Chapter 8

Modulation, Protocols and Modes

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Section 8-2

Digital Protocols and Modes

Digital Modes

* A digital mode consists of both a protocol and a method of modulation.
* Digital protocols can be used to convey speech , video or data.
* The advantage of using digital modes to transfer information is that the signal and its information can be copied and retransmitted multiple times without necessarily introducing errors.
* A good source of information on digital mode technology in amateur radio can be found at TAPR (www.tapr.org)

Digital Modes for HF

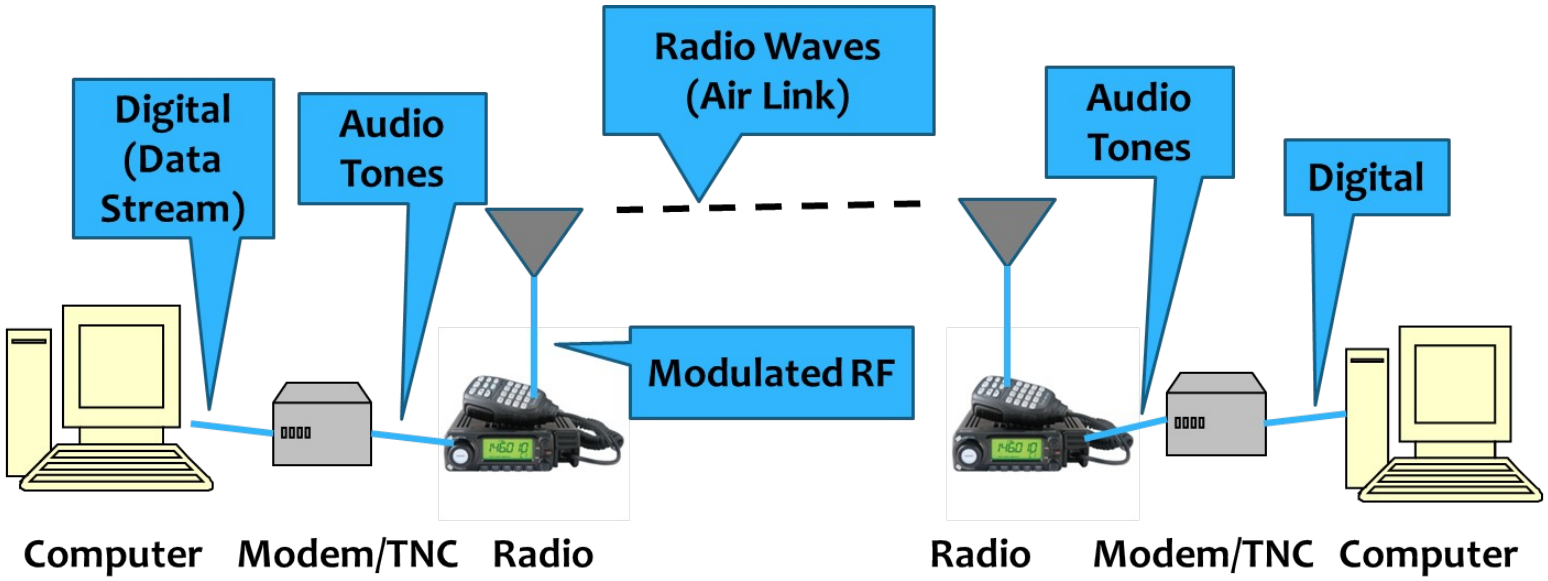
General Review

- Frequency Shift Keying
  - RTTY
  - FT-8
  - FT-4
  - JS8Call
- Phase Shift Keying
  - PSK31
- Packet Modes
  - PACTOR
  - WINMOR

A Basic Digital Communication Setup

Digital Communications Signal Formats

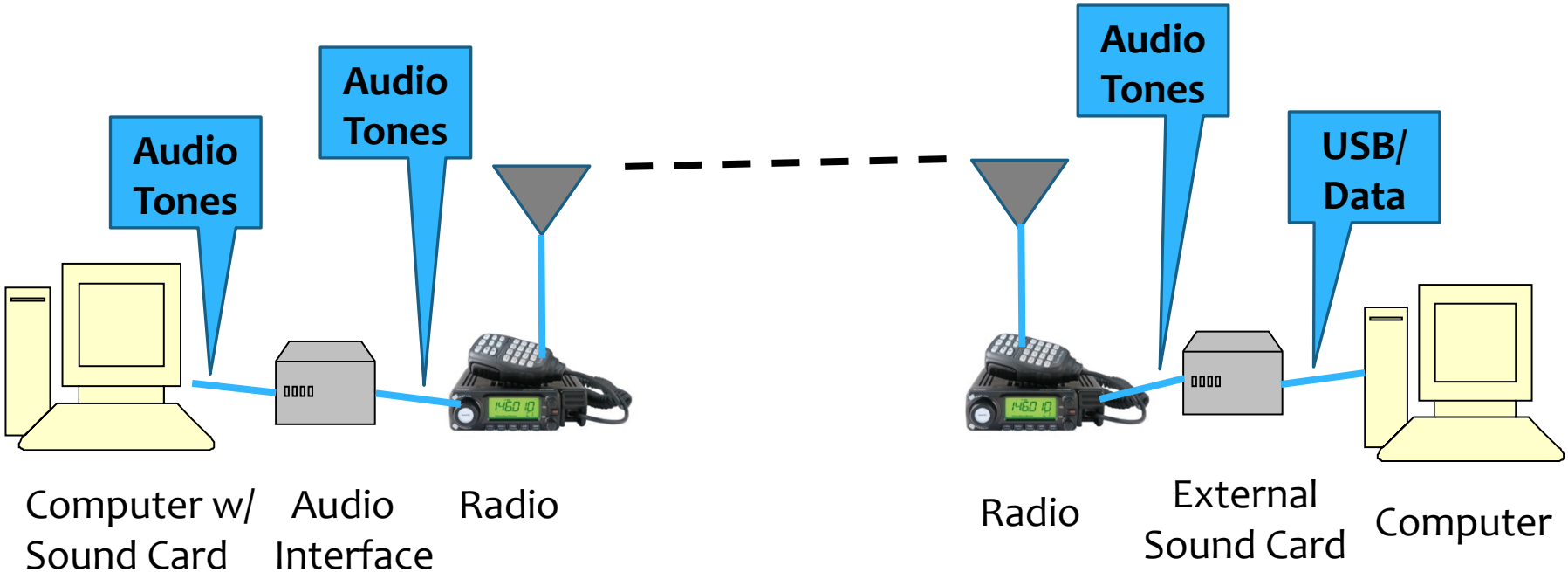
The message is in different form throughout the communication system



* The *Modem/TNC* (Terminal Node Controller) may have significant "smarts"
* Uses USB or UART interface to computer

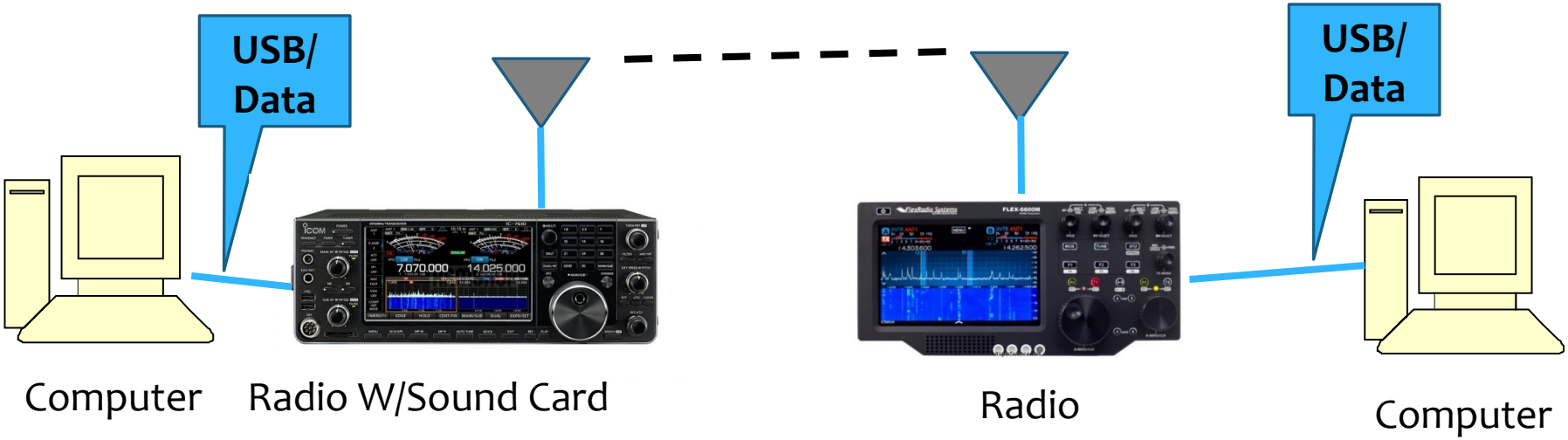
Digital Communications Using a Sound Card

- The **PC and the soundcard** have the **"smarts"**
- The Audio Interface has no "smarts" and provides **isolation between the computer and the radio**
- The Audio interface can be eliminated by using an external sound card



Digital Communications Using SDR Radios

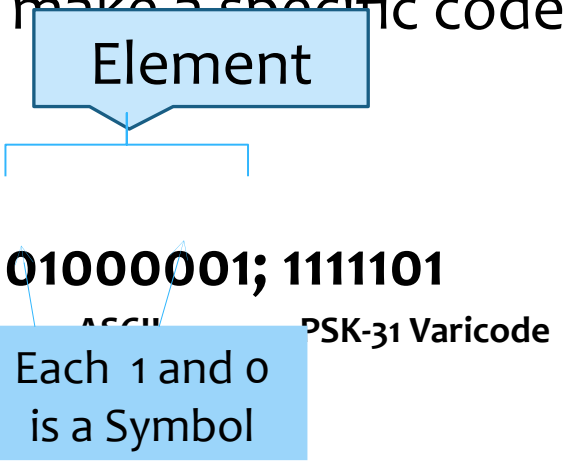
* Modern SDR radios use internal sound cards (ICOM IC-7610, Flex 6400)
* Audio and Cat (Rig) control are passed inside the PC to the digital APP by specialized software applications
* Contact logging can be automated almost entirely
* Remote operation is possible



Data Speed and Symbols

Pg 8-5

- "*Speed*" is the rate of information transfer or *data throughput*
  - *Air Link* – the actual transmitted signal
    - The faster the rate, the wider the bandwidth required
  - *Data Stream* – the digital data to & from the computer
- The individual symbols that make a specific code form an *element*



- **Letter "A": dit dah; 00011; 01000001; 1111101**
- **Morse Code Baudot ASCII PSK-31 Varicode**

A Look at Baud Rate

Pg 8-5

* The *baud rate* refers to the *number of data symbols transmitted per second.*
* On an oscilloscope, the data stream looks like a series of varying patterns of pulses in time.

