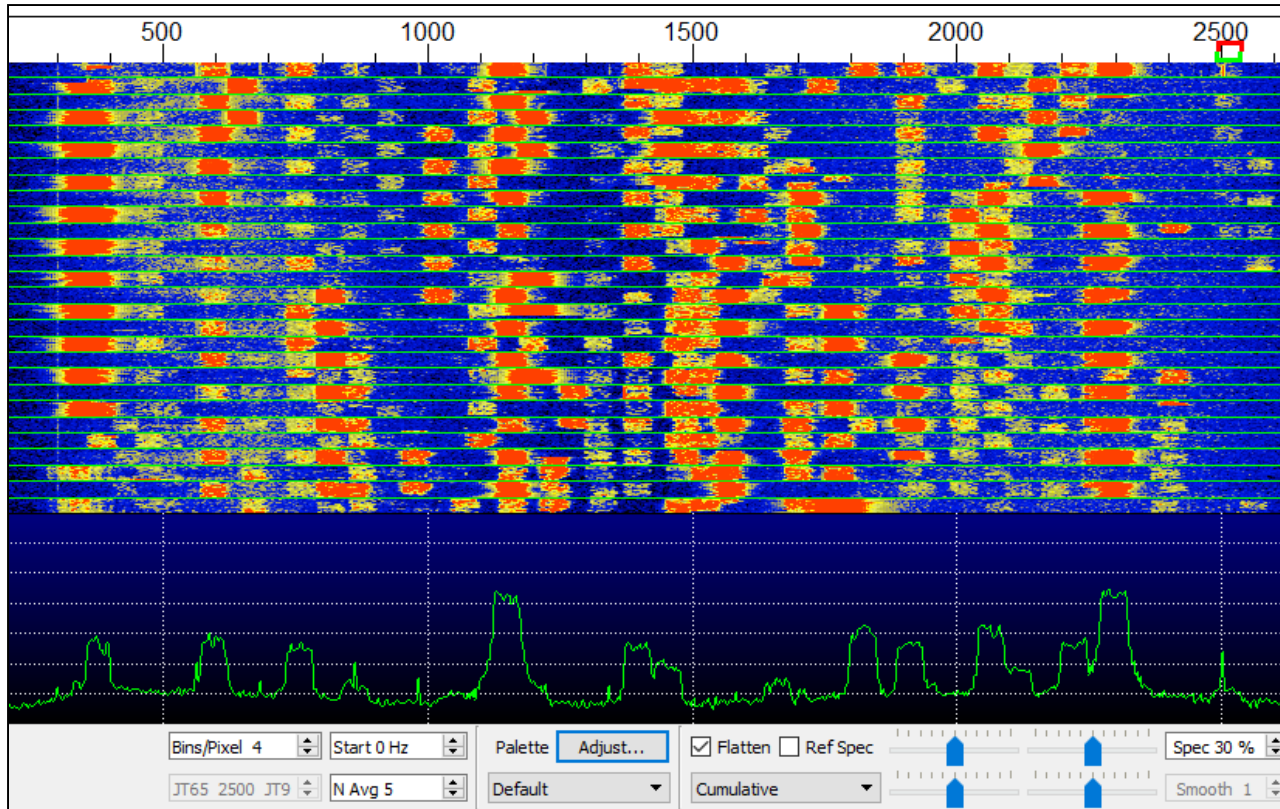
Single FT8 signal:



50 Hz segments where
QSOs take place



What FT8 Looks and Sounds Like



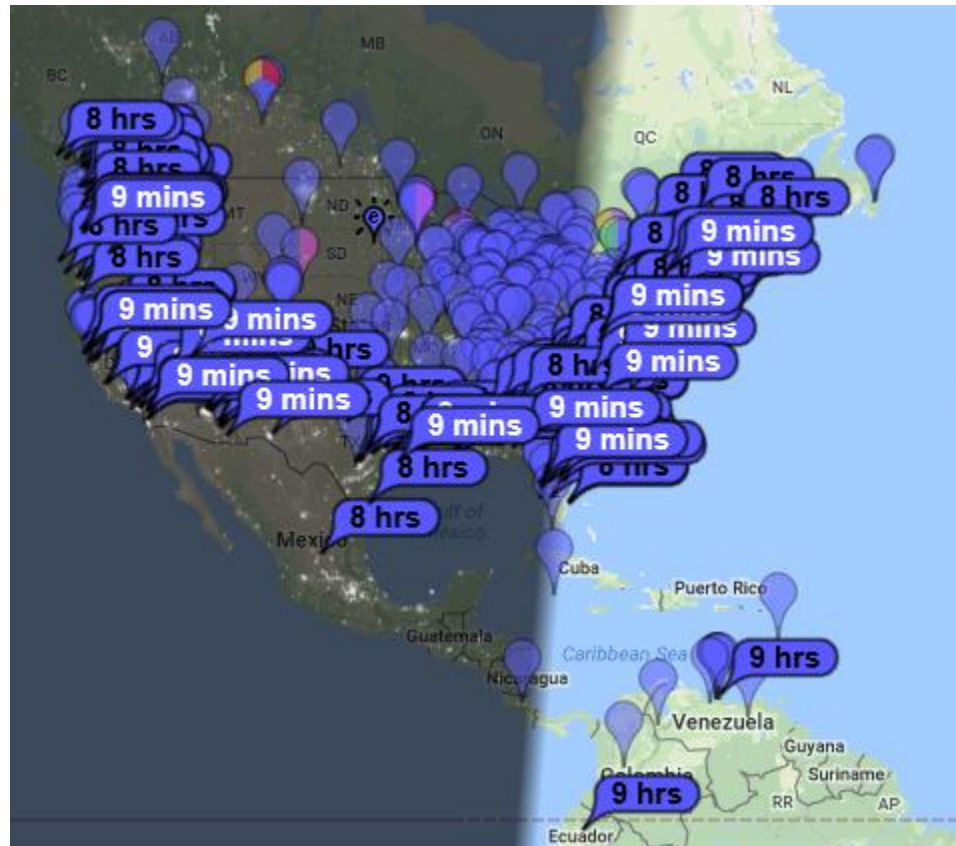
15-second segments
(offset between the
green lines) where
stations alternately
transmit and receive

30-second audio clip
of 40m FT8
transmissions



How's My Signal?

You can use PSK Reporter, <https://pskreporter.info> to see how well your signal is being received throughout the world (this works for just about *all* modes, not just FT8). Here is a snapshot of the map for N0DL on 40m, 1150 UTC March 9th, 2018:



Questions?

Speaker's note:

As of this writing I have spent more time researching and writing about FT8 than actually operating it.

Thanks for your attention!

Time Sync Software

- The built-in Windows facility for time synchronization is usually not adequate. We recommend the program *Meinberg NTP* (see [Network Time Protocol Setup](#) for downloading and installation instructions) or *Dimension 4* from [Thinking Man Software](#).

Additional References and Links

- ¹WSJT User Guide:
<http://physics.princeton.edu/pulsar/k1jt/wsjt-doc/wsjt-main-1.7.1-devel.html>
- ²[The World's Ugliest Music](#) TED Talk
- ³Download link for WSJT-X:
<https://physics.princeton.edu/pulsar/k1jt/wsjt.html>
- FT8 Operating Guide:
http://www.physics.princeton.edu/pulsar/K1JT/FT8_Operating_Tips.pdf

Additional References and Links

- 4DX Lab Suite including Commander:
<http://www.dxlabsuite.com/commander/>
- Digital modes for the beginner:
<http://ve6mvp.com/beginnersdigital.htm>
- Buxcom Rascal Mark IV soundcard + interface:
https://packetradio.com/catalog/index.php?main_page=index&cPath=50
- CQ article, “The Genius of Joe Taylor”
http://www.cq-amateur-radio.com/cq_highlights/2017-cq/2017-09-cq/2017-09-cq-zero-bias.html