Introduction to Ham Radio
Digital Mode* FT8

Dave LeVasseur, N0DL
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* 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

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

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.

Data courtesy of Club Log
Txn 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 Analysis

<table>
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<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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| • Good for weak signals *e.g.* 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 *lots* of HF activity at present | • 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 |

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<th>Opportunities</th>
<th>Threats</th>
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| • User interface improvements, addressing software *design flaws and programming bugs*  
• Enhanced functionality *e.g.* better logging and statistics  
• Further innovation *e.g.* multi-transmit capability for **DXpeditions** | • 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 |

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1 Lifted 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 Music” 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)
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 Commander 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](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](https://www.meinberg.com/download/ntp/) for downloading and installation instructions)

• Or Dimension 4 from [Thinking Man Software](https://www.thinkingmansoftware.com/).
Setting up CAT (rig control)
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
N0DL’s QTH grid square in 6 characters

Grid Square: EN14kv

Getting Started

Set the band, tune up as normal

Use Tune to check power level

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

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
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](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/wsjtx-
doc/wsjtx-main-1.7.1-devel.html

• ²The World’s Ugliest Music TED Talk

• ³Download link for WSJT-X:  
https://physics.princeton.edu/pulsar/k1jt/wsjtx.html

• FT8 Operating Guide:  
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