Digital Modes

General License Class
Chapter 6

Presented by:

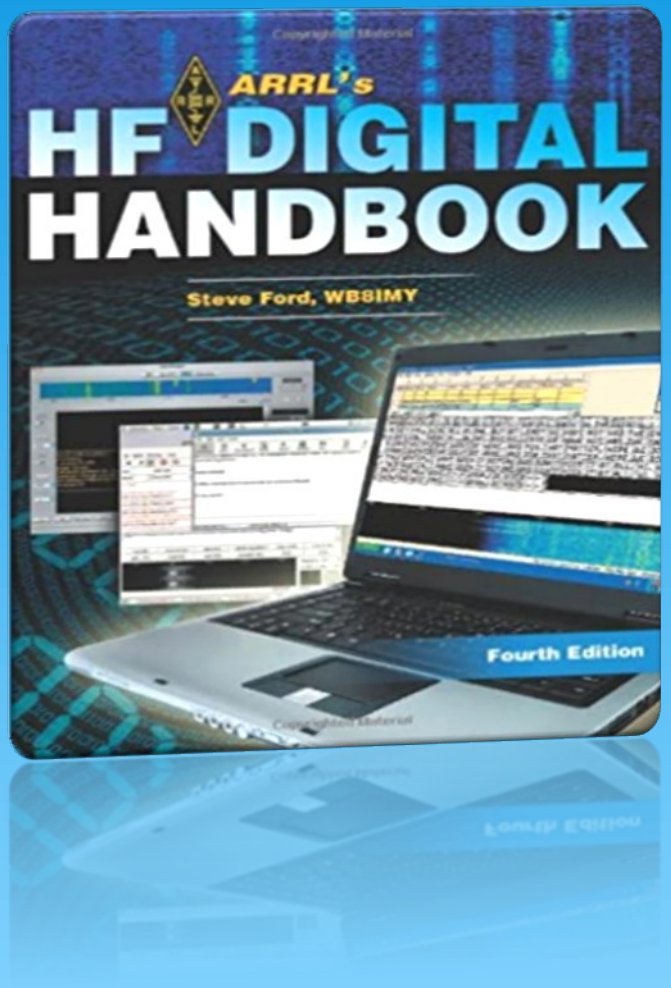
Santa Fe Trail Amateur Radio Club

SFTARC (KIØKK)

https://sftarc.org

Slide Information

- Text related to a question is in Black and **Bold**
- Links are in **Blue**
- Answers to review questions are **Bold** in the slide following the question



6.1 Basics of Digital Modes

6.1 Basics of Digital Modes

Pg. 6-1

- Digital communications modes exchange information using individual characters ***encoded*** as digital bits.
  - "A" using CW is "di dah"
  - "A" using ASCII is "01000001"
- Digital communications ***Modes*** consists of two components
  - ***Protocol*** or information encoding [FCC – 97.309]
  - ***Modulation*** formats
- Examples of Digital Communications Modes
  - RTTY, Packet (VHF/UHF), PSK31, JT-65/JT-9, FT8/FT4 … Keyboard
  - PACTOR, WINMOR , Winlink, JS8CALL…. Email and messaging
- Digital Voice Modes **[G8C16]**
  - DSTAR (ICOM), System Fusion (Yaesu), AOR digital voice, WinDRM, FreeDV …. Voice via digital methods regulated as voice modes

6.1 Where to Find Digital Activity

Pg. 6-2

- Digital modes are restricted to CW/Data segments of the HF bands
  - Usually found at the top end of the CW segment
  - ***Band plans*** define where digital modes may be found
  - Calling frequencies are typically at the lower end of the band and activity moves up with increased activity
  - 20 M band digital mode operating frequencies (14.070 – 14.112 Mhz) **[G2E08]**
    - PSK-31 – 14.070 MHz
    - FT-8 – 14.074 MHz
    - RTTY – 14.080 MHz
- Digital Modes are limited in the maximum data rates and signal bandwidths [FCC – 97.307]
- Information encoding and signal transmission protocols must be defined by FCC rules or be a publicly available method.
- Modes –https://www.sigidwiki.com/wiki/Category:Amateur_Radio

6.1 Digital Signal Band Plan

Pg. 6-2

Table 6.1
Digital Signal Band Plan
Where to Find Digital Signals on the HF Bands

Band (Meters)	*Frequency Range (MHz)*	*Notes|*
160	1.800 – 1.810	
80	3.570 – 3.600	
60	5332, 5348, 5358.5, 5373 and 5405 kHz	Channel center frequencies.*
40	7.070 – 7.125	RTTY DX calling frequency 7.040 MHz
30	10.130 – 10.150	
20	14.070 – 14.0995 and 14.1005 – 14.112	PSK31 calling frequency 14.070 MHz
17	18.100 – 18.110	
15	21.070 – 21.110	
12	24.920 – 24.930	
10	28.070 – 28.189	

*On 60 meters, the FCC continues to require that all digital transmissions be centered on the channel-center frequencies, which the Report and Order defines as being 1.5 kHz above the suppressed carrier frequency of a transceiver operated in the Upper Sideband (USB) mode. This is typically the frequency shown on the frequency display. Automatic operation is not permitted.

US Amateur Radio Bands

US AMATEUR POWER LIMITS

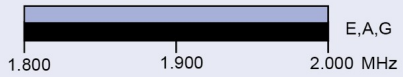
FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications. (b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.

Effective Date March 5, 2012

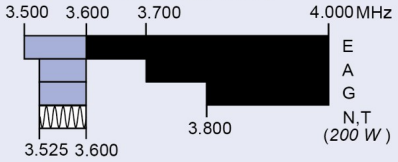
Published by:
ARRL The national association for AMATEUR RADIO®
www.arrl.org
225 Main Street, Newington, CT USA 06111-1494

160 Meters (1.8 MHz)

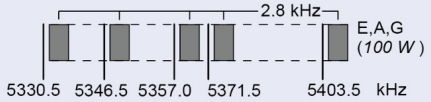
Avoid interference to radiolocation operations from 1.900 to 2.000 MHz



80 Meters (3.5 MHz)

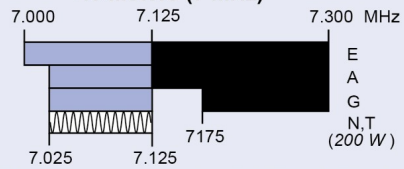


60 Meters (5.3 MHz)



General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated output of 100 W PEP. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III as defined by the FCC Report and Order of November 18, 2011. USB is limited to 2.8 kHz centered on 5332, 5348, 5358.5, 5373 and 5405 kHz. CW and digital emissions must be centered 1.5 kHz above the channel frequencies indicated above. Only one signal at a time is permitted on any channel.

40 Meters (7 MHz)

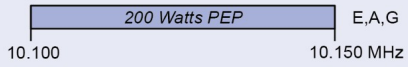


Phone and Image modes are permitted between 7.075 and 7.100 MHz for FCC licensed stations in ITU Regions 1 and 3 and by FCC licensed stations in ITU Region 2 West of 130 degrees West longitude or South of 20 degrees North latitude. See Sections 97.305(c) and 97.307(f)(11).

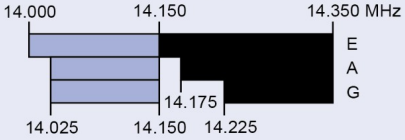
Novice and Technician licensees outside ITU Region 2 may use CW only between 7.025 and 7.075 MHz and between 7.100 and 7.125 MHz. 7.200 to 7.300 MHz is not available outside ITU Region 2. See Section 97.301(e). These exemptions do not apply to stations in the continental US.

30 Meters (10.1 MHz)

Avoid interference to fixed services outside the US.

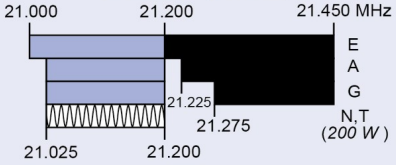


20 Meters (14 MHz)



17 Meters (18 MHz)

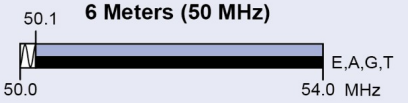
15 Meters (21 MHz)



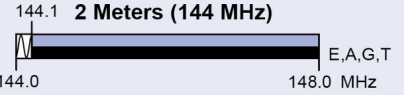
12 Meters (24 MHz)

10 Meters (28 MHz)

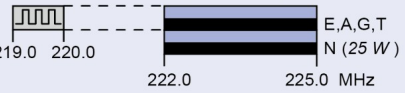
6 Meters (50 MHz)



2 Meters (144 MHz)



1.25 Meters (222 MHz)

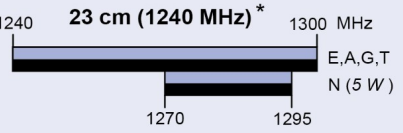


*Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* for information about your area.

