

NHARC

# DIGITAL MODES

# FT8

Working the world below the noise floor, 15 seconds at a time

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# AGENDA

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## 02 MODULATION

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## 03 THE WAVEFORM

8 tones on a 15-second clock

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One contact, start to finish

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Getting the most out of WSJT-X

# WHY FT8 EXISTS

Joe Taylor (K1JT) and Steve Franke (K9AN) released it in 2017. It solved four real problems at once.

## WEAK SIGNAL

Decodes down to -21 dB SNR, roughly 20 dB below what your ear can pull out of the noise. Signals you cannot hear still print a callsign.

## LOW POWER

5 watts and a compromised antenna will work DX. The processing gain does the heavy lifting your amplifier used to.

## CROWDED SPECTRUM

One signal is only 50 Hz wide. Dozens of QSOs stack inside a single 2.5 kHz SSB channel without stepping on each other.

## STRUCTURED + AUTOMATED

A fixed message format and a rigid clock let the software run the exchange. Log a contact while you refill your coffee.

# FT8 IS ONE OF A FAMILY

All built on the same idea: structured messages plus heavy error correction. They trade speed against sensitivity.

## FT8

T/R 15 s

FLOOR -21 dB

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The all-rounder. Fast enough to be fun, sensitive enough for real DX.

## FT4

T/R 7.5 s

FLOOR -17 dB

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Sprint version for contesting. Twice the speed, less margin.

## JT65

T/R 60 s

FLOOR -25 dB

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The ancestor. Very slow, very sensitive. EME and deep QRP.

## WSPR

T/R 120 s

FLOOR -31 dB

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Not a QSO mode. Beacons that map where your signal lands.

# MODULATION: THREE KNOBS

You know CW and SSB in your bones. Line them up with FT8 and the black box cracks open: it's a third way to turn a knob you already use.

## AMPLITUDE

CW keys it on and off

Two states, one bit per symbol.  
Timing spells out Morse and  
your ear does the decoding.  
About 50-150 Hz wide.

## FREQUENCY

SSB and FSK both live here

SSB glides it smoothly with  
your voice (analog, ~2.5 kHz).  
FSK steps it between fixed  
tones. FT8 uses eight of them.

## PHASE

PSK shifts the timing

Where the wave sits in its  
cycle. The third and last knob.  
Not used by FT8, but it  
completes the picture.

## FT8 = THE FREQUENCY KNOB, QUANTIZED

Eight fixed tones instead of a smooth glide. Every clever thing in this talk follows from that one choice.

# FSK: WHY IT SURVIVES THE NOISE

Only the frequency changes, never the amplitude. That buys two things nothing else on the band has.

## CONSTANT ENVELOPE

Amplitude never moves, so the transmitter can run flat out with no distortion, and a deep fade that would gut an AM or SSB signal barely dents a steady tone.

## ONE QUESTION PER SYMBOL

The receiver never has to guess a level. It only asks which tone was loudest. That yes/no call holds up long after audio becomes unreadable.

## THE WHOLE TRICK

CW and SSB fail on weak signals because your ear, or a level detector, eventually runs out of margin.

FT8 turns detection into a tone-picking contest instead, and a computer wins that contest all the way down to -21 dB, where there is no audible signal left at all.

# SIDE BY SIDE

Same three knobs, three very different recipes.

|                   | CW            | SSB                | FT8                 |
|-------------------|---------------|--------------------|---------------------|
| WHAT VARIES       | Amplitude     | Frequency (analog) | Frequency (8 tones) |
| SYMBOL STATES     | 2 (on / off)  | continuous         | 8 (3 bits each)     |
| BANDWIDTH         | ~50-150 Hz    | ~2.4-2.8 kHz       | 50 Hz               |
| TYPICAL POWER     | 5-100 W       | 50-100 W           | 5-25 W              |
| WEAK-SIGNAL FLOOR | the human ear | readable audio     | -21 dB (software)   |

# THE WAVEFORM: 8-FSK BY THE NUMBERS

Franke-Taylor design, 8-FSK modulation. Everything below falls out of two choices: 8 tones, 6.25 Hz apart.

**8**

TONES

one of eight frequencies per symbol

**6.25 Hz**

SPACING

gap between adjacent tones

**50 Hz**

BANDWIDTH

8 tones wide, total

**6.25**

BAUD

symbols sent per second

**0.16 s**

PER SYMBOL

each tone is  $1/6.25$  s long

**3 bits**

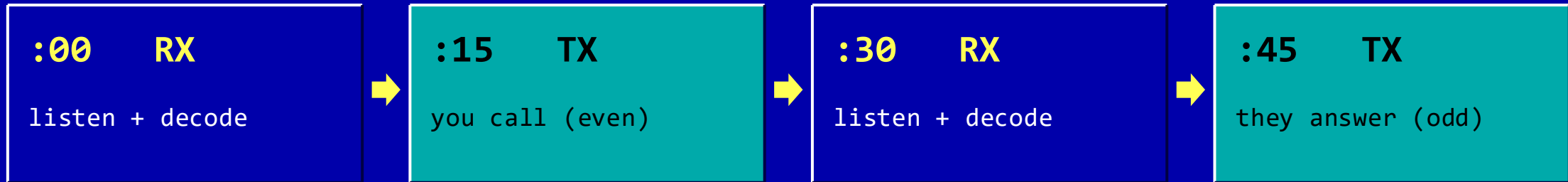
PER SYMBOL

$\log_2(8) = 3$  bits of data



# THE 15-SECOND CLOCK

FT8 is strictly synchronized. Each minute is sliced into four 15-second slots and everyone transmits on the boundaries.



