



WSJT-x and Digital Deeper Dive Part 2

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Part 1 – WSJT-x Use Case for FT8

- Stephen covered the basics of FT8/FT4 and how it is sent
- He touched on the “why” we use it.
- Talked about how to have a QSO with FT8/FT4
- Using PSKReporter to see where you are being heard.

The screenshot displays the WSJT-X v2.7.0 interface. The top section shows two tables: 'Band Activity' and 'Rx Frequency'. The 'Band Activity' table lists various stations and their call signs, such as '150815 -17 -0.3 2003 - CQ WBASH'. The 'Rx Frequency' table shows received signals, including '150600 Tx 1213 - CQ KK4YD EM74'. Below the tables is a control panel with buttons for 'Log QSO', 'Stop', 'Monitor', 'Erase', 'Decode', 'Enable Tx', 'Halt Tx', and 'Tune'. A frequency display shows '7.074000' MHz. The bottom right corner shows the system tray with the date '2025 Aug 02 15:10:54' and the time '11:10 AM 8/25'.

Agenda

- Why do we use digital modes, especially in Ham Radio?
- What are the most common modes?
- What modes are supported by WSJT-x (free application for digital modes)
- Why do these modes work so well?
- What should I know to use these modes?

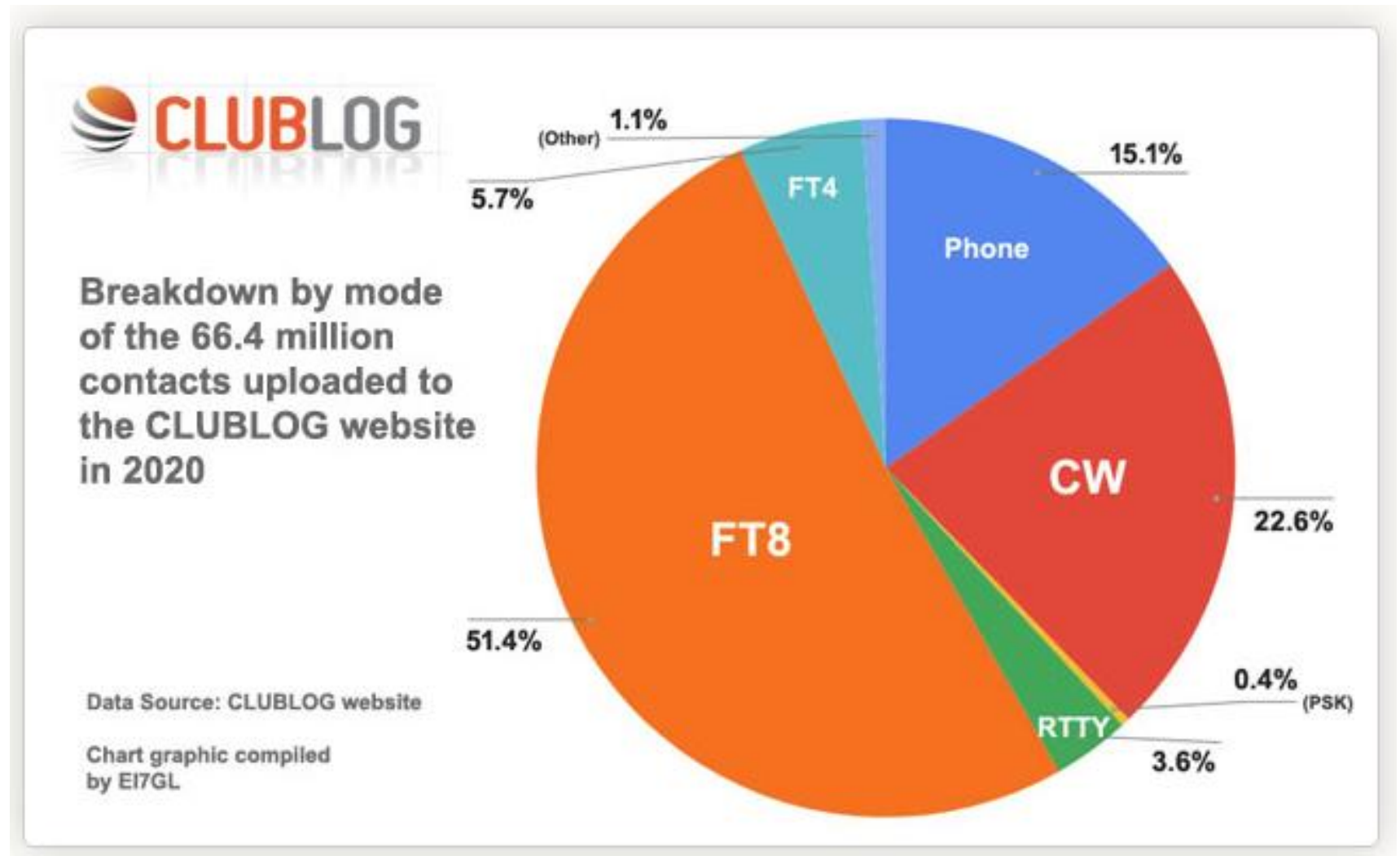


Is digital overtaking other modes?
Cobwebs on your microphone?