70 cm (420 MHz)*

33 cm (902 MHz)*

23 cm (1240 MHz)*



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz *	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

* No pulse emissions

KEY

Note:
CW operation is permitted throughout all amateur bands.

MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.

Test transmissions are authorized above 51 MHz, except for 219-220 MHz

- = RTTY and data
- = phone and image
- = CW *only*
- = SSB phone
- = USB phone,CW, RTTY, and data.
- = Fixed digital message forwarding systems *only*

E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice

See *ARRLWeb at www.arrl.org* for detailed band plans.

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Exams: 860-594-0300 email: vec@arrl.org

 rev. 4/9/2013

Basic Digital Communication Setup (VHF/UHF)

Why use digital – For error free communications

Computers are a key component on any modern amateur radio station not just for digital modes (logging, sending CW)

Digital data is composed of 1s and Øs that are converted into tones

Combinations of ***protocols***, ***digital codes*** and ***modulation types*** create a ***digital mode***

Newer SDR radios integrate the Modem/TNC into the radio

6.1 Definitions

Pg. 6-2

- ***Air Link*** – the part of the communications system involves radio transmission and reception of signals
- ***Bit*** – the fundamental unit of data; 0 or 1 representing all or part of a binary number
- ***Bit Rate*** – the number of digital bits per second sent from one computing system to another
- ***Baud or Bauds*** – the number of symbols per second sent from one computing system to another; also known as symbol rate
- ***Duty Cycle*** – the ratio of time that a transmitter is on to the total of on time plus off time
- ***Protocol*** – the rules that control the method used to exchange data between two systems
- ***Mode*** – the combination of a protocol with a modulation method

6.1 Signal Encoding (Protocol)

Pg. 6-3

- Digital Data Encoding
  - A ***modem*** is a device which encodes information and translates the bits into audio tones for transmission over the air
  - ***Digital signals*** include both information and overhead bits to control signal flow and provide error correction
  - The total count of all information and overhead bits is the *bit rate*
- Symbol Rate (*Baud*)
  - ***Baud*** refers to the number of symbols per second
  - A **symbo**l is the combination of signal characteristics that make up each distinct state
  - CW has one symbol as an on or off state of the transmitter
  - In RTTY there are two tones per symbol of the transmitter
  - For simple codes such as Baudot or ASCII each symbol is one bit

6.1 Digital Modulation

Pg. 6-3

- On-off keying (OOK)
  - CW
  - PCM
- Frequency Shift Keying (FSK)
  - RTTY
- Phase-shift keying (PSK)
  - PSK-31
- I/Q or QAM (Quadrature amplitude modulation)
  - Encodes multiple bits into amplitude and phase values
- Maximum data rates and signal bandwidths are specified by the FCC in 97.307. Digital codes are specified by the FCC in 97.309.

6.1 Frequency Shift Keying - FSK

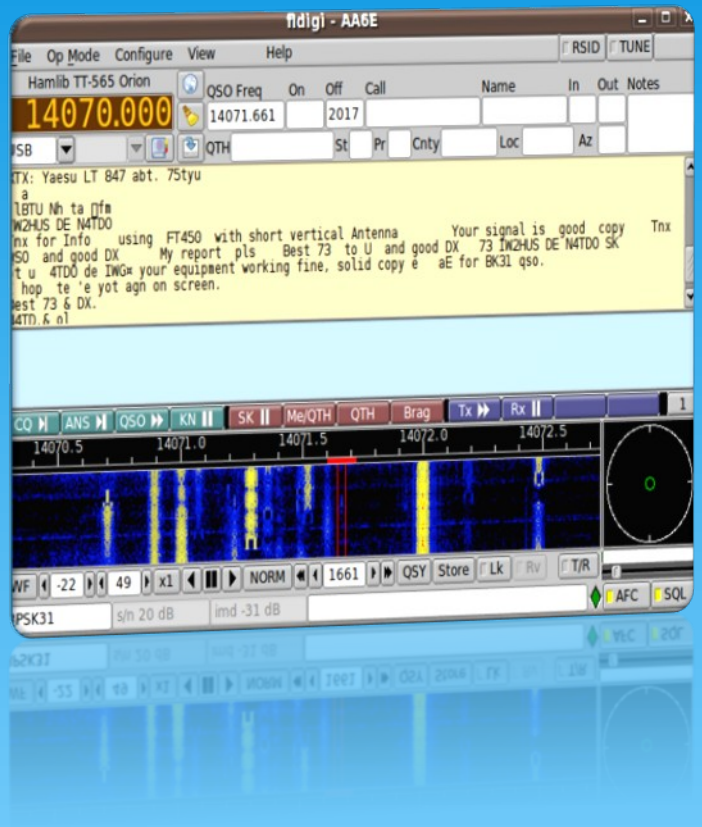
Pg. 6-4

- Frequency Shift Keying (FSK)
  - ***Frequency shift keying*** *is a method of digital communication in which the individual bits of data are encoded as tones*
  - The two tones are called a "***mark***" and "***space***" **[G8C11]**
  - Space represents a "0" and mark represents a "1"
  - ***Direct FSK*** *involves controlling the transmitter VFO directly by the digital signal from the computer* **[G8A01]**
  - ***AFSK*** *(audio frequency shift keying)* uses two audio tones which modulate the SSB or FM transmitter. AFSK is more convenient but requires careful control of audio level to prevent distortion or interference to nearby stations.
- Symbol rate directly effects the required frequency shift for FSK and the tone spacing for AFSK. The receiver requires higher shift or tone spacing to be able to determine the symbol sent
- ***Phase Shift Keying*** – Shifting the phase (180 degrees typical). Sounds like a buzz.

6.1 Multiple Frequency Shift Keying - MFSK

Pg. 6-4

- Multiple Frequency Shift Keying (MFSK) uses more than two tones.
  - *More tones increase error-resistance*
  - *Sounds like musical instrument*
- MFSK Modes: 8-MFSK, 16-MFSK and 64-MFSK.



6.2 Character Based Modes

6.2 Character-Based Modes
RTTY (Radio Teletype)

Pg. 6-5

- RTTY is the original mode designed to be copied and printed off the air by a mechanical teletype device
- A Sound Card and modem software are used today
  - 5 bit code with one additional start/stop bit **[G8C04]**
  - 2125 Hz mark/ 2295 space tones, 170 Hz shift **[G2E06]**
  - Typical 60 WPM
  - Usually found in the CW band above FT-8 and PSK-31 typically

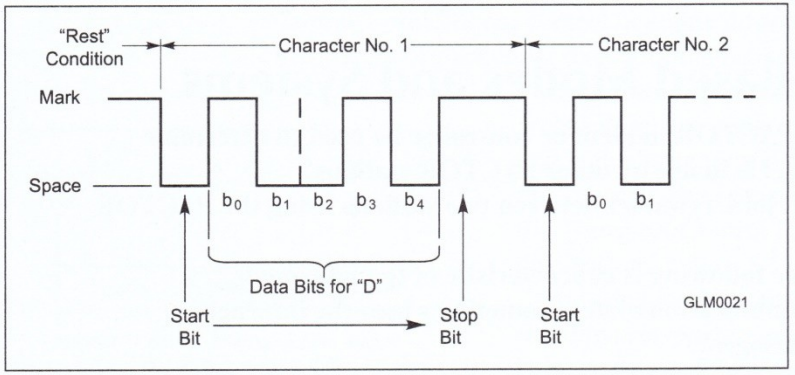


Figure 6.1 — The Baudot timing sequence for the bit pattern that encodes the letter "D." The start bit is sent first. Start and stop bits are required to allow the receiving and transmitting systems to synchronize. Mark and space are represented as audio tones in the transmitted signal.