## WHY THE CLOCK MATTERS

Your 12.6 seconds of tones have to land inside the receiver's 15-second window, so both radios need the same time. Keep the PC clock within about a second with NTP or a GPS source. Drift past a couple of seconds and nobody decodes you.

The payoff: the decoder already knows exactly when a transmission starts and stops, so it can integrate the whole 12.6 seconds of signal. That accumulated energy is a big part of how it hears what your ears cannot.

# PACKING A QSO INTO 77 BITS

Two callsigns and a grid or report ride in 77 bits, total. Here is the budget for a standard message.

**28 bits**

**CALLSIGN 1**

sender, or CQ / QRZ / DE

**28 bits**

**CALLSIGN 2**

the station being called

**15 bits**

**GRID / RPT**

4-char locator, or a report

**6 bits**

**FLAGS + TYPE**

R, /R suffix, message type

## HOW IT FITS

28 bits holds ANY standard callsign. The secret is structure: slot 1 is one of 37 symbols, slot 2 one of 36, then a digit (10), then up to three letters (27 each).  $37 \times 36 \times 10 \times 27 \times 27 \times 27 = 262$  million, just under  $2^{28}$ .

15 bits holds a 4-character grid:  $180 \times 180 = 32,400$  squares, under  $2^{15}$ . Signal reports and RRR / RR73 / 73 reuse that same field with reserved values. Nothing is wasted.

# SPECIAL CALLS, TOKENS & LIMITS

Not every message is two standard calls and a grid. FT8 has escape hatches, and one hard ceiling.

## HASHED CALLSIGNS

Compound and DX calls (like VP2E/KB3LYB) don't fit 28 bits. FT8 sends a short hash of the full call instead, and your rig fills it in from calls it decoded in the last few minutes.

## SPECIAL TOKENS

CQ, QRZ, DE, RRR, RR73, and 73 are never spelled out. They are reserved values inside the callsign and grid fields, so they cost almost nothing to send.

## MESSAGE TYPES

A 3-bit type field picks the layout: standard call, EU VHF contest, nonstandard call, or free text. The decoder knows exactly how to unpack each one.

## 13-CHAR FREE TEXT

Anything arbitrary is capped at 13 characters. That ceiling is the price of packing everything else so tightly. It is why FT8 is for contacts, not conversations.

# WHY IT DECODES BELOW THE NOISE

One transmission is 79 symbols, 12.6 seconds long. Only 58 carry your message. The rest is scaffolding that makes weak decodes possible.

## 91 BITS IN

Your 77-bit message plus a 14-bit CRC. The checksum lets the decoder throw out a guess that is almost right instead of logging a bogus callsign.

## LDPC (174,91)

Those 91 bits become 174 with forward error correction. Half the transmission is redundancy, so the decoder repairs damage instead of asking for a repeat.

## 7x7 COSTAS SYNC

A tone pattern mathematically guaranteed to only match itself. Sent three times (start, middle, end) to pin down timing and frequency before the decoder reads a single data bit.

## SOFT DECODING

The decoder works in probabilities, not hard ones and zeros, and iterates. That soft, belief-propagation approach is what reaches the noise floor.

**RESULT:** a callsign prints at -21 dB SNR, about 20 dB below the noise your ear hears

# A COMPLETE QSO

Six transmissions, about 90 seconds, almost entirely automated. You double-click a decode and the software runs the rest.

|    |     |                  |                                         |
|----|-----|------------------|-----------------------------------------|
| TX | :15 | CQ KB3LYB EN90   | You call CQ from your grid square       |
| RX | :30 | KB3LYB W1AW FN31 | W1AW comes back with their grid         |
| TX | :45 | W1AW KB3LYB -12  | You send a signal report (-12 dB)       |
| RX | :00 | KB3LYB W1AW R-09 | They roger, and report you back         |
| TX | :15 | W1AW KB3LYB RRR  | You confirm all received                |
| RX | :30 | KB3LYB W1AW 73   | They sign 73. Contact complete, logged. |

# OPERATING TIPS: A CLEAN SIGNAL

A clean, well-placed signal gets answered. A loud, splattering one gets ignored (or worse).