What is the popularity of Digital modes compared to others?

~60% of contacts are digital in 2020*

- *Notes
- No new data collected
- Does not count DMR, D-Star, and Fusion



As a note, LOTW does not break down contacts by mode, so we may not know exact numbers



Why do **we** use digital modes?

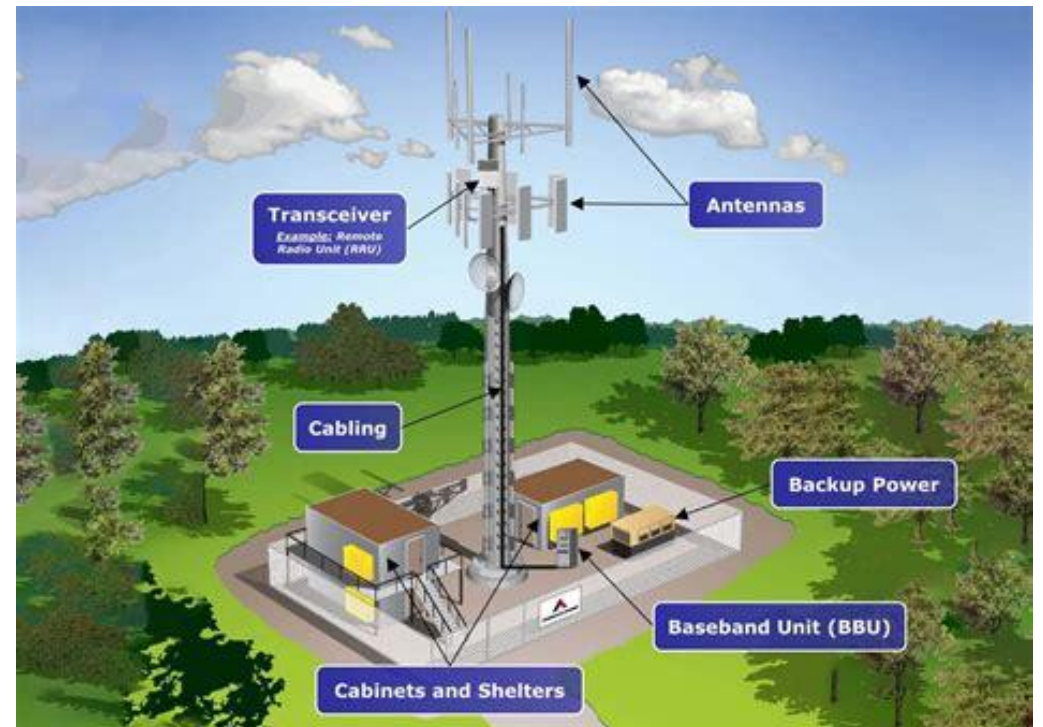
- Digital communications was engineered to overcome numbers of deficiencies with analog methods:
 - Quality or robustness of the message
 - Signal to noise ratio , especially over RF
 - More efficient use of bandwidth
 - Able to add security by way of encryption
 - Leverages the uses and advances in computer technology



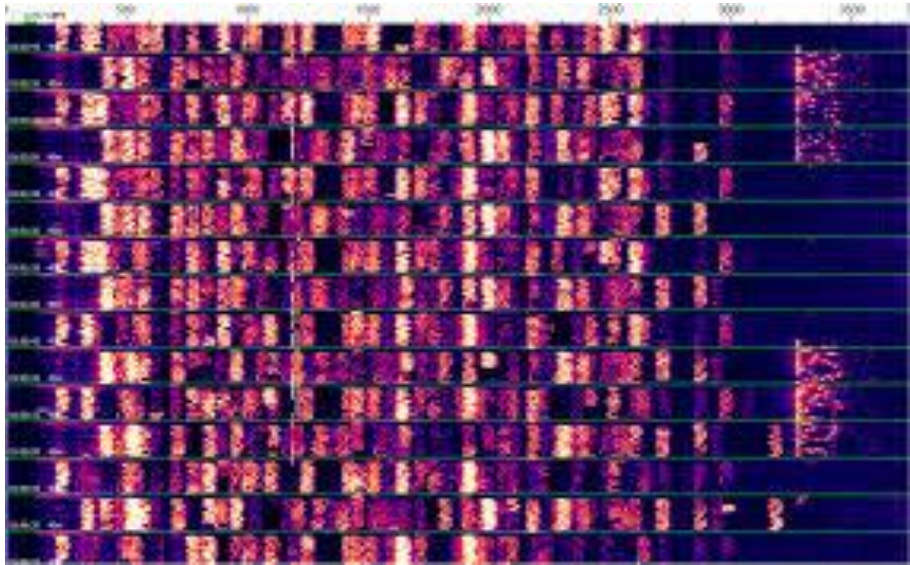
What does bandwidth do for cell phones?