6.2 Character-Based Modes
PSK-31

Pg. 6-5

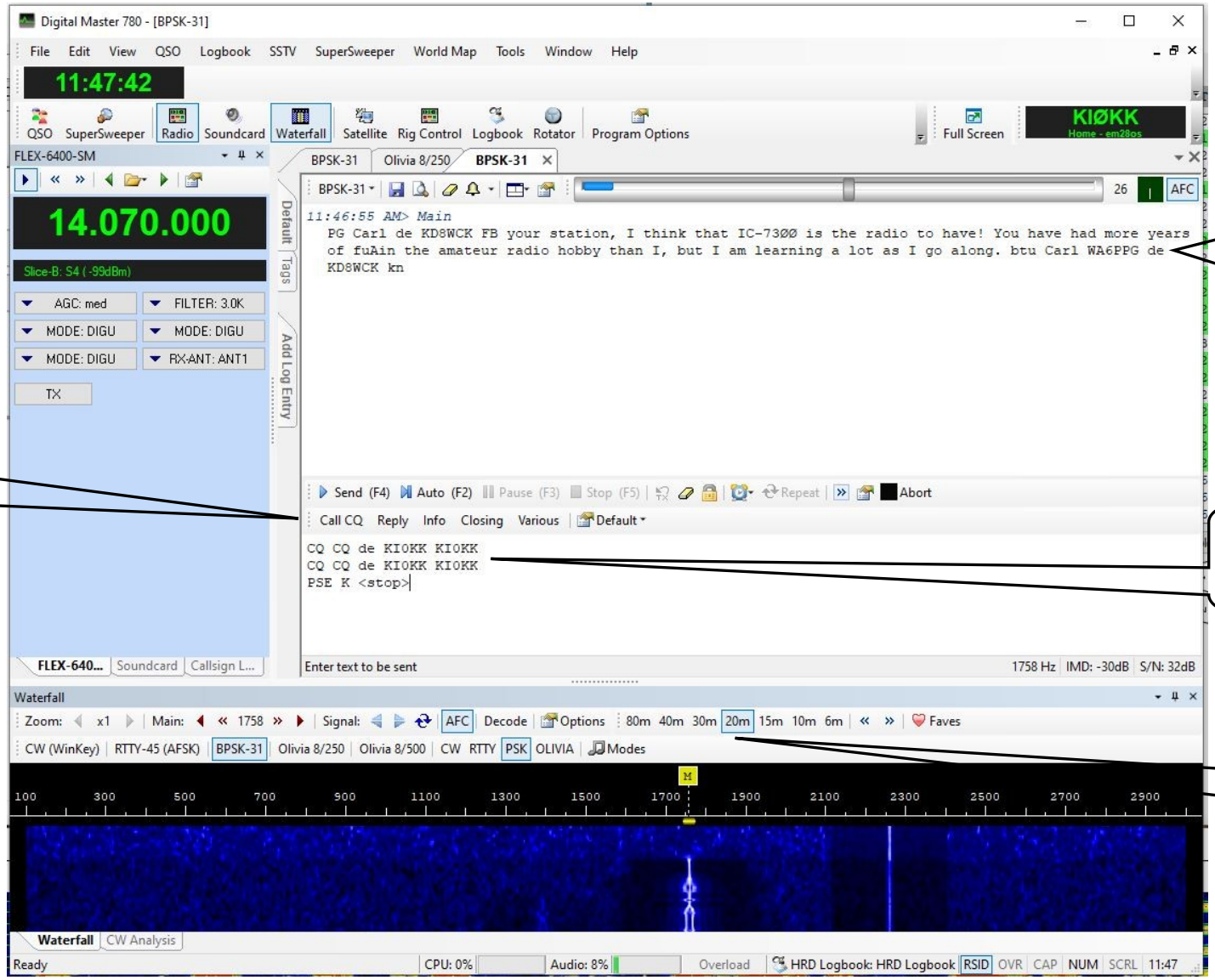
- The "31" in PSK31 stands for the symbol rate (31.25 baud)
  - Keyboard-to-keyboard communications (up to 50 WPM)
  - Narrow bandwidth <100 Hz
  - Good for weak signal on HF
  - Sound card based (external or internal PC card)
  - Sends a single tone phase shifted between symbols for a "0" and no shift for a "1"
- PSK uses a variable length code called *Varicode* that assigns more common characters to shorter codes (en.wikipedia.org/wiki/Varicode) **[G8C12]**
- Upper case characters use longer codes so turn off CAP LOCK **[G8C08]**

6.2 Character-Based Modes
QPSK31 vs PSK31

Pg. 6-5

- ***QPSK31*** (quadrature phase shift keying)
  - Sends two tones with four possible phase shift combinations
  - Error correction to improve weak signal performance
  - Sideband sensitive
- **PSK31** and **QPSK31** have the same approximate bandwidth **[G8A06]**

DM-780 PSK-31



RX Message

TX Macros

TX Message

Standard Frequencies

Review Questions – 6.1 to 6.2

In what segment of the 20-meter band are most PSK31 operations commonly found? [G2E08]

A. At the bottom of the slow-scan TV segment, near 14.230 MHz
B. At the top of the SSB phone segment, near 14.325 MHz
C. In the middle of the CW segment, near 14.100 MHz
D. Below the RTTY segment, near 14.070 MHz

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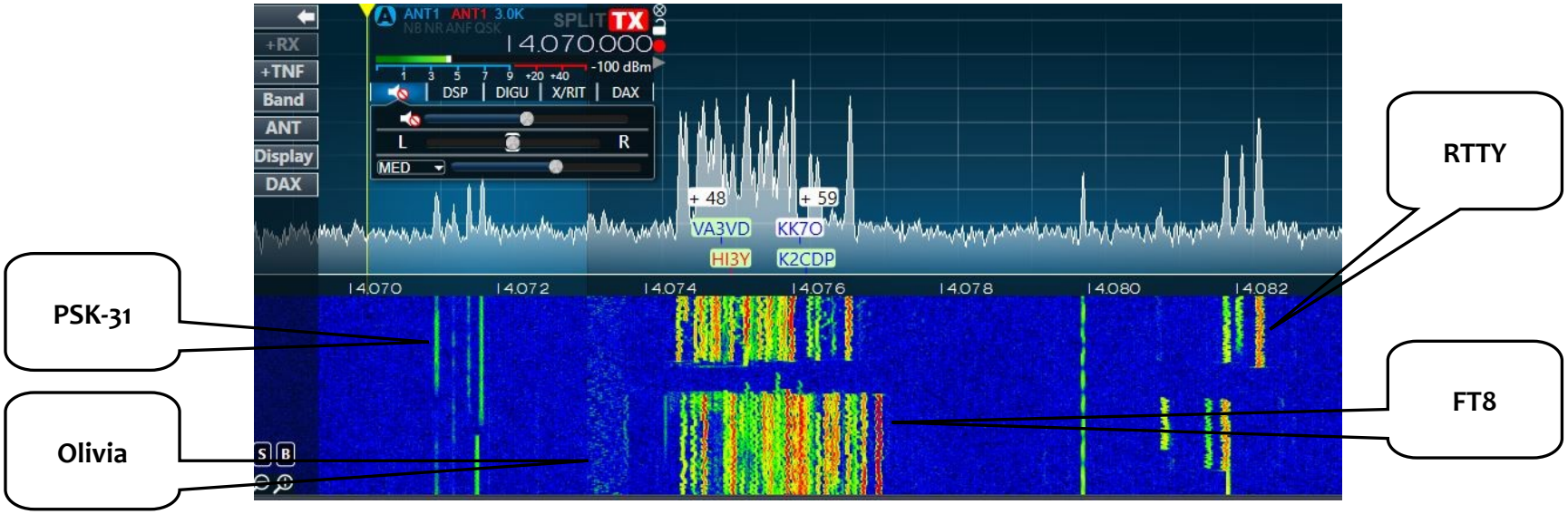

How is an direct binary FSK modulation generated? [G8A01]

A. By keying an FM transmitter with a sub-audible tone
B. By changing an oscillator's frequency directly with a digital control signal
C. By using a transceiver's computer data interface protocol to change frequencies
D. By re-configuring the CW keying input to act as a tone generator

How is an FSK signal generated? [G8A01]

A. By keying an FM transmitter with a sub-audible tone

B. By changing an oscillator's frequency directly with a digital control signal

C. By using a transceiver's computer data interface protocol to change frequencies

D. By re-configuring the CW keying input to act as a tone generator

How are the two separate frequencies of a Frequency Shift Keyed (FSK) signal identified? [G8C11]

A. Dot and Dash
B. On and Off
C. High and Low
D. Mark and Space

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A. Dot and Dash
B. On and Off
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D. **Mark and Space**

What is the most common frequency shift for RTTY emissions in the amateur HF bands? [G2E06]

A. 85 Hz

B. 170 Hz

C. 425 Hz

D. 850 Hz

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A. 85 Hz

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Which of the following describes Baudot code? [G8C04]

A. 7-bit code with start, stop and parity bits

B. A code using error detection and correction

C. A 5-bit code with additional start and stop bits

D. Code using SELCAL and LISTEN

Which of the following describes Baudot code? [G8C04]

A.7-bit code with start, stop and parity bits

B. A code using error detection and correction

C. **A 5-bit code with additional start and stop bits**

D. Code using SELCAL and LISTEN

Which type of code is used for sending characters in a PSK31 signal? [G8c12]

A. Varicode

B. Viterbi

C. Volumetric

D. Binary

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A. Varicode

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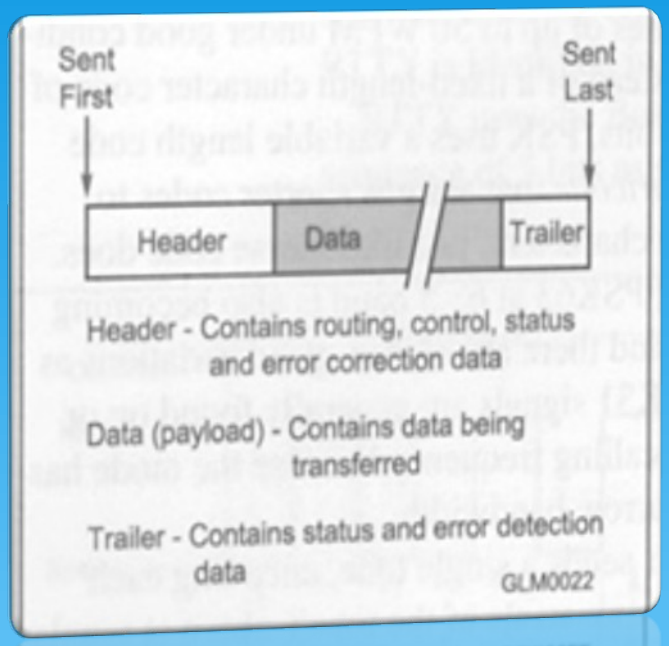