Baudot Code

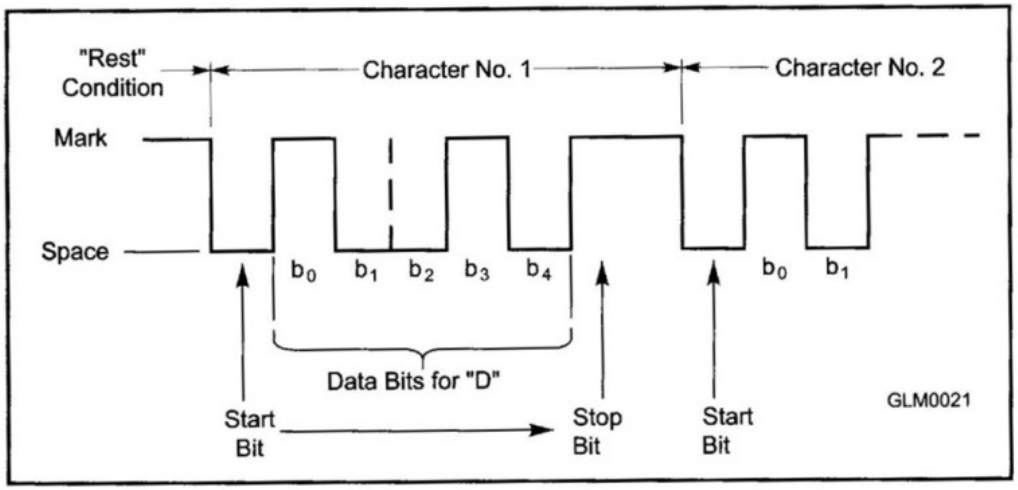


Fig 8-1

Data Rate vs Symbol Rate

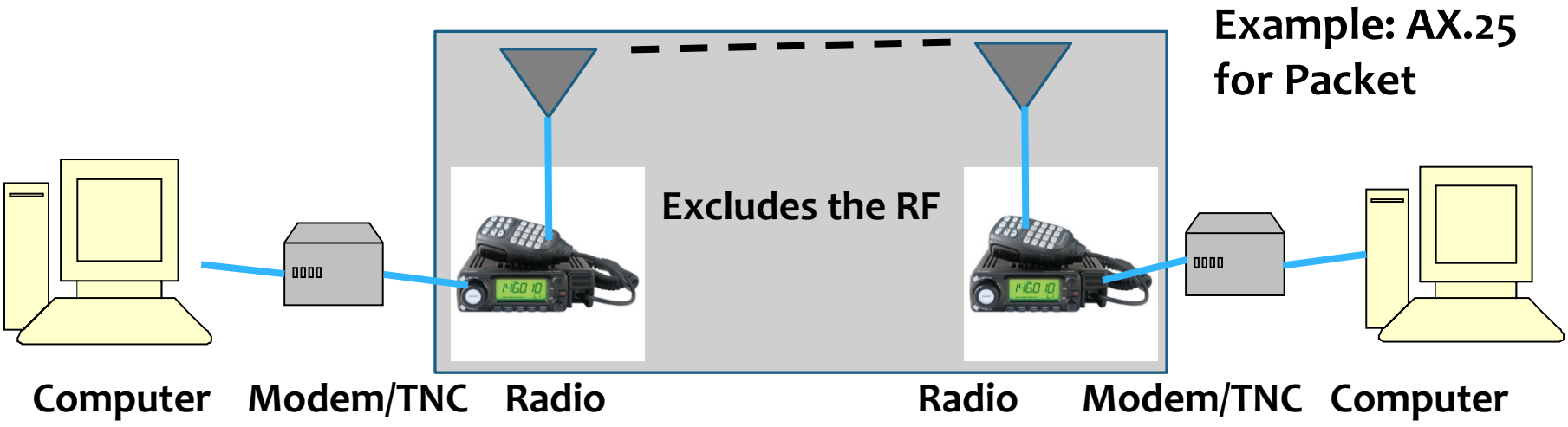
Pg 8-6

* The *symbol rate* refers to the rate at which the transmitted signal changes in order to convey information ***[E8C02]***.
* When discussing the speed of an air link, the unit of speed is the *baud*
* Baud counts *signaling events* that refer to changes in the transmitted signal which represent one *symbol*.
* Thus, the Baud Rate and symbol rate are the same ***[E8C11]***.
* However in some advanced systems – each data symbol can encode more than one bit at a time.
  - Example: D-STAR, 9600 baud packet
  - Data rate is higher than symbol rate (higher coding efficiency)
  - More data in less bandwidth ***[E8C10]***

Digital Protocol

Pg 8-6

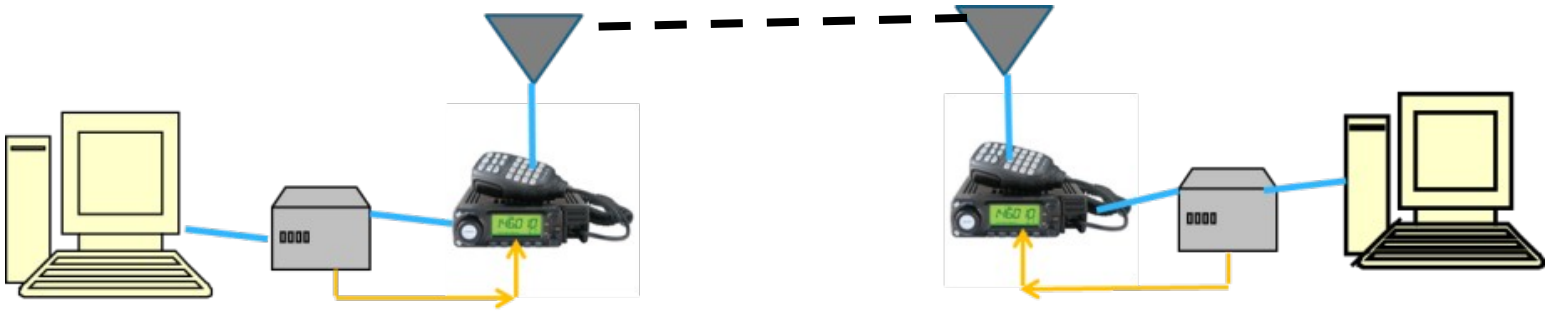
* A *protocol* is the overall digital specification or set of rules. It includes:
  - Encoding, Packaging, Exchanging and Decoding
* It does not include the RF communication link



Control Operator Responsibilities

Pg 8-7

* Practical digital protocols require that the receiving and transmitting stations operate under the control of a microprocessor.
  - Specific segments of the band are set aside for fully automatic control
* *ALE (Automatic Link Establishment)* is fully automatic, under microprocessor control [E2E12]. The microprocessor can change radio frequencies and even bands.



Codes

Pg 8-7

* A *code* is a method by which information is converted to and from digital data
* Individual symbols that make up a specific code it's elements

* We will look at:
  - Morse & Varicode (PSK-31)
  - Baudot (RTTY)
  - ASCII (PKT)
  - Gray Code

Morse & Varicode

Pg 8-7

- Most digital codes use a fixed number of bits for each character (ASCII and Baudot).
- A *variable-length* code (*varicode*) use a different number of bits in each symbol or character (PSK-31 and Morse).
  - The length of a character varies with the frequency of it's use to save transmission time thus maximizing *bandwidth or spectral efficiency*.
- PSK-31 and Morse use the shortest symbol for the most used character "E" ***[E2E09]***.

PSK-31 Varicode)

PSK-31 uses ***Varicode*** that includes upper and lower case letters

www.arrl.org/psk31-spec

? 1010101111	b 1011111
@ 1010111101	c 101111
A 1111101	d 101101
B 11101011	e 11
f 111101	s 10111
g 1011011	t 101
h 101011	u 110111

A lower-case "e" is made up of two symbols, however an upper case "E" has seven symbols

PSK-31 elements are the same length but characters have different lengths. Most common is "E" being the shortest. ***[E2E09]***

Sample of the Baudot Code

Binary	Decimal	Letter	U.S. Figures
00000	0	N/A	N/A
00001	1	E	3
00010	2	LF	LF
00011	3	A	-
00100	4	Space	Space
00101	5	S	BELL
00110	6	I	8
00111	7	U	7
01000	8	CR	CR
01001	9	D	$
01010	10	R	4

Elements

Baudot consists of 5 binary digits

$2^5 = 32$

So we only have 32 combinations, however we can double that to 64 by pulling a "trick" of sending LTRS or FIGS

Baudot

Pg 8-7

- The *Baudot code* is used in RTTY systems and has two elements --- *Mark* and *Space* --- each the same length.
- The code uses five different mark and space combinations.
- A continuous mark tone is an idle state.
- *Start* and *stop* bits are sent at the beginning and end of each character and are called *framing* bits.
- The framing bits synchronize the transmit and receive systems
- A complete character, including the framing bits, is called a *frame*

ASCII

Pg 8-8

- ASCII character set includes upper/lower case letters, numbers, punctuation, and control characters. ***[E8D11]***
  - Some systems use the 8th bit to provide 256 characters. ***[E8D10]***
- The eight bit can also be used as a parity bit, 1 = even, 2= odd parity.
- Parity bits allow the receiving system to detect single-bit errors.
- Failure of the parity bit check results in the character being rejected. ***[E8D06]***
- A full ASCII character is 10 or 11 bits long
  - 7 data bits
  - One parity bit
  - One start bit
  - One or two stop bits

ASCII Code

Pg 8-8

At least 7 bits are for characters
$2^7 = 128$

128 possibilities **allows for upper and lower case letters *[E8D11]***

The 8th bit can be a *parity bit*, **used to detect transmission errors *[E8D06]*** or it can be used to extend the character set to 256 ***[E8D10]***