- A 4G base station typically supports around **2,000** connected devices in a similar area.
- 5G is designed to support up to **1 million** connected devices per 0.38 square miles, showcasing its enhanced capacity for IoT and mobile users.

Bandwidth = more calls
more calls = more \$\$



Why do Hams use digital modes?



Digital modes are
Ham Radio

- Operate in weak signal & high noise conditions
- Efficient use of bandwidth – less co-interference issues
- Low power (QRP) operation for portable use – e.g. POTA
- Can support error correction and accuracy
- Encourages experimentation
- Emergency communications requires accuracy and robustness
 - Transmitting ICS Forms
 - Accurate information in times of emergency



Popular Digital Modes

Mode	Use Case	Bandwidth	Special Feature
FT8, FT4	Weak signal Dxing, FD, general uses	50 Hz	Time-synced QSO's
JS8Call	Chat-style with FT8 Robustness	~50 Hz	Message store and Relay
PSK31	Chat-style keyboard QSO, but no error checking	31 Hz	Narrow and efficient
RTTY	Contesting and some general use	~170 Hz	Legacy, but still popular
WinLink	Emergency email via HF/VHF -robust	Varies	Uses VARA or PACTOR as protocol



WSJT-x is the most used application

- Developed by a team led by Dr Joe Taylor, K1JT
- Joe's initial interest was to improve the QSO success for meteor scatter mode.(MSK144)
- Today we know it as the premier digital mode application with robust results.
- It is also being used for
 - Moon Bounce (EME)
 - Ionospheric Research (WSPR)
 - Propagation studies (WSPR & other modes)



Dr. Joseph Taylor – K1JT

Co-inventor is Steve Franke – K9AN

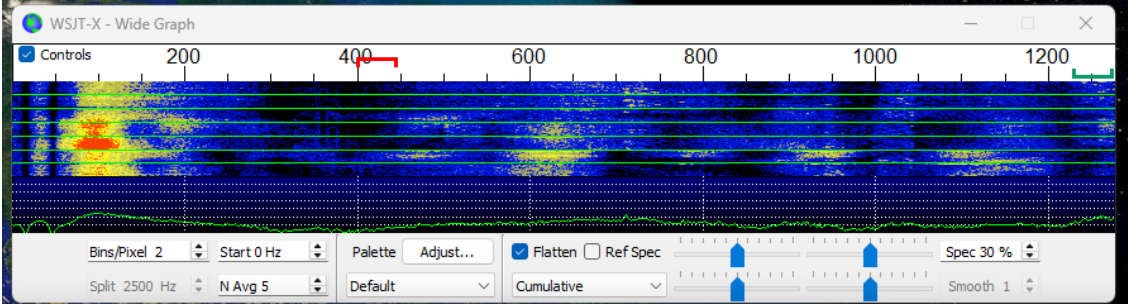
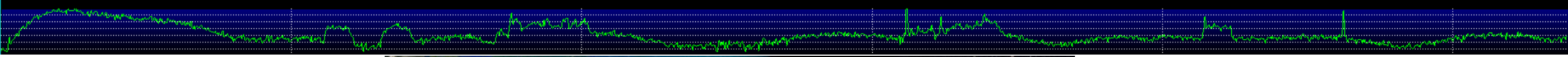


Modes Supported in WSJT-x

- There are 11 digital modes* supported, however some are for special purposes like meteor and rain scatter, EME, and propagation testing.
- Most hams will use only 4 of these modes

Mode	Features	Use Cases
FT-8	15 sec T/R sequence	Used for general contacts and contesting, as well as FD
FT-4	7.5 sec T/R sequence	Contesting and difficult propagation conditions
JT-9	Low bandwidth	Used for LF bands
WSPR	QRP beacon mode	Test antennas and propagation

*Other modes are: FST4, JT4, JT65, Q65, MSK144, FST4W, Echo



Spectrum Graph pane

WSJT-X v2.7.0 by K1JT et al.