6.3 Packet-Based Modes and Systems

6.3 Packet-Based Modes and Systems

Pg. 6-7

- Packet-based or structure modes are derived from early teletype over radio modes and computer-to-computer network protocols
- PACTOR was created packet radio in an HF environment
- As modulation and coding techniques become more sophisticated they place more demands on the computer systems associated with them
- FT8 Mode
  - Higher processing power and precise timing is required for weak signal modes such as FT8 and JT65
  - Utility software is used on the computer to keep clock timing within 1 second of standard time **[G2E07]**

6.3 Packet Basics
Packet Protocol Structure

Pg. 6-7

- ***Packet*** refers to the transmission of data in structured groups
  - *Header* - **[G8C03]**
    - Synchronization
    - Control and Routing
    - Error correction and detection
  - *Data* – usually ASCII, compressed
  - *Trailer* – additional control, status or error detection

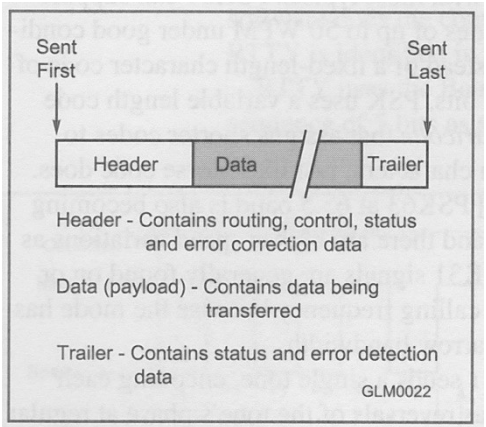


Figure 6.2 — Packet communication systems package data with control and routing information and add error detection information. Different packet protocols use different sets of information and methods of packaging.

- ***Encapsulation*** is the process of putting data in the packet structure. i.e TCP/IP, AX.25 packet.
- Error Detection – ***Cyclic Redundancy Check*** *(CRC) value* is calculated based on the data and sent. ACK is returned if there is no error. NAK on error.
- FEC – ***Forward Error Correction*** adds bits used to correct errors at the receiver **[G8C10]**

6.4 Packet Error Correction
ARQ

Pg. 6-8

- ***ARQ*** *Systems (Automatic Repeat reQuest),*
  - Used in PACTOR and packet radio modes
  - A error check mismatch results in a NAK being generated at the receiving station and the protocol requests the packet be resent. **[G8C05]**
  - The transmitting station sends until a valid packet is received or a retry time out is reached. **[G8C06]**
  - You cannot break in on an ongoing contact between stations using ARQ mode.
  - Broadcast mode announces a stations presence without a connection to another station **[G2E09]**
  - MON mode lets a station listen and copy the data but without error correction. MON mode allows you to determine if a frequency is in use

6.3 Packet Radio

Pg. 6-8

- Used almost exclusively on VHF/UHF bands
- Based on the x.25 protocol
- AX.25 Packet
  - The AX.25 protocol defines only the packet construction and data flow rules
  - Data modem (TNC) output (audio tones) use a 1200 baud modem standard
  - 1200 and 9600 baud
  - Operating practices according to the band plan determines the modulation method (SSB or FM)
  - Easily disrupted by noise and fading even at 300 baud on HF
  - Used as transport for APRS positioning protocol

6.3 PACTOR

Pg. 6-8

- RTTY does not manage transmission errors
- Teletype Over Radio (TOR) systems were developed to improve communications reliability (AMTOR, GTOR and others)
- Sends short bursts of characters with error detection and correction
- PACTOR (Packet-based-TOR) was developed to extend the capabilities of TOR modes (HF modes)
- Uses Quadrature Phase Shift Keying (QPSK)
  - Shifts two signal between four relative phases; 0, 90,180,270 degrees to represent pairs of bits **[G8A12]**
- PACTOR
  - PACTOR 1 uses FSK
  - PACTOR 2, 3 and 4 use more advanced PSK modulation
  - PACTOR 4 is not legal for use in the US

6.3 WINLINK System

Pg. 6-8

- WINLINK System (http://www.winlink.org)
  - Email and file transfer
  - Uses the internet to connect a system of email servers with gateway and mailbox stations around the world on HF, VHF and UHF frequencies **[G2E13, G2E13]**
  - No direct connection to the internet
  - Provides a means for providing email access where it is not available locally or the internet is not available due to disasters or local outages.
  - Can act as stand alone mailboxes
  - WINLINK modes **[G2E02]**
    - VHF/UHF - Packet Radio
    - HF – PACTOR and VARA

6.3 FT8 and WSPR (WSJT-X)

PG. 6-9

- FT8 and WSPR are modes supported by the WSJT-X software along with FT4, MSK144, JT-65 and other modes
  - Both FT8 and WSPR; 8 tone FSK modulation with sophisticated error decoding and correction
  - Successful decoding at very low signal-to-noise ratios (SNR) **[G8A09, G8C07]**
  - FT8
    - FT8 Message Structure – 75 bit plus 12 bits for error detection codes in a 50 Hz bandwidth in a 15 second period
    - Exchange is limited to call signs, grid locations and signal reports **[G2E11]**
    - Signal reports are S/N ratio, +3 is 3db above noise floor **[G8C15]**

6.3 WSJT-X QSO

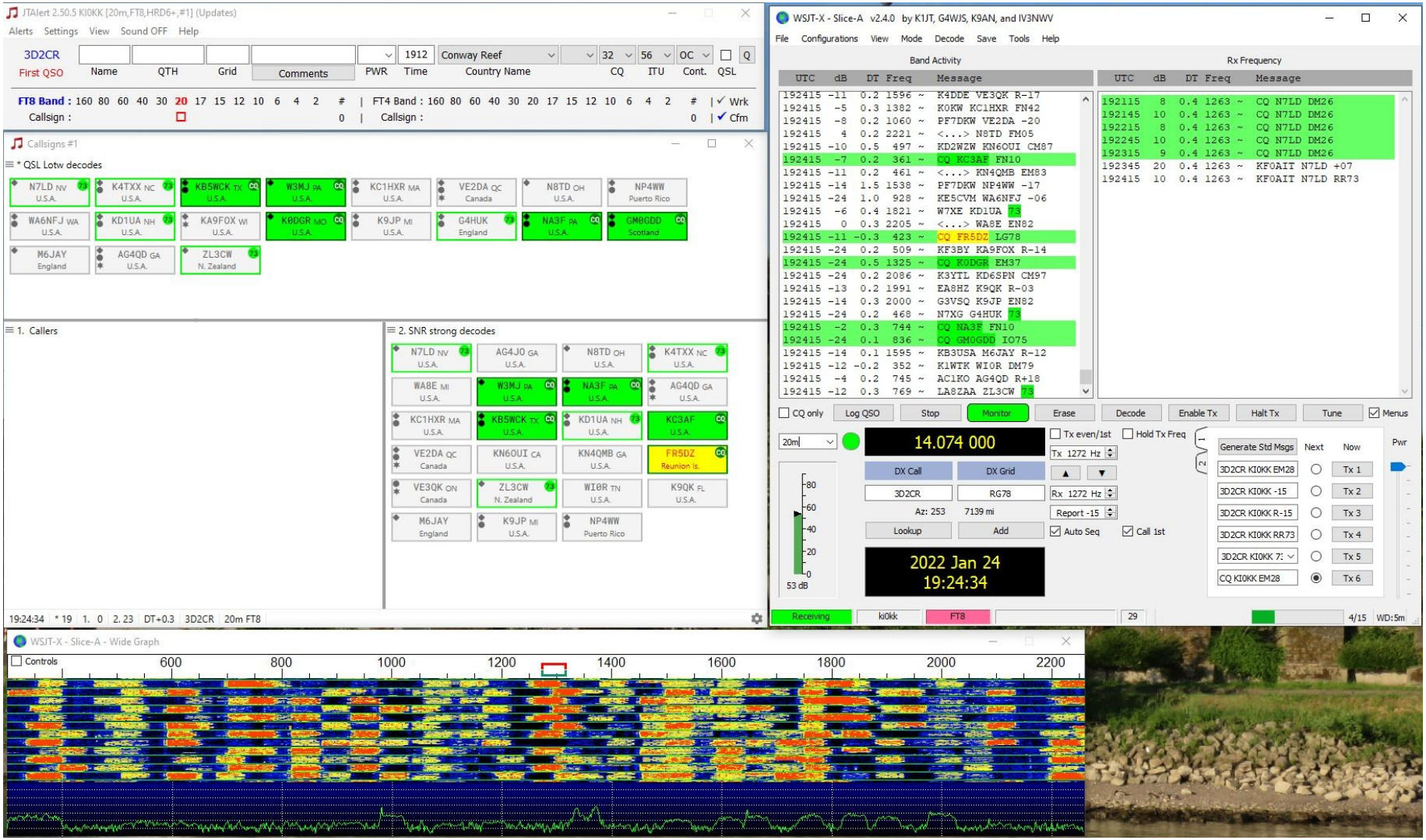
PG. 6-9

- Some differences between releases
- Found typically between 14.074 and 14.077 MHz **[G2E15]**
- When answering a CQ choose a clear frequency on the waterfall [G2E04]
- Time synchronization is critical ! If you are not decoding stations check your NTP time synchronization