7 or 8 Bits

DEC	OCT	HEX	BIN	Symbol	Description
32	040	20	00100000		Space
33	041	21	00100001	!	Exclamation mark
34	042	22	00100010	"	Double quotes (or speech marks)
35	043	23	00100011	#	Number
36	044	24	00100100	$	Dollar
65	101	41	01000001	A	Uppercase A
66	102	42	01000010	B	Uppercase B
67	103	43	01000011	C	Uppercase C

http://ascii-code.com/

Grey Code

Pg 8-8

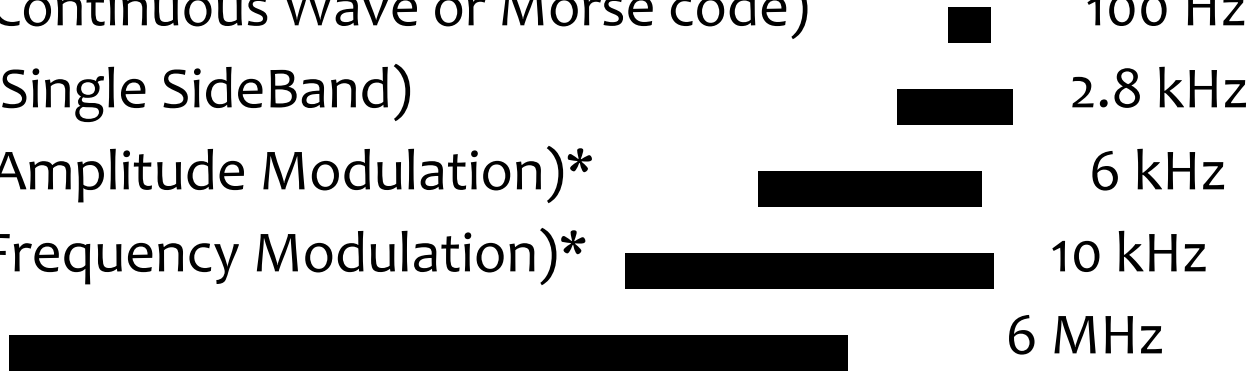
* *Grey codes* are arranged so that only one bit changes between any consecutive value ***[E8C09]***.
  - Most useful in applications where the data we are sending is counting-up or counting-down.
* If a Gray code results in more than one bit being changed between two consecutive characters, it assumes a transmission error has occurred.

Bandwidths by Mode

General Review

* Different types of modulation have various bandwidths

- **CW** (Continuous Wave or Morse code) 100 Hz
- **SSB** (Single SideBand) 2.8 kHz
- **AM** (Amplitude Modulation)* 6 kHz
- **FM** (Frequency Modulation)* 10 kHz
- **TV** 6 MHz



Digital Signal Bandwidth

Pg 8-9

* *Shannon's Information Theorems* define the fundamental laws of information transmission (baud related to required bandwidth)
* For a digital signal, the bandwidth is defined as;
  - Bandwidth formulas are taken from ITU-R SM.1138-2
* **BW = B x K** **(Equation 8-3)**
* **Where:**
  - **B** is the speed of the transmission in baud
  - **K** is the shape factor of the keying envelope

CW

Pg 8-10

* A CW signal has the advantage of being very narrow
* **BW = (WPM x 0.8) x K** **(Equation 8.4)** ***[E8C12]***
* The **"K"** is the shape (abruptness) of the keyed waveform. For CW, **K is normally a value of 5.**

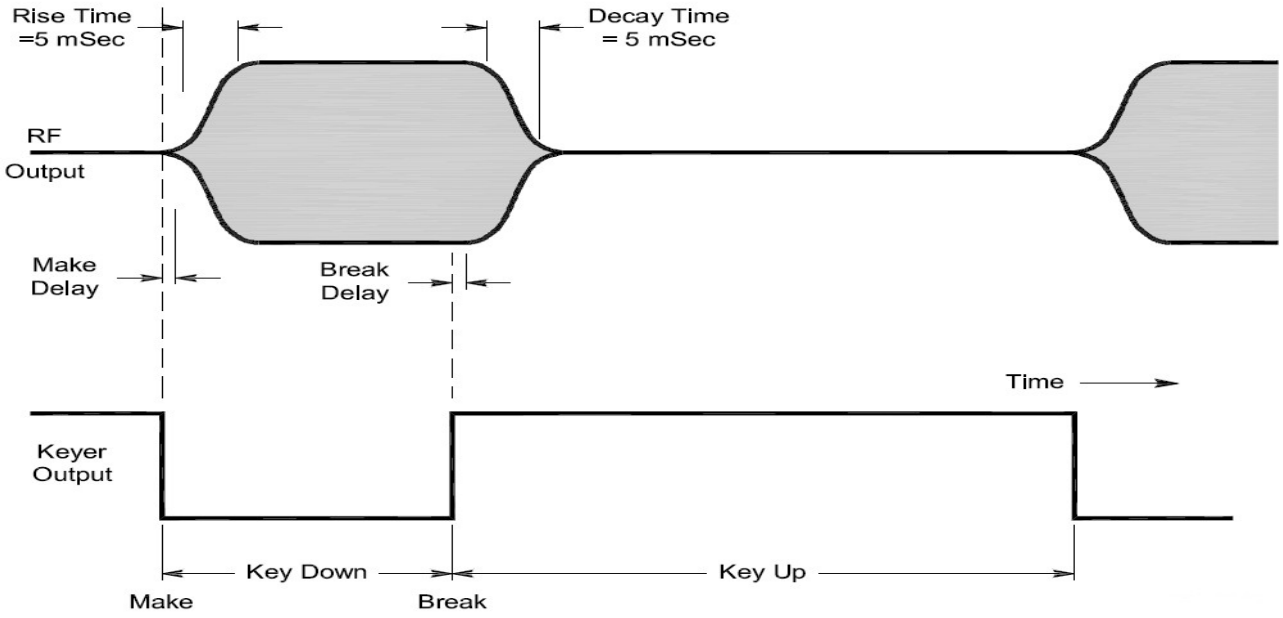
Example

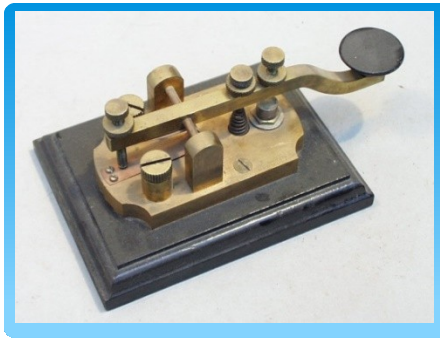
* What is the BW of a 13 WPM Morse code signal [E8C05]?
* **BW = (WPM x 0.8) x K**
  = (13 x 0.8) x 5 = 52 Hz

CW Signal

General Review

An oscilloscope is the best instrument to use when checking the keying waveform of a CW transmitter.





CW Bandwidth

Pg 8-10

* If the keying waveform has an extremely short rise time and fall time (1 msec or less), it will cause ***key clicks*** to be head on the signal. ***[E8D04]***
* To reduce the key clicks, increase the rise and fall times:
  - A menu-selected adjustment on modern radios **[E8D05]**
  - Add capacitance across the key line on an analog radio

RTTY

General Review

* The abbreviation "***RTTY***" stands for ***radioteletype***.
* FSK vs. AFSK
* ***170 Hz*** is the most common frequency shift for RTTY emissions in the amateur HF bands.
* ***2125 Hz (mark)*** or ***2295 Hz (space)***
* LSB is the mode normally used when sending

FSK Modes Beyond RTTY

General Review

- ***RTTY*** uses only two tones (***2125 Hz or 2295 Hz***)

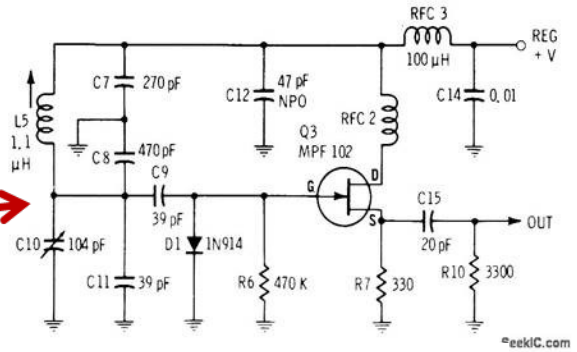
- ***MFSK*** is a more advanced approach to FSK—using multiple tones
- For example, MFSK16 uses 16 tones

- The abbreviation "MFSK" stand for Multi (or Multiple) Frequency Shift Keying.
- A major advantage of MFSK16 compared to other digital modes is that it offers good performance in weak signal environments without error correction.

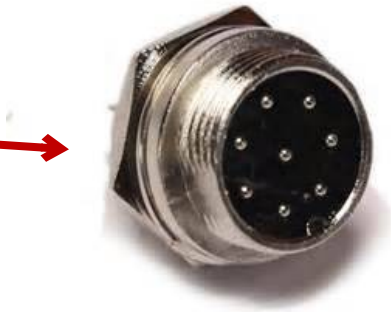
FSK / AFSK

Pg 8-10

* Most Amateur Radio data transmissions employ ***frequency shift keying*** ***[E2E01]***
  - ***Direct FSK*** is created by shifting the frequency of the transmitter's oscillator directly.



  - ***Audio FSK (AFSK)*** is created by injecting two audio tones into an audio (microphone) input. *[E2E11]*



* The difference between the two tones frequencies is called the ***shift***.

FSK / AFSK Bandwidth

Pg 8-10

FSK or AFSK bandwidth (BW) is:

* **BW = (K x Shift) + B** **(Equation 8.5)**
  - Where **K** is a constant that depends on the allowable signal distortion and transmission path. Typically **K = 1.2.**
  - **B** is the *symbol rate* in *baud*

Example 8-5

What is the bandwidth of a 170 Hz shift 300-baud ASCII signal as a J2D emission?

* **BW = (1.2 x 170 Hz) + 300 = 504 Hz**

FSK / AFSK Tuning

Pg 8-11

RTTY and other FSK/AFSK modes require careful tuning of the SSB transceiver.