File Configurations View Mode Decode Save Tools Help

Band Activity					Rx Frequency				
UTC	dB	DI	Freq	Message	UTC	dB	DI	Freq	Message
205500	-16	0.1	943	~ W8ZBR W6DPM R+06	205130	-24	0.6	1228	~ CQ POTA CO6XX FL02
205500	-18	0.6	972	~ WA9TT N9IAT EN54	205154	Tx		400	~ CO6XX KB4MG EM74
205500	-14	0.1	1258	~ W6SFG EA4T IN70	205215	Tx		400	~ CO6XX KB4MG EM74
205500	-18	0.6	1229	~ KB4MG CO6XX -01	205245	Tx		400	~ CO6XX KB4MG EM74
----- 20m					205315	Tx		400	~ CO6XX KB4MG EM74
205530	-9	0.2	998	~ CQ POTA KC1UYZ/P FN31	205330	-19	0.6	1229	~ KB4MG CO6XX -09
205530	-17	-0.0	248	~ CQ KF9UG EN71	205345	Tx		400	~ CO6XX KB4MG R-19
205530	-16	0.1	943	~ W8ZBR W6DPM R+06	205415	Tx		400	~ CO6XX KB4MG R-19
205530	-15	-0.0	883	~ SO9AB WB2WJF FN02	205430	-18	0.6	1229	~ K7ACT CO6XX RR73
205530	-19	0.6	974	~ WA9TT N9IAT R-12	205445	Tx		400	~ CO6XX KB4MG EM74
205530	-18	-0.0	328	~ CQ N2CR FN20	205500	-18	0.6	1229	~ KB4MG CO6XX -01
----- 20m					205515	Tx		400	~ CO6XX KB4MG R-18
205600	-12	0.2	998	~ W9NG KC1UYZ/P +02	205545	Tx		400	~ CO6XX KB4MG R-18
205600	-16	0.0	710	~ K2EZR MW3FLI RRR	205615	Tx		400	~ CO6XX KB4MG R-18
205600	-17	0.1	943	~ W8ZBR W6DPM R+06	205630	-17	0.6	1229	~ KB4MG CO6XX RR73
----- 20m					205645	Tx		400	~ CO6XX KB4MG 73
205630	-17	0.6	1229	~ KB4MG CO6XX RR73					
205630	-15	0.0	710	~ CQ NA MW3FLI IO83					
205630	-14	0.3	1006	~ SO9AB W1BIU FN43					
205630	-19	0.7	973	~ WA9TT N9IAT R-12					

CQ only Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx Tune Menu

20m **S** **14.072 500** Tx even/1st Hold Tx Freq
 Tx: 400 Hz Rx: 1229 Hz Report: -18 Auto Seq CQ: None

H DX Call DX Grid
 FT8 CO6XX FL02
 FT4 Az: 155 1453 km
 MSK Lookup Add
 Q65 **2025 Jul 22**
 JT65 **20:56:46**

Generate Std Msgs Next Now Pwr
 CO6XX KB4MG EM74 Tx 1
 CO6XX KB4MG -18 Tx 2
 CO6XX KB4MG R-18 Tx 3
 CO6XX KB4MG RRR Tx 4
 CO6XX KB4MG 73 Tx 5
 CQ KB4MG EM74 Tx 6

Tx: CO6XX KB4MG 73 FT8 Last Tx: CO6XX KB4MG R-18 4 1/15 WD:6m

Band Activity pane

Rx Frequency pane

Took 4 tries to get the first reply from CO6XX

Took 6 more go rounds to complete the QSO

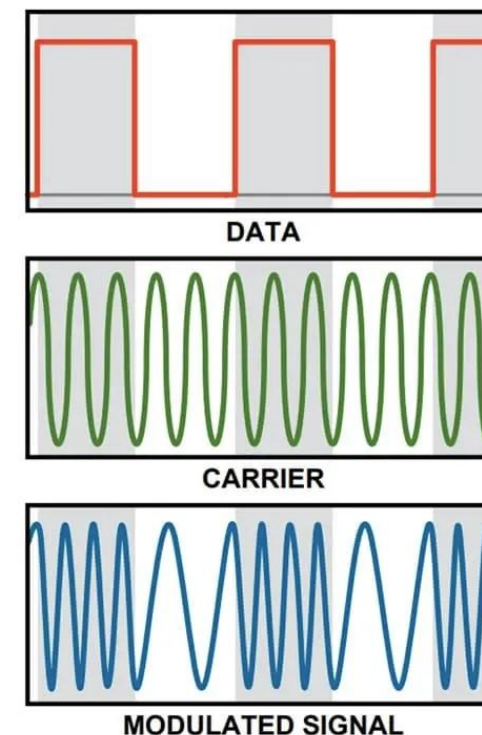
Why?