## PLACE YOUR SIGNAL

Click an open slice of the waterfall to set your TX offset. Keep it in the flat part of the audio passband (roughly 1000-2000 Hz) so the rig radiates full, clean power instead of rolling off at the edges.

## MIND YOUR ALC

FT8 is a single tone at 100% duty cycle. Drive it so the ALC barely moves, ideally near zero. Overdriving does not add power, it just splatters across the band and decodes worse.

## SPLIT vs FAKE IT

Turn on Rig split (or 'Fake It' if the rig can't). WSJT-X shifts the carrier so audio tones stay in the linear region. It keeps the transmitted signal clean without you touching a dial.

## ONE AND DONE

Let each sequence finish. Low audio, clean signal, and patience beat brute force every time. If you are not decoded, it is rarely a power problem.

# OPERATING TIPS: WORK THE SOFTWARE

WSJT-X has a few defaults worth changing, and a couple of settings worth understanding.

## HOLD TX FREQ

Check 'Hold Tx Freq' so your transmit slot stays put. The default drags your TX onto whoever you answer, usually into a pileup. Stay on your own clear frequency and let them come to you.

## DECODE DEPTH vs CPU

Fast, Normal, and Deep trade decodes for processor time. A quick PC on Deep with AP digs out the weakest signals; on a Raspberry Pi, back off so decoding finishes before the next cycle starts.

## PICK YOUR CYCLE

Transmit on the opposite slot (even vs odd) from the station you are calling. Two stations keying on the same cycle are deaf to each other the whole time.

## WATCH YOUR RX LEVEL

Keep input audio in the green, around 30-50 on the meter, not pinned. Clipped receive audio buries weak decodes just like an overdriven signal splatters on transmit.

# COMPANION TOOLS

WSJT-X does the radio work. These free add-ons make it far more usable, especially chasing awards.

## GRIDTRACKER

A live map of every decode. Grid, DXCC, and state tracking, award progress, and logging, all in a visual you can read at a glance.

## JTALERT

Watches decodes for the calls, grids, and states you still need, pops an alert, and pushes contacts straight into your logger. Never miss the new one.

## JTSYNC

Keeps the PC clock disciplined for FT8 timing without fighting Windows' built-in time service. Set it and forget it.

## PSK REPORTER

A crowd-sourced map of where your signal is being decoded worldwide. Instant, honest feedback on your antenna and propagation.



# WHERE FT8 IS HEADED

The mode is still moving. A few developments worth watching.

## SUPERFOX (2024)

WSJT-X 2.7 added SuperFox for big DXpeditions: one constant-envelope waveform carrying up to 9 messages at once, about +10 dB over the old multi-signal Fox/Hound. N5J on Jarvis Island ran it first.

## THE FAMILY FILLS IN

Q65 is taking over weak-signal VHF, EME, and scatter; FST4 and FST4W do the same on LF and MF. Different bands, same structured-message-plus-FEC playbook.

## SMARTER DECODERS

Each release squeezes more out of the same signal through better a-priori and soft-decision decoding. The waveform is stable; the software keeps getting more sensitive.

## THE OPEN QUESTION

As FT8 keeps growing, clubs keep debating what it does to conversation and to CW/SSB activity. The technology is settled; the culture is still being written.

# WHAT YOU GAIN / WHAT YOU GIVE UP

FT8 is not better than SSB or CW. It is a different set of tradeoffs, tuned hard for one job: completing contacts at the edge of nothing.

## YOU GAIN

- > Work DX with 5 watts and a wire
- > Decode signals 20 dB under the noise
- > 50 Hz wide, so the band holds hundreds of QSOs
- > Runs itself once you click a caller
- > Instant feedback via PSK Reporter maps

## YOU GIVE UP

- x Conversation: messages are 13 characters, period
- x Spontaneity: you wait for the next 15-second slot
- x Ragchewing, contest nuance, personality
- x Clock freedom: no time sync, no decode
- x The romance. Some folks ask if it's even radio

# RESOURCES

Further reading for anyone who wants to dig deeper than one meeting allows.

## WSJT-X

[wsjt.sourceforge.io](https://wsjt.sourceforge.io)

The software, docs, and user guide

## THE QEX PAPER

[wsjt.sourceforge.io/FT4\\_FT8\\_QEX.pdf](https://wsjt.sourceforge.io/FT4_FT8_QEX.pdf)

Franke, Somerville & Taylor on how FT4/FT8 really work

## THE 77-BIT PROTOCOL

[wsjt.sourceforge.io](https://wsjt.sourceforge.io)

Section 17 of the QEX paper breaks down every message type

## PSK REPORTER

[pskreporter.info](https://pskreporter.info)

See in real time where your signal is decoded

## GRIDTRACKER / JTALERT

[gridtracker.org](https://gridtracker.org) | [hamapps.com](https://hamapps.com)

Mapping, alerts, and one-click logging

# Questions?

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## Credits

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FT8 by Joe Taylor K1JT and Steve Franke K9AN