Off Frequency

Lissajous **Patterns**

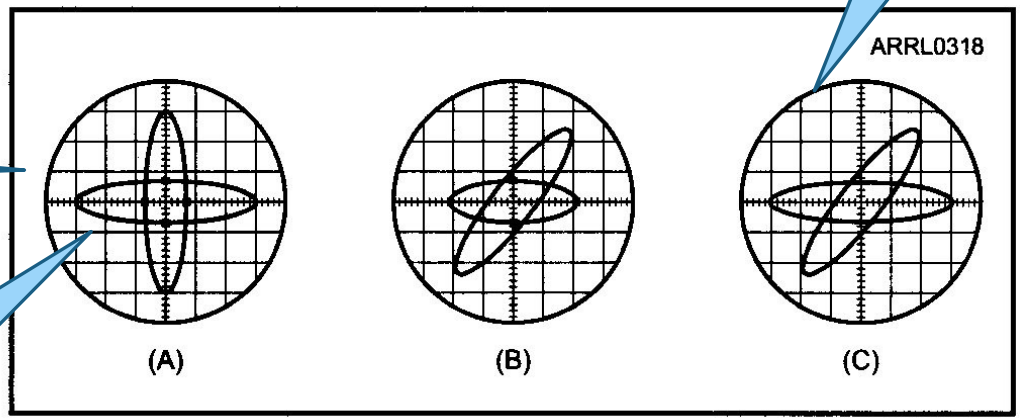


Figure 8-2 — The two tones of an FSK or AFSK signal are represented as a pair of ellipses on a crossed-ellipse display. For the best copy, the signal should be tuned so that the ellipses are of equal size and at right angles as in (A). Displays such as at (B) and (C) indicate a mistuned signal.

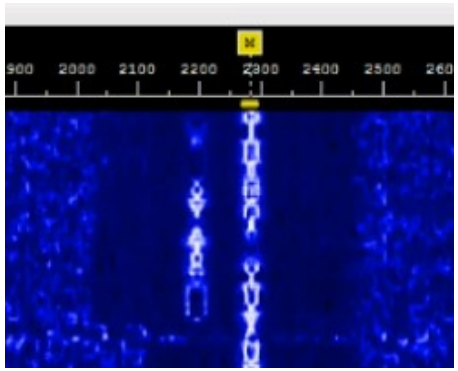
If one of the ellipses rapidly shrinks in size or disappears, it can indicate selective fading

PSK 31 (Phase Shift Keying)

General Review

Pg 8-11

Thank you Peter Martinez, G3PLX



The **number of data bits** sent in a single PSK31 character **varies.**

* ***14.070 - 14.100 MHz*** is the segment of the 20 meter band that is most often used for **data transmissions.**
* Supports a 50 word/min typing speed using 32 bits.
* 31.25 bps is easily derived from a standard 8kHz sampling rate used in many DSP systems.
* PSK-31 bandwidth is minimized by special sinusoidal shaping and shifting modulation phase only when RF carrier frequency crosses zero. ***[E8C03, E8C04]***

PSK31

General Review

* The number 31 in the term PSK31 represents **the approximate transmitted symbol rate (31.25 baud).**

Don't let the smoke out !!!

* **It is important to know the *duty cycle* of the data mode you are using when transmitting because some modes have high duty cycles which could exceed the transmitter's average power rating.**

* If using a 100W transceiver, reduce the transmitter power to 20 – 30 W (based on Radio specifications)

PSK 31 Shaping

* PSK 31 is the narrowest of all HF Modes! **37.5 Hz typ.**

* The bandwidth of a PSK31 signal is minimized **by special sinusoidal shaping of the transmitted data symbols** ***[E8C04]***

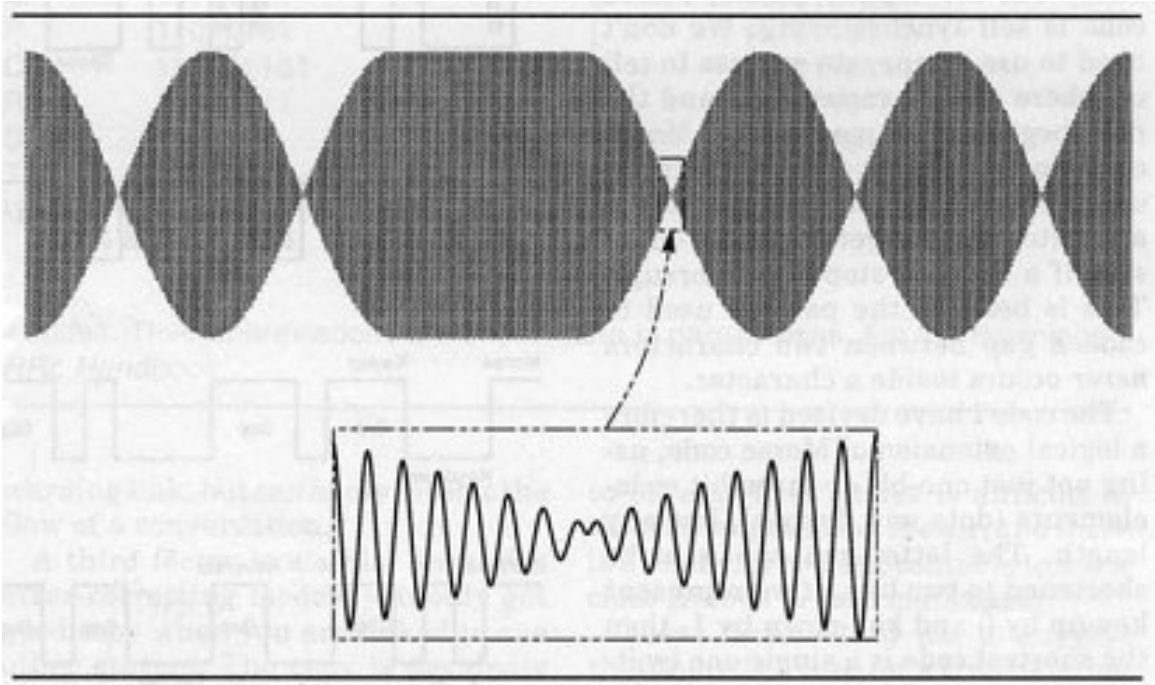


Fig 2—The waveform of BPSK sending the Varicode space symbol., with a close-up of the detail during a phase reversal.

Packet Radio

Pg 8-12

* VHF and UHF using AFSK modulation at 1200 baud over an FM link.
* Data packets, called frames, defined by the AX.25 protocol are used to send information.
* Tucson Amateur Packet Radio (TAPR) web site describes the AX.25 protocol.
* Used for store and forward systems and APRS.

Automatic Packet Reporting System (APRS)

Pg 8-12

* Uses the AX-25 protocol to broadcast position and other data to local stations and internet servers. ***[E2D07]***
* APRS station operates on 2M FM at 144.39MHz.
* APRS station components:
  - VHF FM radio
  - Terminal Node Controller (TNC)
  - Computer running APRS software
  - A Global Positioning System (GPS) receiver

APRS Messages

Pg 8-12

- APRS stations transmit a beacon packet containing the stations location, WX conditions and short text messages.
- Uses an unnumbered information (UI) frame. ***[E2D08]***
- Other stations act as digipeaters to relay packets to other stations or gateways that connect to internet APRS servers. ***[E2D11]***
- A computer running APRS software displays station information on a map.
- Position data is sent as latitude and longitude.
- Uses NEMA-0183 formatted text to receive GPS data
- Applications:
  - Ballon Tracking *[E2D04]*
  - Public Service events

HF Packet Modes

Pg 8-13

* **Most HF Packet transmission use FSK at 300 baud.**
  - Contrast that to VHF at 1200 baud
  - Uses AX.25 same as VHF

* **HF Packet has a significantly higher data rate than RTTY, AMTOR and PSK31.** ***[E2E13]***
  - That means it takes up more bandwidth
  - 40 Byte packets

* HF packet is not very forgiving of fading conditions

Pactor

Pg 8-12

* Designed to perform well with noise and weak signals or strong signals.
  - **It supports the transfer of binary files** ***[E2E08]***
  - Automatically evaluates the conditions and adjust the speed to match. Includes error detection and correction.
* Up to 5.2 kbps is achievable in a 2.4 kHz BW
* ***Winlink*** is a system of modes and protocols that can be used to exchange files and email. **But it *does not* support keyboard to keyboard communications** ***[E2E05]***.
* ***Pactor IV*** is kept proprietary by the German company, SCS and is not legal for use by US amateurs

WSJT-X Protocol

Pg 8-14

WSJT-X is a family of digital protocols developed by Joe Taylor, K1JT, for weak-signal communications

* ***MSK144*** **for Meteor scatter** ***[E2D01]***
* ***JT4, JT65 & Q65*** **for EME (moonbounce)** ***[E2D03]***
  - JT65 decodes very well with signals that are well below the noise
  - JT65 uses 1-minute alternating transmit receive periods synchronized to accurate timing signals
* **FT4, FT8 and FST4 for low S/N HF contacts**
* WSPR mode for propagation reports, no keyboard communications. Reports to pskreporter. ***[E2E05]***
* FT8 most popular digital mode on HF, 15 sec interval and 50Hz bandwdth. ***[E2E06, E2E10, E2C06]***

WSJT Characteristics

Pg 8-14

* WSJT protocols use ***multi-tone AFSK modulation*** and sophisticated codes to recover signals in the noise floor which are undetectable by the ear (JT-65).
* Numbers in the mode name indicates the number of tones used. ***[E2E03]***
* ***Gausian frequency shift keying (GFSK)*** is used for Q65 and FST4. ***[E2E04]***
  - Requires accurate timing signal for your PC. ***[E2E02]***
  - Alternating TX periods synchronized to an accurate time clock at 1 minute intervals; FT4 - 7.5 sec and JT65 1 min [E2E06].
* WSJT-X information
  - Home page: https://wsjt.sourceforge.io/wsjtx.html