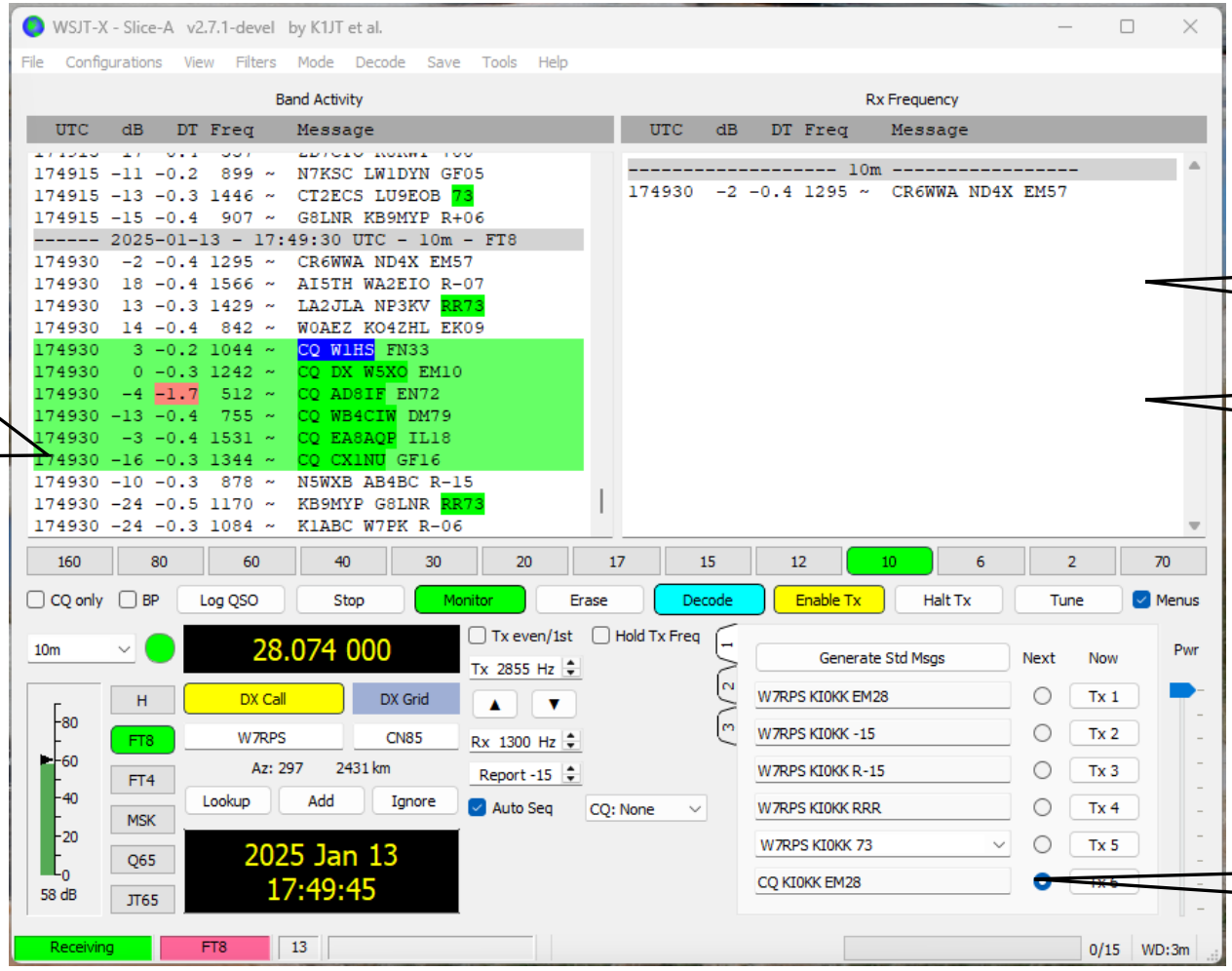
FT8 Applications

- WSJT-X
  - FT8 and FT4 application
  - Recent updates support enhanced Fox & Hound DXpedition modes
- JTAlert
  - Provides enhanced band activity display
  - Automates logging
  - Provides audio alert for wanted stations

JT Alert and WSJT-X (FT8 Mode)