Signal to noise. His signal was -18db
Some replies not decoding
FT-8 tries 8 times

Controls pane

Are “digital modes” fully digital?

- NOT Really! The digital data is not sent directly, like over wires. It is “encoded” audio
- Information is encoded in digital format (1’s and 0’s) but transmitted as an analog signal. These modes require a soundcard.
- The modulation used varies by the specific mode.
 - FT8 uses an 8-tone continuous-phase frequency shift keying (CPFSK). It is always on upper sideband. Each tone maps to 3 bits.
 - WSPR and JT4 use a 4-tone FSK modulation.

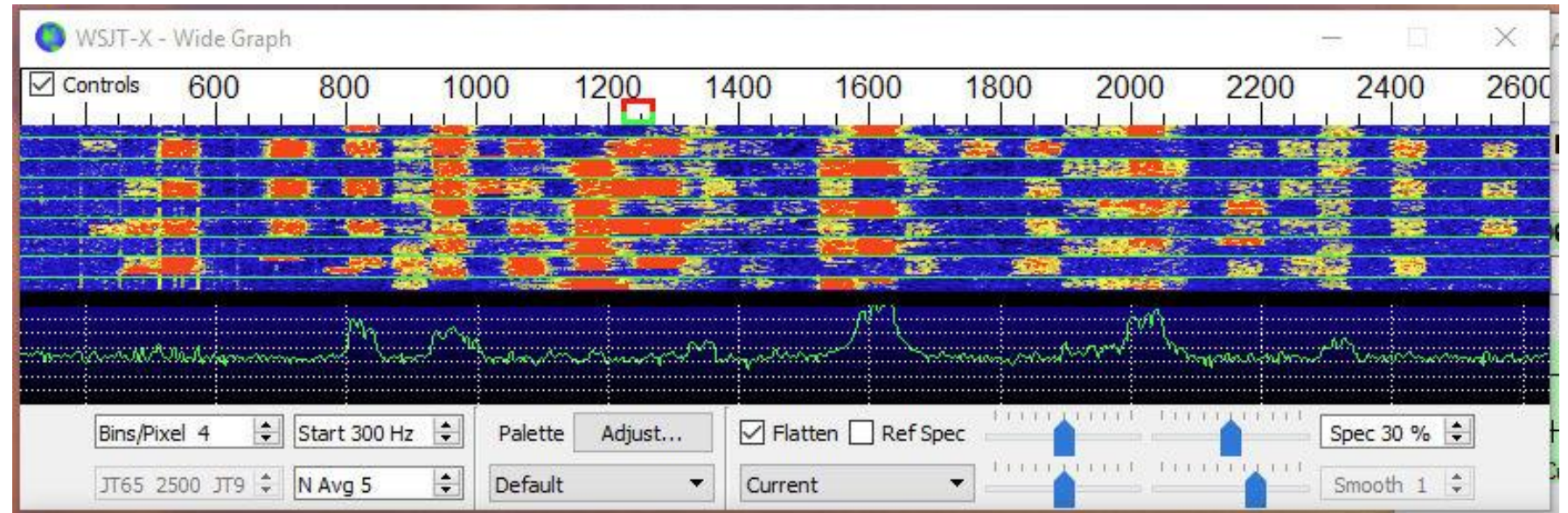


Sample of FT8



Example FT8 Band

Frequency



- Tones are spaced 6.25Hz apart and total signal is 50Hz bandwidth
- T/R cycle is 15 seconds long , counting the decode period
- Total available band is 3.6 KHz
- Message length is 77 bits of data and 14 bits of CRC (error correction)