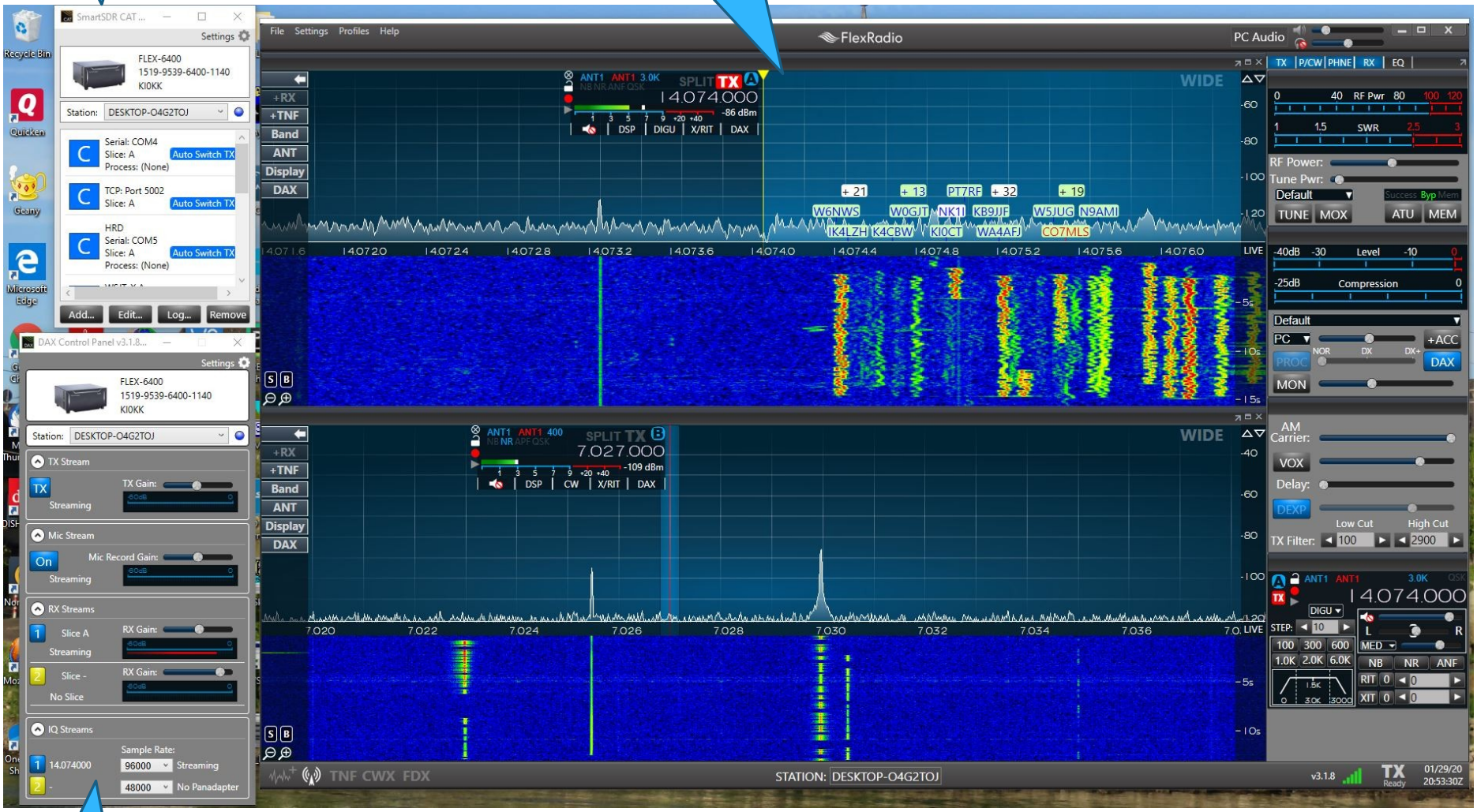
Q65 and FST4

Pg 8-14

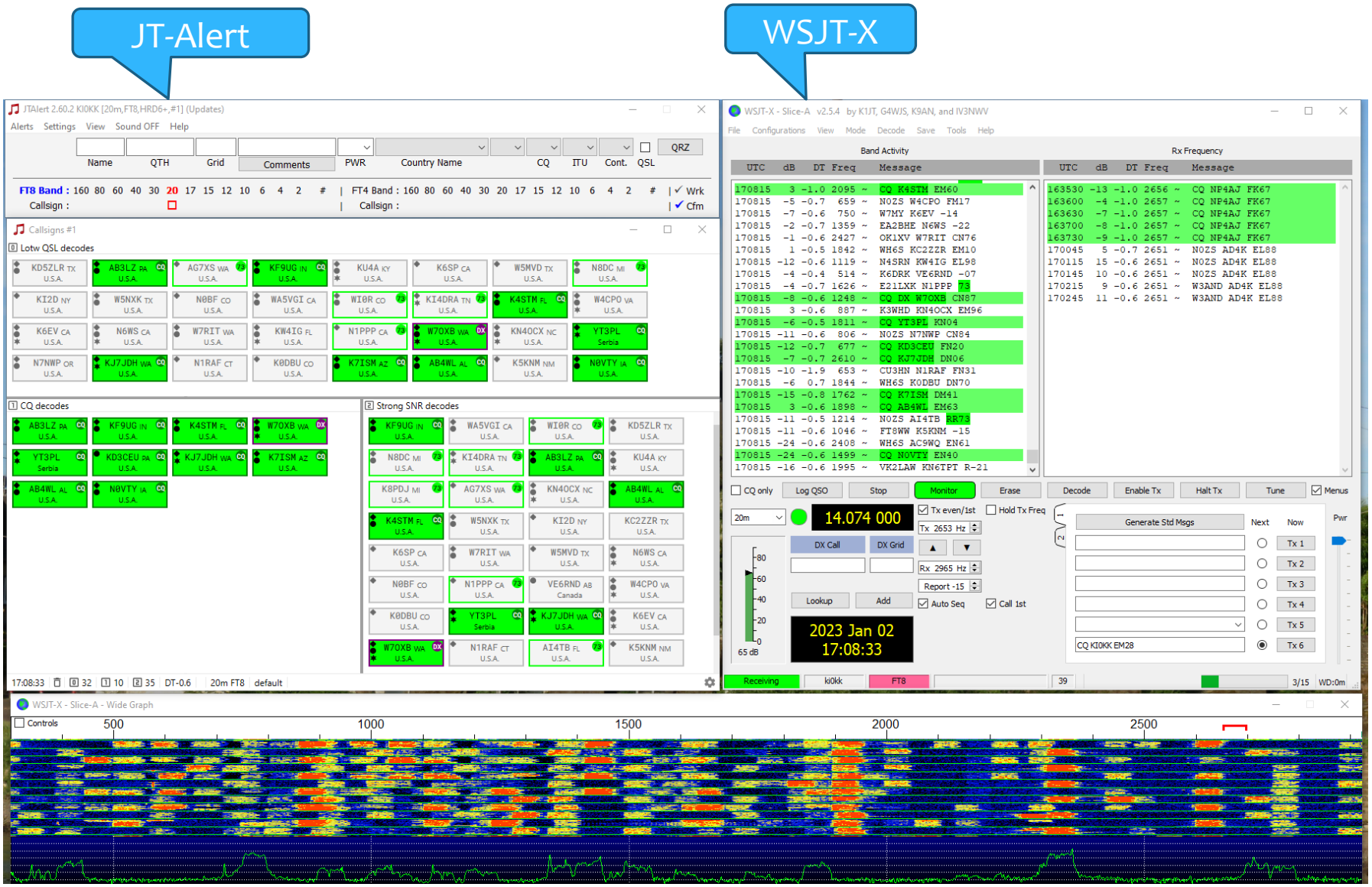
* Allow for variable transmit and receive lengths (15, 30, 60, 120 or 300 seconds)
- Q65
  - Used for HF and VHF+
  - Average multiple receive cycles ***[E2E07]***
- FST4 is LF/MF only (also 900 or 1800 Seconds)