WSJT-X FT8



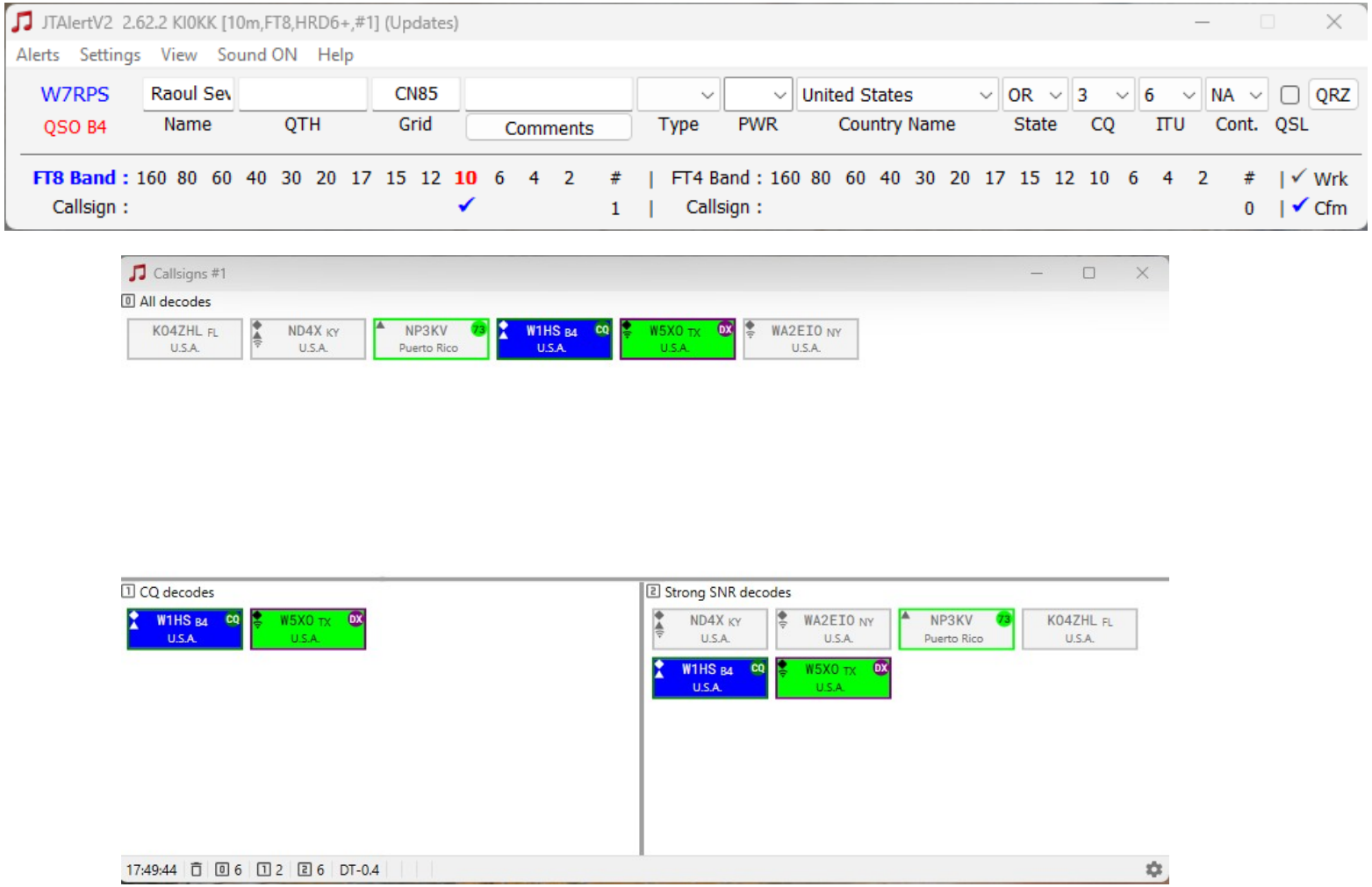
Calling CQ Green highlight black text

TX in Yellow highlight

Station calling in Red

Standard Messages

JTAlert


JTAlertV2 2.62.2 KI0KK [10m,FT8,HRD6+,#1] (Updates)
Alerts Settings View Sound ON Help
W7RPS
QSO B4
Raoul Sev
Name
QTH
CN85
Grid
Comments
Type
PWR
United States
Country Name
OR
State
3
CQ
6
ITU
NA
Cont.
QSL
QRZ
FT8 Band : 160 80 60 40 30 20 17 15 12 10 6 4 2 #
Callsign :
1
FT4 Band : 160 80 60 40 30 20 17 15 12 10 6 4 2 #
Callsign :
0
Wrk
Cfm
Callsigns #1
All decodes
K04ZHL FL U.S.A.
ND4X KY U.S.A.
NP3KV Puerto Rico
W1HS B4 CQ U.S.A.
W5XO TX DX U.S.A.
WA2EIO NY U.S.A.
CQ decodes
W1HS B4 CQ U.S.A.
W5XO TX DX U.S.A.
Strong SNR decodes
ND4X KY U.S.A.
WA2EIO NY U.S.A.
NP3KV Puerto Rico
K04ZHL FL U.S.A.
W1HS B4 CQ U.S.A.
W5XO TX DX U.S.A.
17:49:44 0 6 1 2 2 6 DT-0.4

6.3 WSPR (WSJT-X)

PG. 6-9

- *WSPR*
  - WISP was designed to experiment with and evaluate HF propagation paths at very low signal-to-noise levels
  - Can decode signals at SNR levels near -30 dB
  - Low power WSPR transmitters generate coded packets and stations that receive and decode the packets report success on websites such as wsprnet.org **[G8C02]**

6.3 Amateur Wireless Networks

PG. 6-9, 10

- Amateur bands overlap Unlicensed Wireless Frequencies (Table 6.2)
- Supports wide band applications
  - VoIP
  - Video
  - Repeater linking
  - Web servers
  - Email
- Two configurations; Mesh (ARDEN) and star
- Mesh typologies allow a packet to find an available route during node failures **[G8C09]**

Table 6.2
Wireless Networking Frequencies

airMAX	*Ubiquiti*	*ISM*	*Amateur*
M900 900MHz	902 – 928	902 – 928	902 – 928
M2 2.4 GHz	2402 – 2462	2400 – 2500	2390 – 2459
M3 3 GHz1	3370 – 3730		3300 – 35003
M5 5GHz	5725 – 5850	5725 – 58752	5650 – 5925

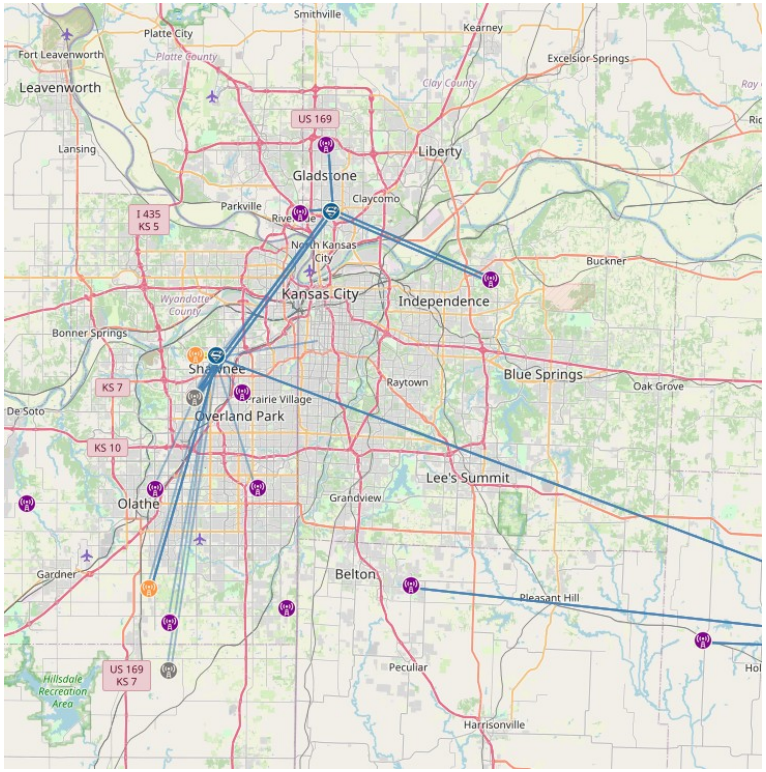
[1]For export from USA
[2]U-NII: 5150 – 5350, 5470 – 5825 MHz
[3]ARRL Band Plan

6.3 ARDEN (Amateur Radio Emergency Data Networks)

PG. 6-10

- Uses commercially available routers (900 MHz, 2.4, 3.4, 5.8 GHz)
- See https://aredenmesh.org for a list of supported devices
- Firmware updated with ARDEN software
- Used during emergencies and to support community events **[G2E11]**

KC Mesh Network



6.3 Additional Modes

- Multiple Frequency Shift Keying (MFSK)
  - ***Multiple-frequency shift keying*** *or MFSK* uses more than two tones to encode data.
  - ***MFSK16*** uses 16 separate tones spaced 15.25 Hz apart using a 50 Hz CW bandwidth. Highly tolerant to fading and multi path distortion as compared to two tone FSK.
  - **DominoEX** is an improved MFSK mode that encodes data using the difference between successive tones. Less sensitive to tuning errors and drift. Data rates range from 4 to 21.5 baud in bandwidths up to 524 Hz.
  - ***Olivia*** is a wider bandwidth MFSK mode that occupies from 125 to 1000 Hz depending on the number of tones used. Useful at very low signal levels and includes forward error correction.
  - ***MT63*** is composed of 64 tones and uses advanced DSP techniques which enable it to perform well under noisy and fading conditions.

Review Questions – 6.3

How do you join a contact between two stations using the PACTOR protocol? [G2E09]

A. Send broadcast packets containing your call sign while in MONITOR mode

B. Transmit a steady carrier until the PACTOR protocol times out and disconnects

C. Joining an existing contact is not possible, PACTOR connections and limited to two stations

D. Send a NAK code

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What is the standard sideband for JT65, JT9, FT4 or FT8? [G2E05]

A. LSB

B. USB

C. DSB

D. SSB

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Which of the following is a common location for FT8?
[G2E15]

A. Anywhere in the voice portion of the band
B. Anywhere in the CW portion of the band
C. Approximately 14.074 to 14.077 MHz
D. Approximately 14.110 to 14.113 MHz

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What type of modulation is used by FT8? [G8A09]

A. 8-tone frequency shift keying
B. Vestigial sideband
C. Amplitude compressed AM
D. 8-bit direct sequence spread spectrum

What type of modulation is used by FT8? [G8A09]

A. 8-tone frequency shift keying

B. Vestigial sideband

C. Amplitude compressed AM

D. 8-bit direct sequence spread spectrum

What part of a packet radio frame contains the routing and handling information? [G8C03]

A. Directory
B. Preamble
C. Header
D. Footer

What part of a packet radio frame contains the routing and handling information? [G8C03]

A. Directory

B. Preamble

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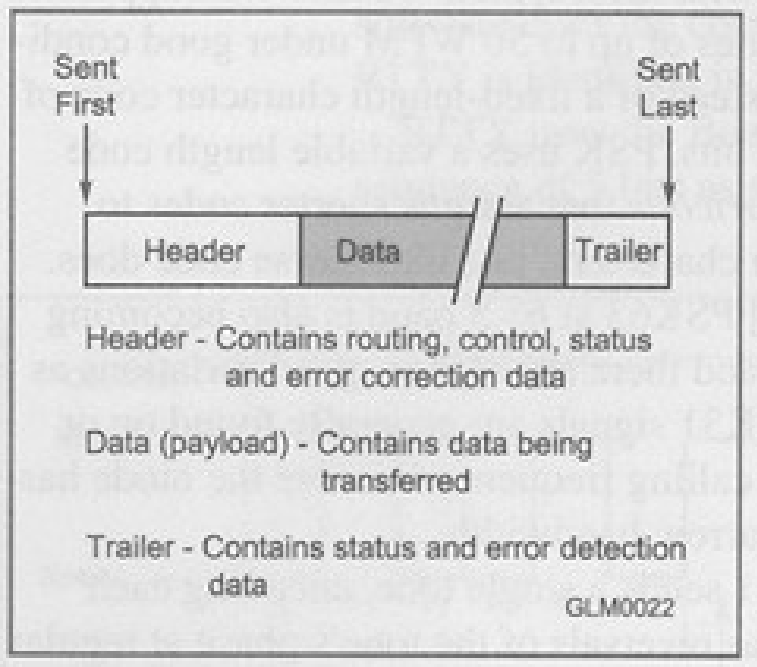