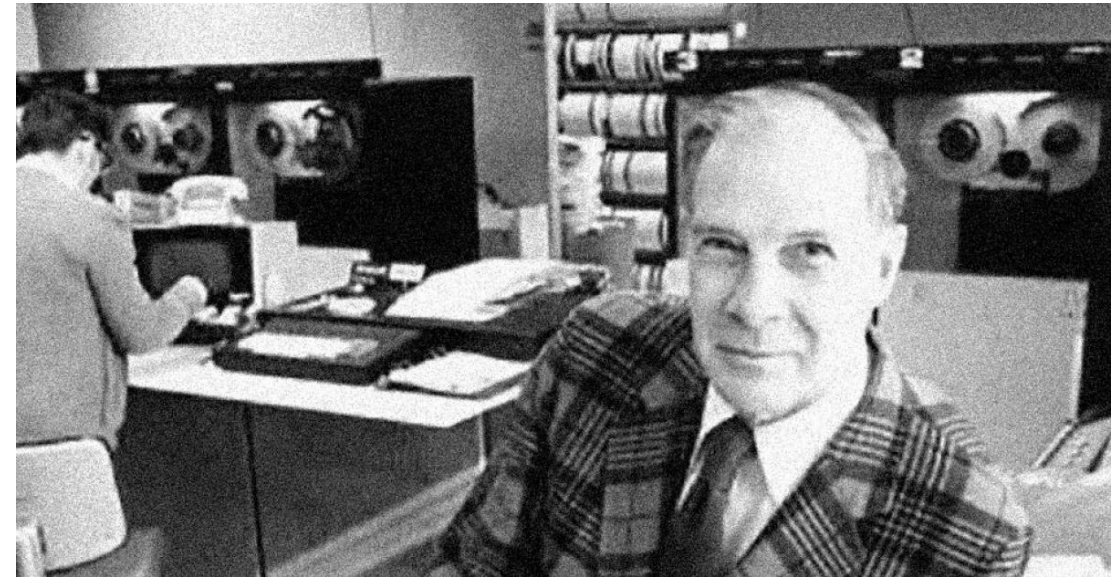


Hams have limitations on data rates

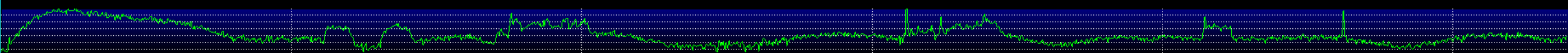
- On November 13, 2023, the Federal Communications Commission (FCC) adopted a Report and Order that eliminated the baud rate limitation for certain Amateur Radio HF bands. (Still 300 baud in 2200m and 630m bands)
- **Baud rate**, also known as **symbol rate**, is the rate at which the amplitude, frequency, and/or phase of a carrier waveform is varied to transmit information. With RTTY and other legacy modes, increased speed proportionally increased Bandwidth.
- FCC replaced the baud rate limitation with a 2.8 kilohertz (kHz) bandwidth limitation in the affected bands. Reference part 97.307(f)
- FCC says this change will promote continued sharing in these bands and incentivize innovation and experimentation by allowing licensees to use modern digital emissions. [We will see]

Why do these modes work so well?

- **Digital Error Correction** is required for any transmission system that has even a small component of noise.
- Interference comes from many sources
 - Atmospheric, electrical, RF, even intentional (ie jamming)
- **Forward Error Correction** was invented by Richard Hamming in 1950
 - Used to help correct incorrect readings of punch cards.
 - Same principals were applied to all sorts of digital communications
 - Newer methods still build on his work



Richard Hamming



How does this work?

101101

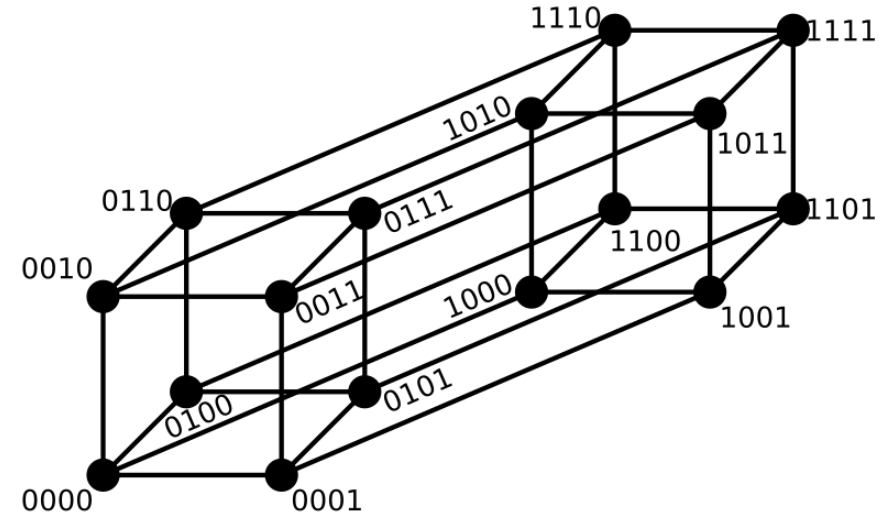
What we sent

110100

What we received

1XX10X

Differs in 3 bit positions



The **HAMMING DISTANCE** = 3

Written: $d(101101, 110100) = 3$



Forward Error Correction Simple Example

Encoded Bit Pattern	Error Correcting Codeword
00	00000
01	11100
10	10011
11	01111