CAT Application Connections

Flex 6400 Smart SDR Rig Control



DAX Digital Audio Cross-connect

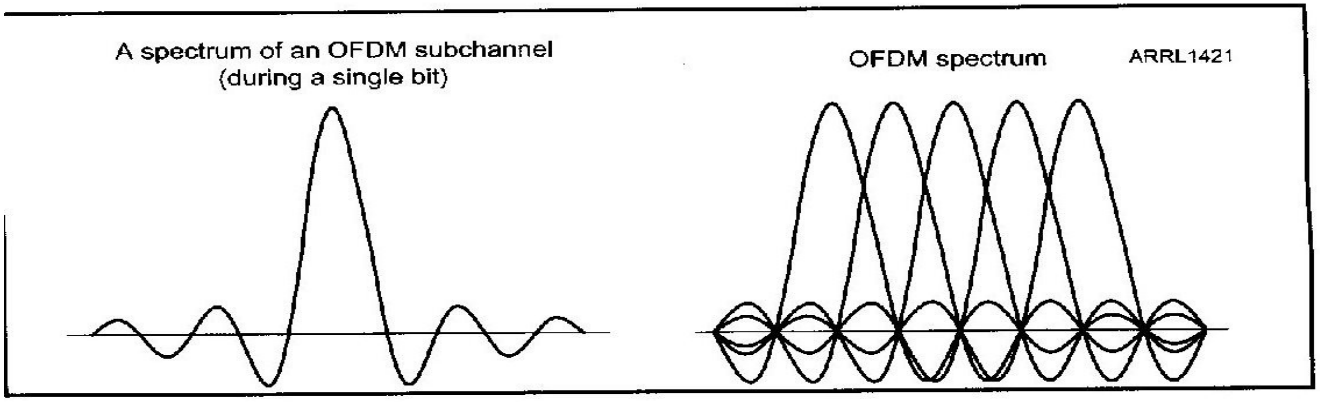

JT-Alert
WSJT-X
JTAlert 2.60.2 KI0KK [20m,FT8,HRD6+,#1] (Updates)
Alerts Settings View Sound OFF Help
Name QTH Grid Comments PWR Country Name CQ ITU Cont. QSL QRZ
FT8 Band : 160 80 60 40 30 20 17 15 12 10 6 4 2 #
FT4 Band : 160 80 60 40 30 20 17 15 12 10 6 4 2 #
Callsign :
Wrk
Cfm
Callsigns #1
Lotw QSL decodes
CQ decodes
Strong SNR decodes
WSJT-X - Slice-A v2.5.4 by K1JT, G4WJS, K9AN, and IV3NWV
File Configurations View Mode Decode Save Tools Help
Band Activity
Rx Frequency
UTC dB DT Freq Message
170815 3 -1.0 2095 ~ CQ K4STM EM60
170815 -5 -0.7 659 ~ N0ZS W4CPO FM17
170815 -7 -0.6 750 ~ W7MY K6EV -14
170815 -2 -0.7 1359 ~ EA2BHE N6WS -22
170815 -1 -0.6 2427 ~ OK1XV W7RIT CN76
170815 1 -0.5 1842 ~ WH6S KC2ZZR EM10
170815 -12 -0.6 1119 ~ N4SRN KW4IG EL98
170815 -4 -0.4 514 ~ K6DRK VE6RND -07
170815 -4 -0.7 1626 ~ E21LXK N1PPP 73
170815 -8 -0.6 1248 ~ CQ DX W7OXB CN87
170815 3 -0.6 887 ~ K3WHD KN4OCX EM96
170815 -6 -0.5 1811 ~ CQ YT3PL KN04
170815 -11 -0.6 806 ~ N0ZS N7NWP CN84
170815 -12 -0.7 677 ~ CQ KD3CEU FN20
170815 -7 -0.7 2610 ~ CQ KJ7JDH DN06
170815 -10 -1.9 653 ~ CU3HN N1RAF FN31
170815 -6 0.7 1844 ~ WH6S K0DBU DN70
170815 -15 -0.8 1762 ~ CQ K7ISM DM41
170815 3 -0.6 1898 ~ CQ AB4WL EM63
170815 -11 -0.5 1214 ~ N0ZS AI4TB RR73
170815 -11 -0.6 1046 ~ FT8WW K5KNM -15
170815 -24 -0.6 2408 ~ WH6S AC9WQ EN61
170815 -24 -0.6 1499 ~ CQ N0VTY EN40
170815 -16 -0.6 1995 ~ VK2LAW KN6TPT R-21
163530 -13 -1.0 2656 ~ CQ NP4AJ FK67
163600 -4 -1.0 2657 ~ CQ NP4AJ FK67
163630 -7 -1.0 2657 ~ CQ NP4AJ FK67
163700 -8 -1.0 2657 ~ CQ NP4AJ FK67
163730 -9 -1.0 2657 ~ CQ NP4AJ FK67
170045 5 -0.7 2651 ~ N0ZS AD4K EL88
170115 15 -0.6 2651 ~ N0ZS AD4K EL88
170145 10 -0.6 2651 ~ N0ZS AD4K EL88
170215 9 -0.6 2651 ~ W3AND AD4K EL88
170245 11 -0.6 2651 ~ W3AND AD4K EL88
CQ only
Log QSO
Stop
Monitor
Erase
Decode
Enable Tx
Halt Tx
Tune
Menus
20m
14.074 000
Tx even/1st
Hold Tx Freq
Tx 2653 Hz
DX Call
DX Grid
Rx 2965 Hz
Report -15
Lookup
Add
Auto Seq
Call 1st
2023 Jan 02
17:08:33
65 dB
Generate Std Msgs
Next
Now
Pwr
Tx 1
Tx 2
Tx 3
Tx 4
Tx 5
Tx 6
CQ KI0KK EM28
Receiving
ki0kk
FT8
3/15
WD:0m
WSJT-X - Slice-A - Wide Graph
Controls
500
1000
1500
2000
2500

OFDM Modulation

Pg 8-15

Orthogonal Frequency Division Multiplexing (OFDM)

- Used with wide-band high–speed digital modes (PACTOR). ***[E8B07]***
- OFDM, a special type of modulation used with multi-tone modes creates specially-shaped and spaced carriers that inter symbol interference ***[E8B08]***.
- Uses **subcarriers** at frequencies chosen to avoid ***inter-symbol interference***



Transmitting Digital Mode Signals

Pg 8-15

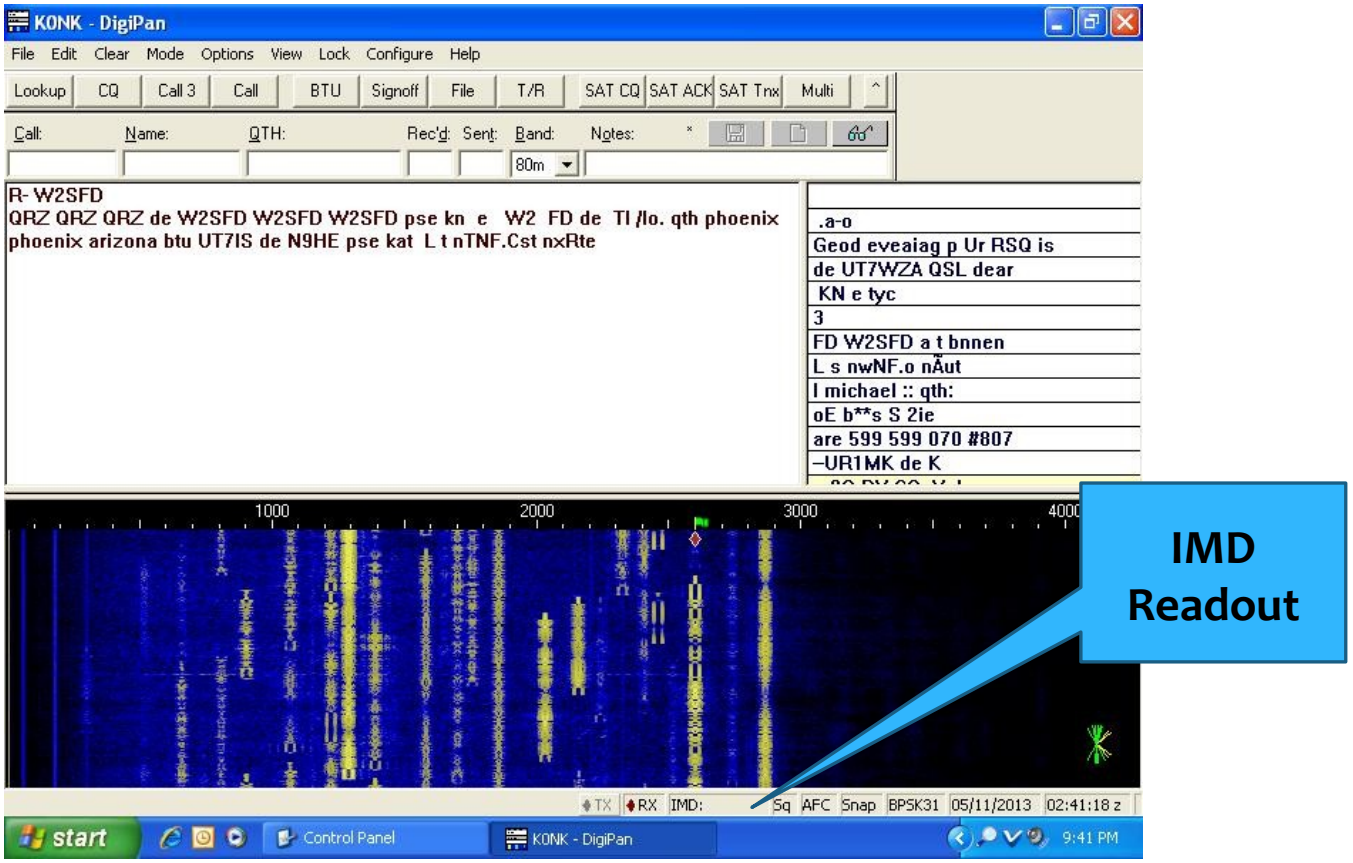
* With AFSK, ***excessive audio signal levels*** into the transmitters audio input can ***overdrive the modulator***.
* Overdrive creates ***intermodulation distortion*** (**IMD**)
* **If the transmitter's ALC (*Automatic Level Control*) meter is active during a digital transmission, the signal is overdriving the modulator. Adjust for no ALC reading during Tx *[E8D07]***

Transmitting Digital Mode Signals

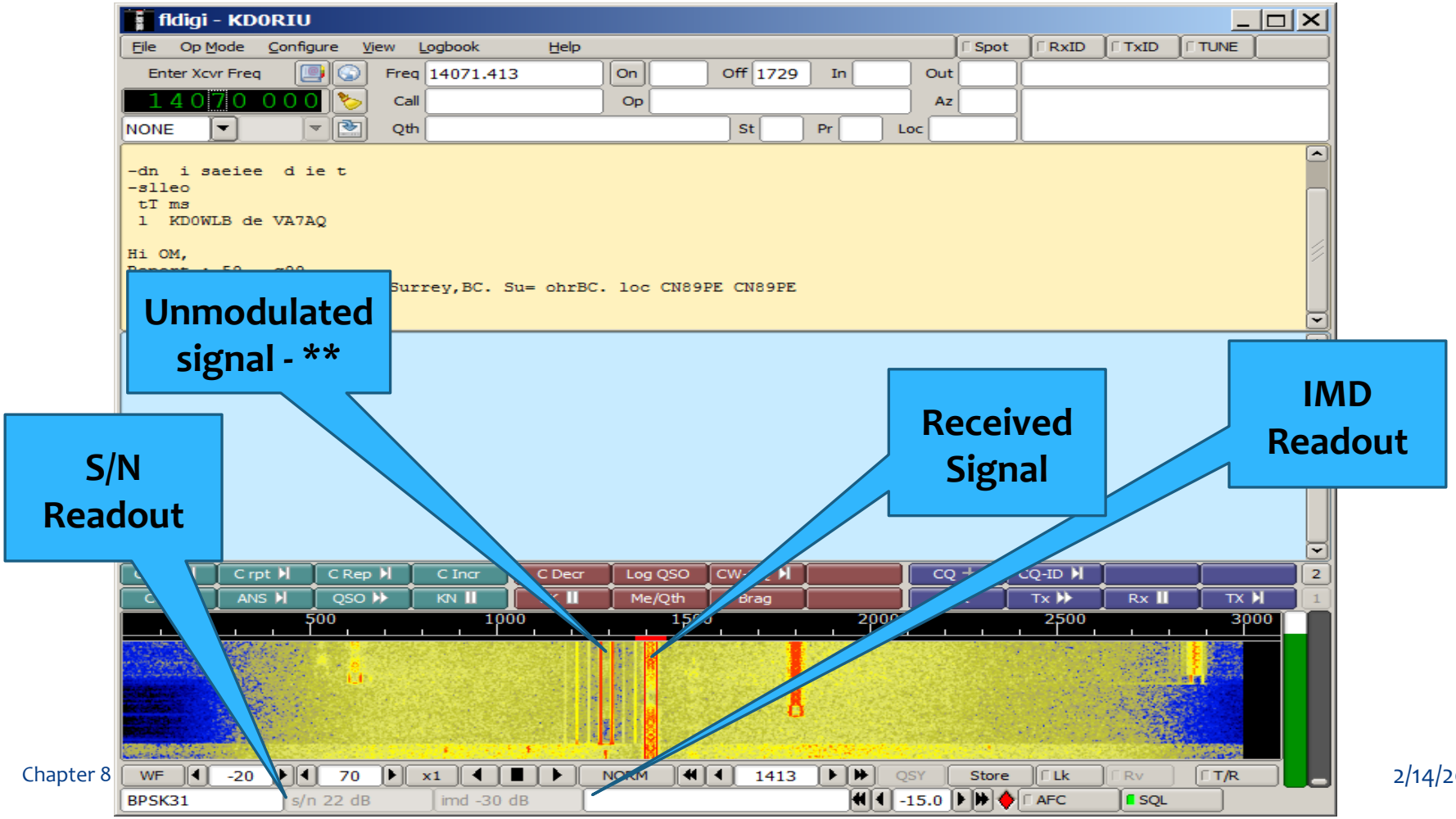
Pg 8-16

* Software can report the RX IMD ***[E8D08]***
* A clean PSK signal that is idling will have an IMD level about -30 dB below the main signals. ***[E8D09]***
* Over-modulation is seen as "ghost" signal above and below the main transmitted signal on the waterfall display.
* There can be several reasons that attempts to initiate contacts with a digital station on a clear frequency are unsuccessful.
  - Your transmit frequency is incorrect.
  - You are using a protocol not supported by the other station.
  - The frequency is being used by another station you are unable to hear (hidden transmitter).