How does forward error correction (FEC) allow the receiver to correct data errors ? [G8C10]

A. By controlling transmitter output power for optimum signal strength

B. By using the varicode character set

C. By transmitting redundant information with the data

D. By using a parity bit with each character

How does forward error correction (FEC) allow the receiver to correct data errors ? [G8C10]

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6.4 Receiving and Transmitting Digital Modes

6.4 Receiving and Transmitting Digital Modes

Pg. 6-12

- Most digital signals on HF (FT8, FT4, JT65) are transmitted as USB **[G2E05]** except RTTY which uses LSB **[G2E01]**
- Key settings for digital communications **[G2E14]**
  - Sideband
  - Baud rate
  - Tones
- Staying in Band
  - Use care when operating near the edge of a digital signal band segment
  - FSK LSB bandwidth calculation; 18103 kHz carrier – 2295 Hz tone =18100.705 kHz radiated signal

6.4 Bandwidth of Digital Modes

Pg. 6-12

- Defined by FCC rules [97.3(a)(8)]
- As symbol rate increases the required bandwidth increases **[G8B10]**
- Tones generated by audio from a PC sound card are input to the TX MIC in
- Standard is to use SSB voice BW of 2.8 kHz
- As SDR equipment becomes more common wider bandwidth modes may be developed as long as they comply with FCC rules

Table 6.3
Bandwidth Comparison of Digital Modes

Mode	*Bandwidth (Hz)*
PSK31	50
FT8	50
RTTY	200
MFSK16	300
JT65	350
DominoEX	524
Olivia	1,000
MT63	2,000
PACTOR-III	2,300
PACTOR-4	2,300

Bandwidths are approximate for the highest commonly used symbol rate and are not specifications

6.4 Transmitter Duty Cycle

Pg. 6-12

- Most amateur transmitters are not designed to operate at full power for an extended period of time
- CW and voice have duty cycles of 40 to 50% and 20 to 25% respectively
- Digital signals such as RTTY and PSK31 have 100% duty cycles
- ARQ modes have slightly reduced duty cycles
- For most digital modes reduce power to about 50% **[G8B08]**

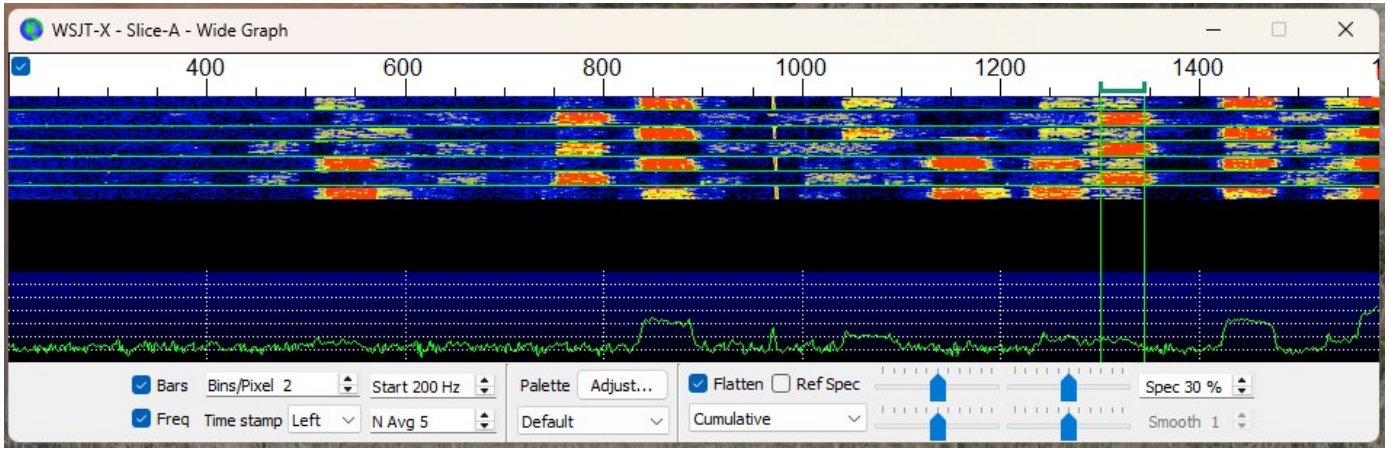
6.4 Digital Mode Signal Quality

Pg. 6-13

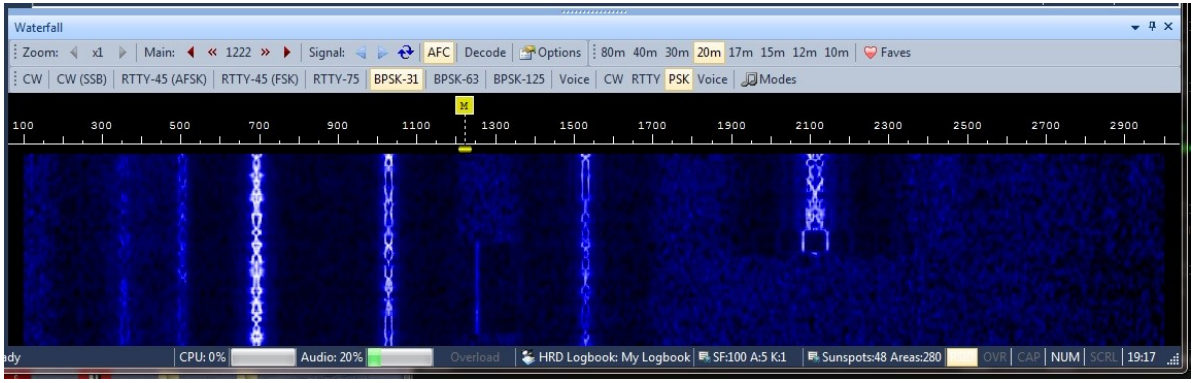
- Requires good signal quality in some cases
- Can cause adjacent channel interference if not properly setup
- **RF coupling into the audio between the computer and radio are a common problem**
  - SDR radios and USB modem to radio interfaces eliminate this problem
- **Incorrect audio levels are a common problem and may cause splatter or spurious signals**
- Digital interfaces to the computer such as USB can eliminate level and RF coupling issues
- A distorted signal on the waterfall display will have addition lines on either side of the main signal or look broader than normal a signal. Caused by over modulation from high audio input levels **[G8C13]**

Digital Signal Waterfall Examples

FT8



PSK31



6.4 ALC and Digital Modes

Pg. 6-13

- ALC is used to prevent excessive drive to amplifier inputs
- ALC males the signal harder to decode and creates spurious emissions just like overmodulation does **[G4A11]**
- With digital modes ALC should be disabled or gain reduced to where ALC does not activate.

Review Questions – 6.4

Which mode is normally used when sending an RTTY signal via AFSK with an SSB transmitter? [G2E01]

A. USB

B. DSB

C. CW

D. LSB

Which mode is normally used when sending an RTTY signal via AFSK with an SSB transmitter? [G2E01]

A. USB

B. DSB

C. CW

D. LSB

What is the standard sideband for JT65, JT9, FT4 or FT8 digital signal when using AFSK ? [G2E05]

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B. USB

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D. SSB

What is the standard sideband for JT65, JT9, FT4 or FT8 digital signal when using AFSK ? [G2E05]

A. LSB

B. USB

C. DSB

D. SSB

Why should the ALC system be inactive when transmitting AFSK signals? [G4A11]

A. ALC will invert the modulation of the AFSK mode

B. The ALC distorts the signal

C. When using digital modes, too much ALC activity can cause the transmitter to overheat

D. All these choices are correct

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C. When using digital modes, too much ALC activity can cause the transmitter to overheat

D. All these choices are correct

Why is it important to know the duty cycle of the mode you are using when transmitting? [G8B08]

A. To aid in tuning your transmitter

B. Some modes have high duty cycles which could exceed the transmitter's average power rating

C. To allow time for the other station to break in during a transmission

D. To prevent overmodulation

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C. To allow time for the other station to break in during a transmission

D. To prevent overmodulation

What is indicated on a waterfall display by one or more vertical lines on either side of a data mode or RTTY signal?
[G8C13]

A. Long path propagation
B. Backscatter propagation
C. Insufficient modulation
D. Overmodulation

What is indicated on a waterfall display by one or more vertical lines on either side of a data mode or RTTY signal?
[G8C13]