Both Transmitter and Receiver have the same Codeword dictionary

Notice in these 5 bit codewords there are combinations not represented. It is this property that allows us to detect errors

01 00 01 11 11 10 00 10

 Here is the bit sequence we are trying to send

Each sequence is mapped to a codeword and sent

Codeword Assignment

Encoded Bit Pattern	Error Correcting Codeword
00	00000
01	11100
10	10011
11	01111

Here is the bit sequence we are trying to send

01 00 01 11 11 10 00 10

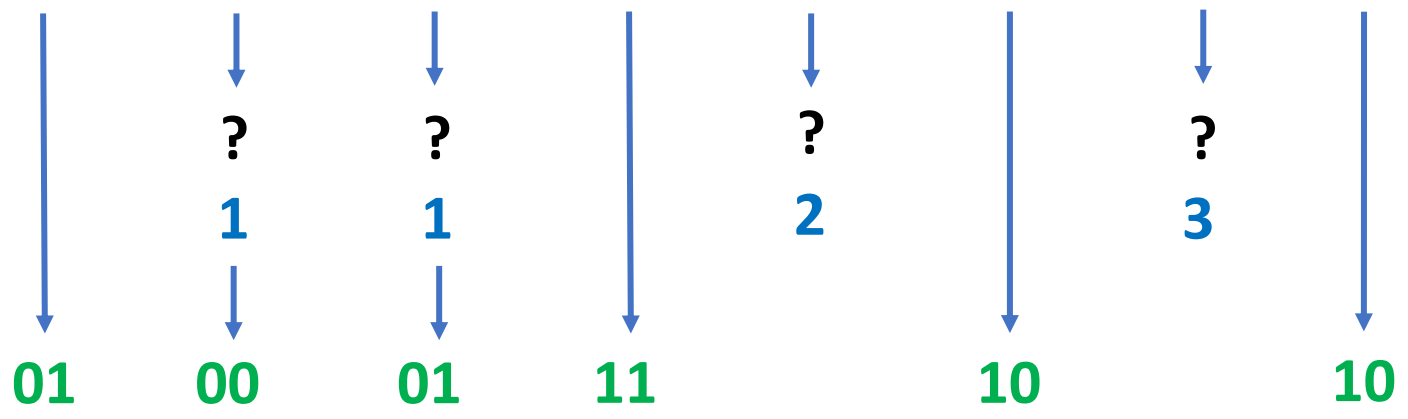
Codeword mapping

11100 00000 11100 01111 01111 10011 00000 10011

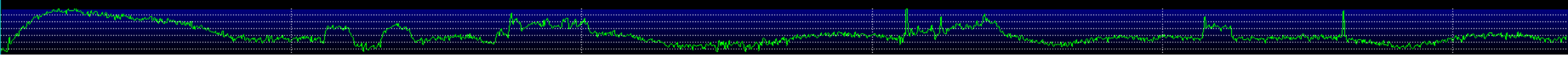
Received Values

11100 10000 11110 01111 01010 10011 10011 10011

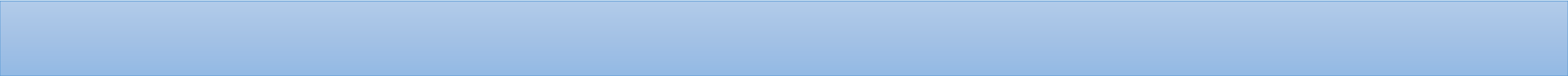
Hamming Distance



This is what is transmitted
16 bits becomes 40 bits



Using Digital Modes



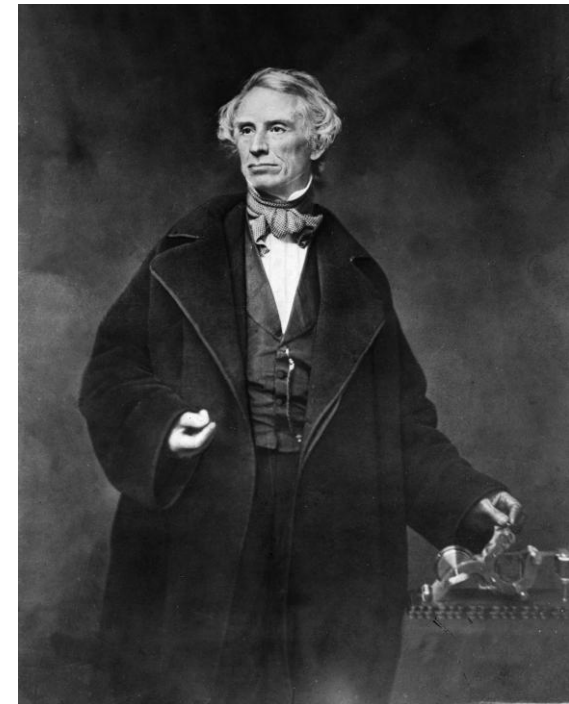


What should I know to use these modes?