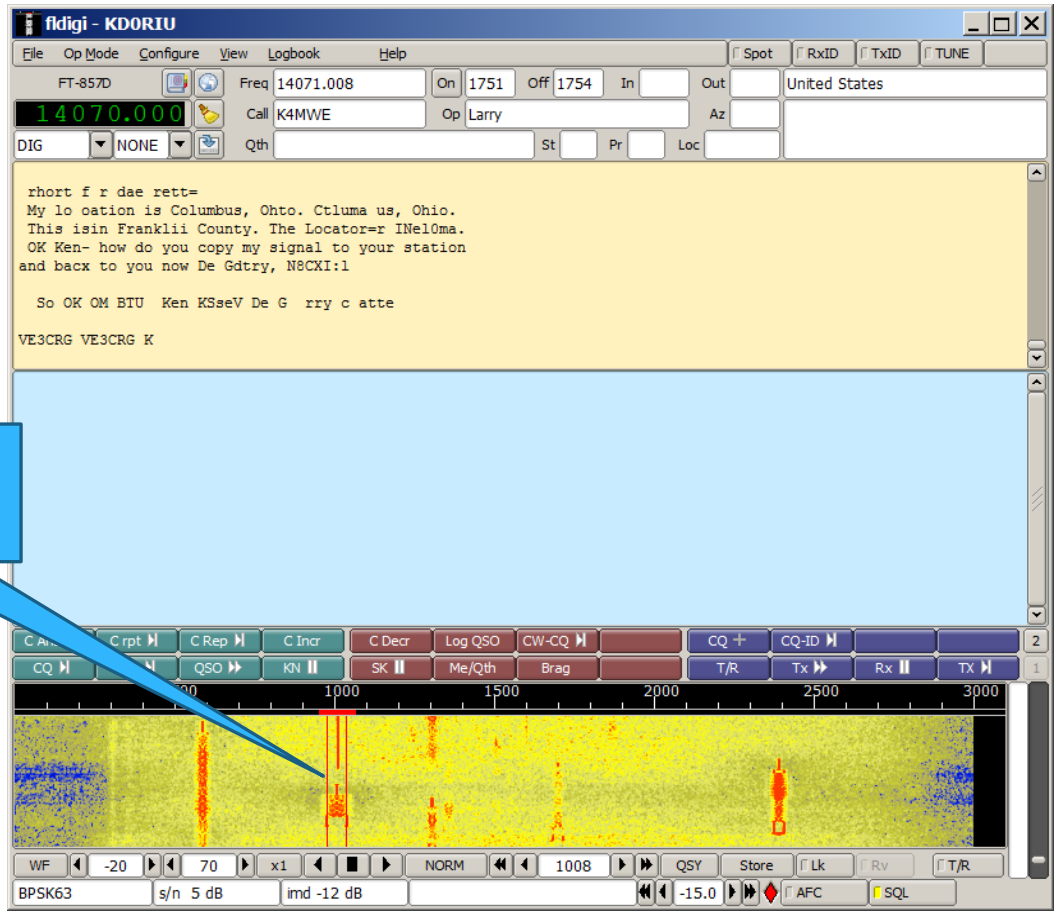
PSK31 “Waterfall” with Digipan



PSK31 "Waterfall" fldigi



PSK63 "Waterfall" fldigi



PSK63 signal

Digital Modes Sounds

Spread Spectrum

Pg 8-16

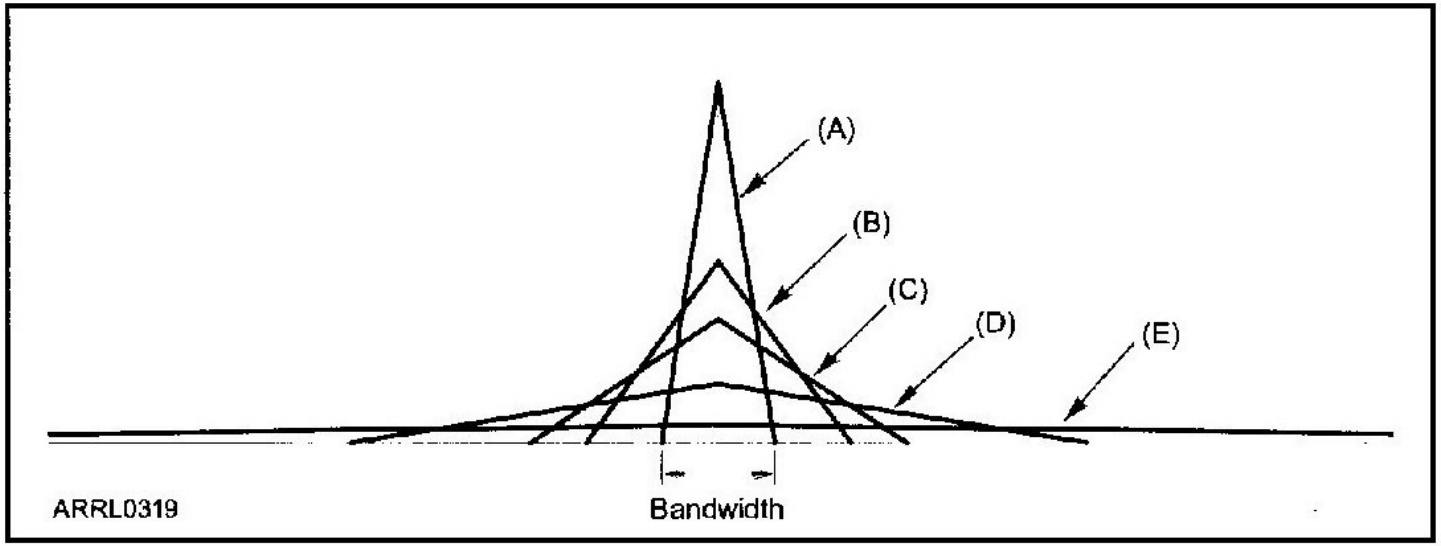


Figure 8-4 – A graphic representation of the distribution of power as the signal bandwidth is increased. The unspread signal (A) concentrates most of its energy near a center frequency. As the bandwidth increases (B), the power near the center frequency falls. At C and D, the energy is distributed wider and wider across the spread signal's wider bandwidth. At E, the signal energy is spread over a very wide bandwidth and there is little power at any one frequency.

Spread Spectrum Key Points

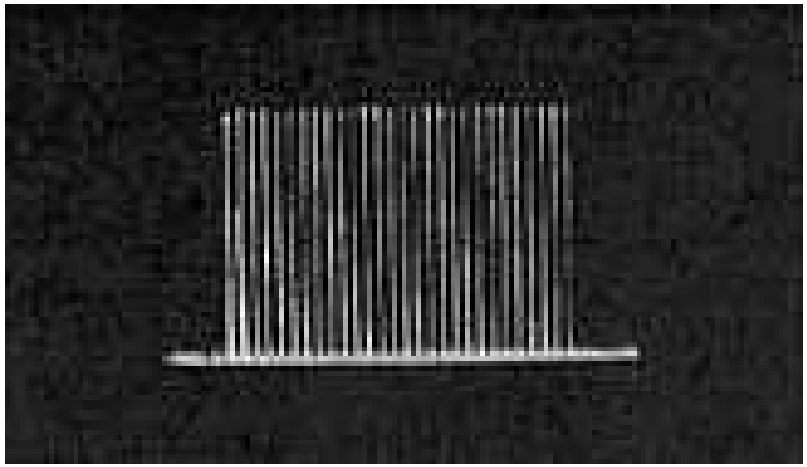
Pg 8-16

* The signal is spread over a very wide bandwidth by rapidly varying the carrier frequency in a predefined sequence (***spreading code***).
* **Spread spectrum signals appear as wideband noise** to a conventional receiver.
* The spread spectrum receiver can reject strong undesired signals.
* Non-spread signals tend to be suppressed by the spread-spectrum receiver ***[E8D01]***.
* ***Code Division Multiple Access (CDMA)*** allows several spread spectrum systems operating on different spreading codes to use the same frequency

Frequency Hopping (FH)

Pg 8-17

* ***Frequency hopping (FH)*** is a form of spreading the RF energy in which the center frequency of a conventional carrier is altered many times a second in accordance with at predetermined ***pseudo-random code [E8D03]***.
* The signal may "park" on a given frequency for only 10 msec or less, (***dwell time***).