A. Long path propagation
B. Backscatter propagation
C. Insufficient modulation
D. Overmodulation

6.5 Digital Operating Procedures

6.5 Initiating and Terminating Digital Contacts

Pg. 6-14

Calling CQ

CQ CQ CQ DE KIØKK KIØKK KIØKK K

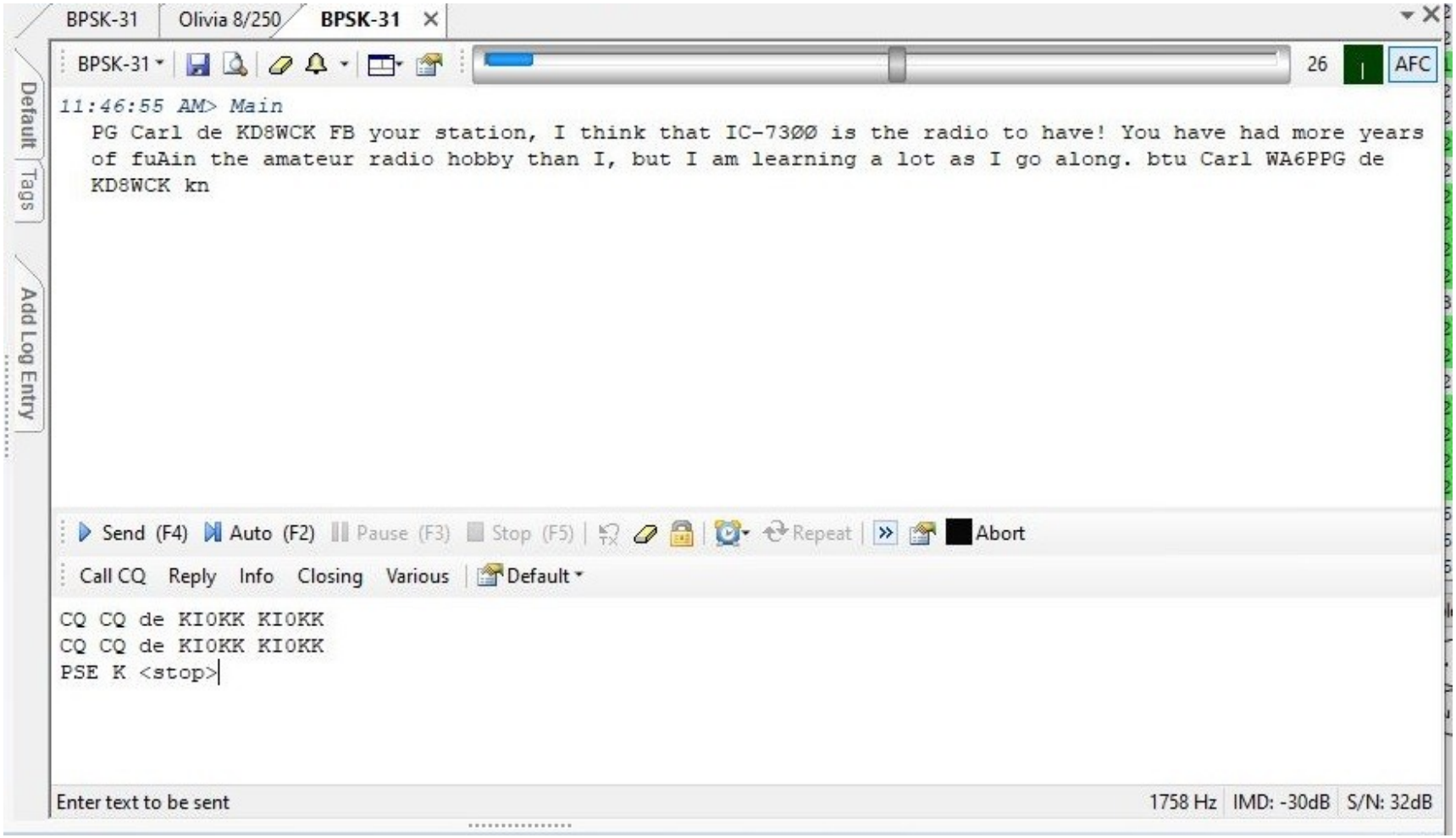
Responding

KIØKK KIØKK DE KSØJD KSØJD K

Typical QSO

KSØJD Jeff de KIØKK FB. Name is Greg. Rig is a Flex 6400. Antenna is a Butternut 9BTV. QTH is Spring Hill KS. BTU Jeff KSØJD de KIØKK KN

DM-780 QSO Screen



6.5 Connecting to Gateway and Mailbox Stations

Pg. 6-15

- Classified by the FCC as ***automatically-controlled digital stations***
- Restricted to certain segment of amateur bands only using RTTY below 220 MHz **[G1E11]**
- Non US stations may be outside of FCC allocations.
- Must be under local or remote control to contact these stations **[G1E03]**
- The contact starts with a connect message **[G2E10]**

Table 6.4
Automatic Control Band Segments for RTTY and Data

Band (Meters)	*Frequency Range (MHz)*
160	Not permitted
80	3.585 – 3.600
60	Not permitted
40	7.100 – 7.105
30	10.140 – 10.150
20	14.095 – 14.0995 and 14.1005 – 14.112
17	18.105 – 18.110
15	21.090 – 21.100
12	24.925 – 24.930
10	28.120 – 28.189
6	50.1 – 54.0
2	144.1 – 148

6.5 Operating Displays

Pg. 6-15

- Waterfall Display shows the presence of signal as a series of lines Fig 6.5A
- Strength of a signal or noise is represented as the brightness Intensity or color of the line at each frequency. Older lines are at the bottom or right **[G8C14]**
- RTTY audio spectrum is shown in Fig 6.5B. The two vertical lines are the mark and space tones
- At the right is a crossed ellipse used for fine tuning, two lines at right angles is the correct tuning

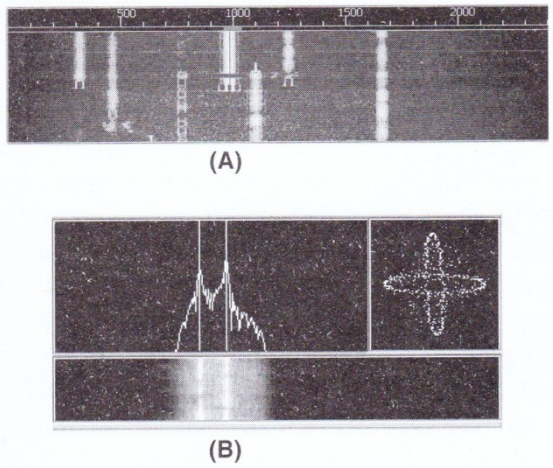


Figure 6.5 — At A, the waterfall display shows seven different digital signals being received in an audio frequency range of 0 to 2400 Hz. They appear as vertical traces. B shows an RTTY tuning display that includes a filter output window at the upper left (the signal is tuned properly when the tone peaks align with the vertical lines) and a crossed-ellipse display at the upper right for fine tuning. A waterfall display across the bottom is included as well.

6.5 Third Party Traffic

Pg. 6-16

- Rules for digital contacts are the same as for voice or CW
- All FCC rules about third party traffic messages apply to digital transmissions **[G1E09]**

6.5 Interfering Signals

Pg. 6-16

- ***Hidden transmitter*** – where you or another station cannot hear or be heard
- Garbled messages may be corrected by the protocol or by the operator.
- Results of transmission errors or interference may be as follows **[G2E03, G8C06]** :
  - Failure to connect
  - Frequent retries or transmission delays
  - Timeouts or dropped connections
- Dealing with interference
  - It is usually because the other station cannot hear you
  - Change frequency or use a directional antenna

Review Questions – 6.5

What is required to conduct communications with a digital station operating under automatic control outside the automatic control band segments? [G1E03]

A. The station initiating the contact must be under local or remote control

B. The interrogating transmission must be made by another automatically controlled station

C. No third party traffic maybe be transmitted

D. The control operator of the interrogating station must hold an Extra Class license

What is required to conduct communications with a digital station operating under automatic control outside the automatic control band segments? [G1E03]

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D. The control operator of the interrogating station must hold an Extra Class license

What symptoms may result from other signals interfering with a PACTOR or VARA transmission? [G2E03]

A. Frequent retries or timeouts

B. Long pauses in message transmission

C. Failure to establish a connection between stations

D. All of these choices are correct

What symptoms may result from other signals interfering with a PACTOR or WINMOR transmission? [G2E03]

A. Frequent retries or timeouts

B. Long pauses in message transmission

C. Failure to establish a connection between stations

D. All of these choices are correct

What action results from a failure to exchange information due to excessive transmission attempts when using an ARQ mode?
[G8C06]

A. The checksum overflows
B. The connection is dropped
C. Packets will be routed incorrectly
D. Encoding reverts to the default character set

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[G8C06]

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C. Packets will be routed incorrectly

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Which of the following describes a waterfall display? [G8C14]

A. Frequency is horizontal, signal strength is vertical, time is intensity

B. Frequency is vertical, signal strength is intensity, time is horizontal

C. Frequency is horizontal, signal strength is intensity, time is vertical

D. Frequency is vertical, signal strength is horizontal, time is intensity

Which of the following describes a waterfall display? [G8C14]

A. Frequency is horizontal, signal strength is vertical, time is intensity

B. Frequency is vertical, signal strength is intensity, time is horizontal

C. Frequency is horizontal, signal strength is intensity, time is vertical

D. Frequency is vertical, signal strength is horizontal, time is intensity