- The WSJT modes require a “computer” and an accurate time base.
 - Windows, MAC, Linux, Linux variants on Raspberry Pi
- Most modes, except for JS8 (discussed later), are not conversational modes. You do, however, exchange information between 2 stations.
- FT8 signals can be decoded well below the noise floor (-21dB), and therefore are good for poor propagation conditions and when using low power (QRP).
- There are some special modes for contesting and Field Day.
- Often, a contact does not happen on the first transmission.
- If you have a rig with built in sound card or an external one, you can run digital modes.

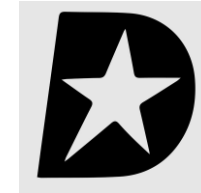
Digital Modes – How Recent?

- Morse Code – digital? – sort of - (1890)
- RTTY (1922)
- SSTV (1958)
- Packet/AX.25 (1978)
- PSK31 (1998)
- JT65 (2003)
- FT8/FT4 (2017)
- JS8 (2017)
- Next?



Digital Voice Modes

Format	Description	Key features
D-Star	Developed by the Japan Amateur Radio League, it uses a proprietary vocoder.	VoIP capabilities, GPS location sharing.
DMR	A commercial standard adapted for amateur use, supporting multiple vendors.	Time Division Multiple Access (TDMA), robust. Needs a code-plug for programming.
Fusion	Yaesu System Fusion, designed specifically for amateur radio and uses proprietary hardware.	Easy integration with existing systems.
FreeDV	An open-source digital voice mode for HF radio.	High-quality voice transmission, flexible setup.



FreeDV

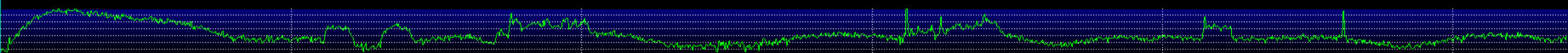


Digital Voice



Summary of WSJT-x modes & uses

Mode(s)	Uses	Notes
FT8, FT4	HF through UHF	15sec for FT8, 7.5 sec for FT4 exchanges
JT4, JT9, JT65, Q65	EME (moon bounce)	Optimized for this mode. 60 sec T/R times
FST4, FST4W	Low band (LF, MF)	Better sensitivity for low band work
WSPR	Beaconing	Testing antennas and propagation
MSK144	Meteor Scatter	VHF bands, short messages



JS8Call (app) – JS8 mode

- Simple explanation – robustness of FT8 with messaging layered on the mode.
- Uses same Forward Error Correct, so messages are robust
- Requires multiple “packets” to be sent to complete a message transmission. They call them Frames.
- Developed by Jordan Sherer (KN4CRD) in Atlanta, GA
 - Just for fun

JS8Call 



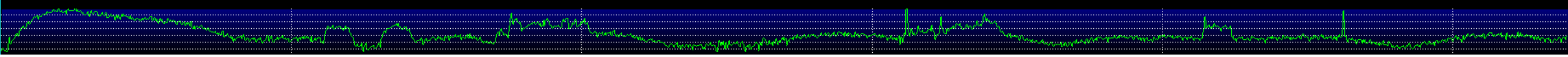
Other Digital Modes

- APRS: Automatic Packet Reporting System (144.39MHz)
- WINLINK
 - Supports Email with attachments, position reporting, weather and information bulletins.
 - Well known for its role in interoperable emergency and disaster relief communications.
- WSPR: Weak Signal Propagation Reporting



Digital Modes are a huge part of Ham Radio

- Efficiency and Weak-Signal Performance
- Spectrum Efficiency
- Automation and Logging
- New Capabilities and likely more to come
 - Modes like APRS send position data.
 - Winlink allows email over HF.
 - JS8Call supports keyboard-to-keyboard messaging with store-and-forward relays.
 - FT8/FT4 is optimized for contesting and rapid QSOs.
- Expands Ham Radio's Relevance



Thank you! Questions?