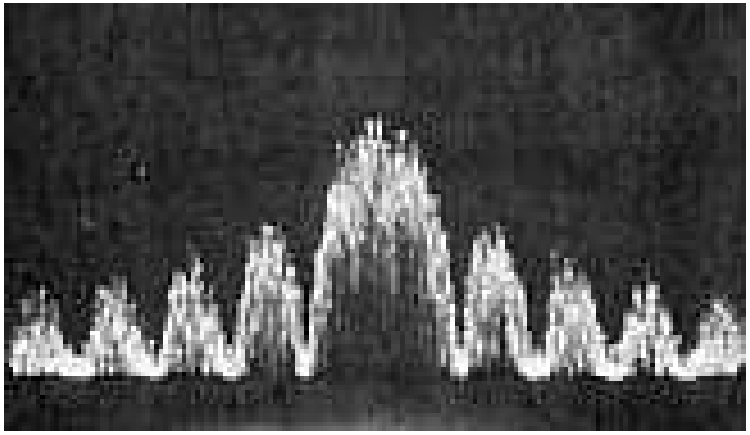


http://sss-mag.com/ss.html

Direct Sequence (DS)

Pg 8-18

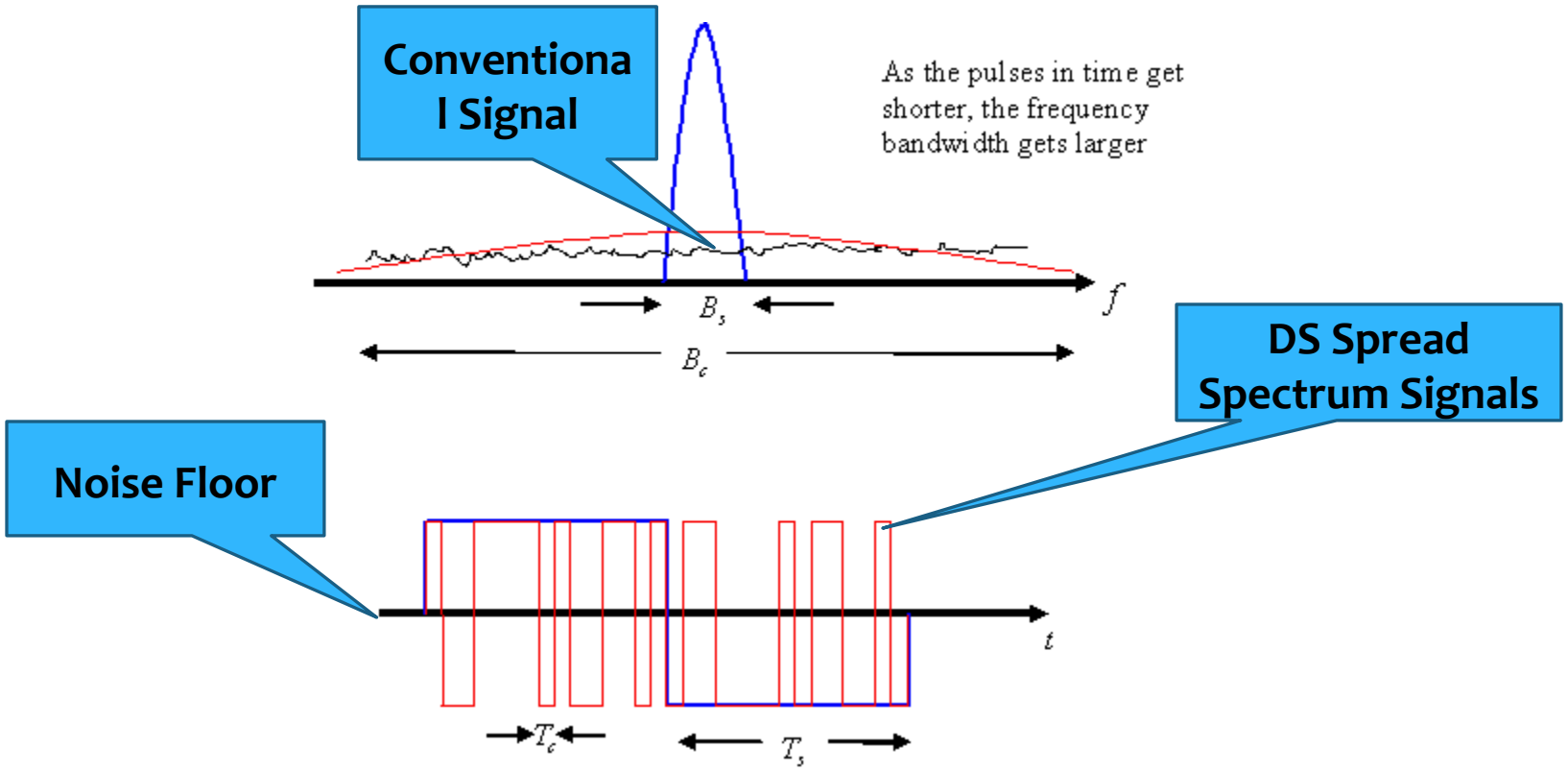
* In ***direct sequence (DS)***, *a very fast binary stream (**pseudo-noise, PN**) is used to shift the phase of the modulated carrier **[E8D02]**.*
  - *Each bit of the PN is called a chip*
  - *The rate at which the chips shift the carrier phase is called the **chip rate***
* DS spread spectrum is usually used to transmit digital signal's
* Phase shift types
  - Binary phase-shift keying (BPSK), 0-180
  - Quadrature phase-shift keying (QPSK), 0,90,180,270 shift ***[E8C01]***



http://sss-mag.com/ss.html

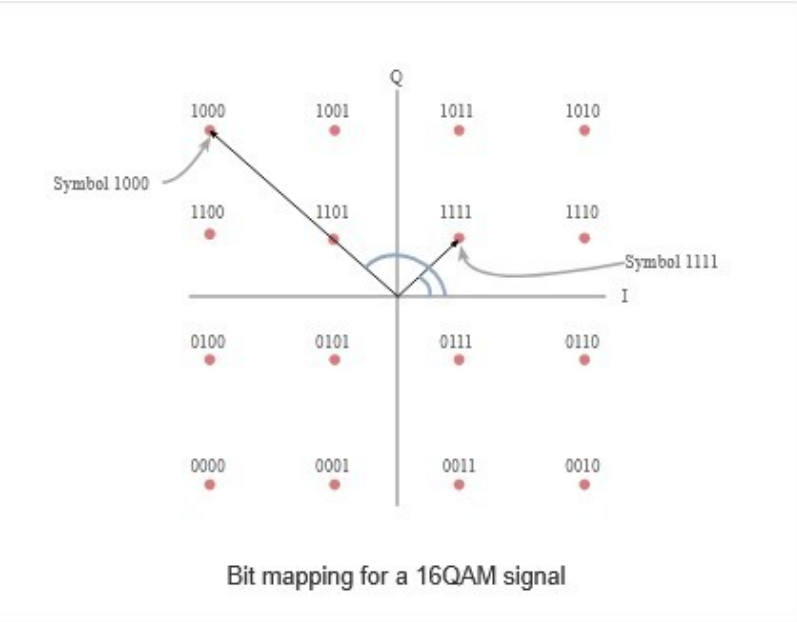
Direct Sequence Signals

Pg 8-18

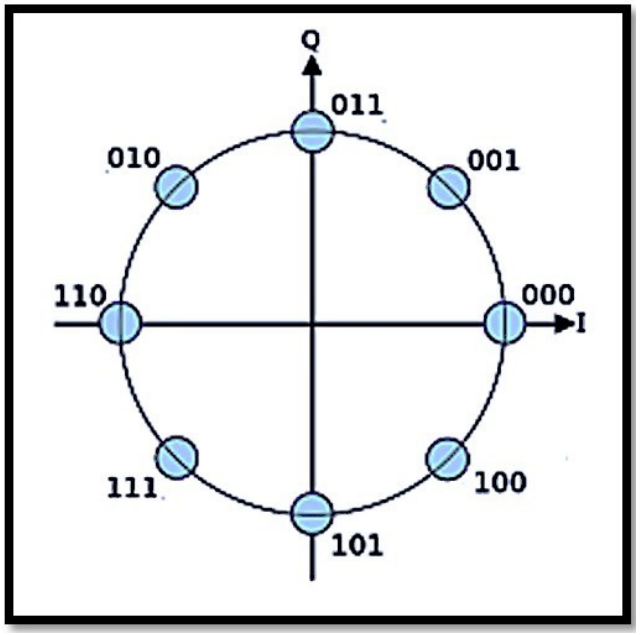


Spread Spectrum Communications - Definition & Techniques ; www.ni.com/white-paper/4450/en/

16 QAM vs 8-PSK Constellation Diagram



Bit mapping for a 16QAM signal



Bit Mapping 8-PSK

I and Q are different inputs to the I/Q modulator

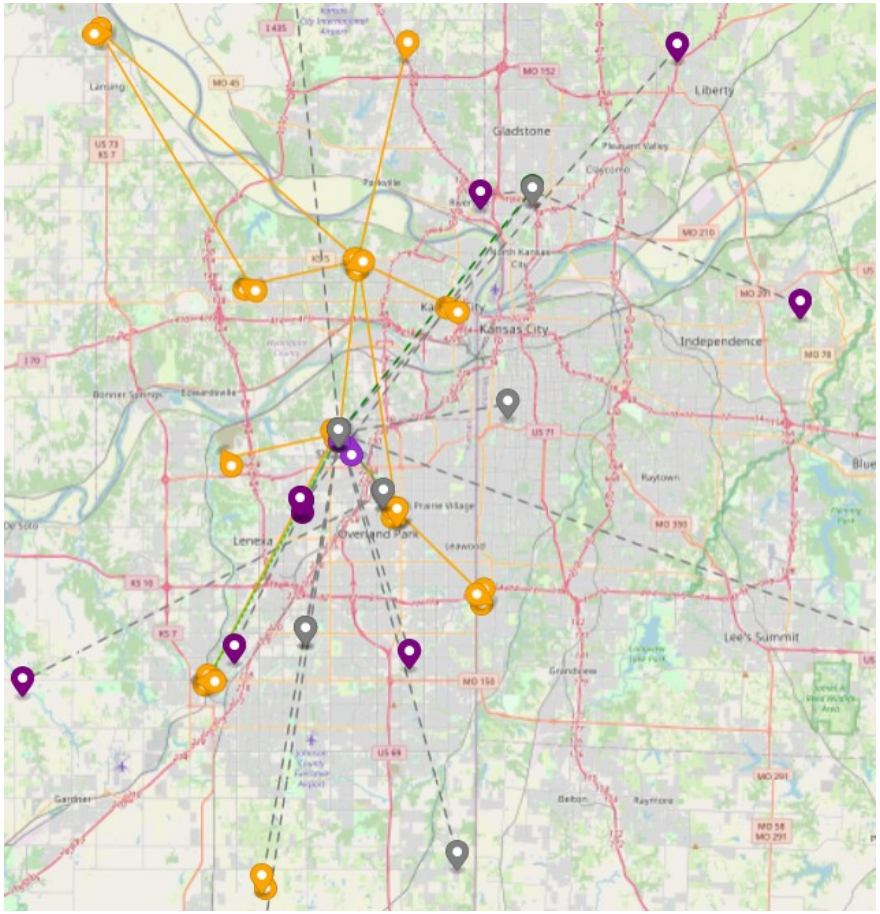
Amateur Spread Spectrum Applications (Wi-Fi)

Pg 8-19

- ***Ham WAN, BBHN and ARDEN*** are ham networks.
- Used in the shared 2.4 and 5.6 GHz Wi-Fi bands ***[E2C04]***
- Commercial WiFi routers that are reprogrammed with custom software to meet Amateur Radio regulations ***[EC209]***
- Nodes use auto discovery and link establishment protocols ***[E8C15]***
- FCC regulations apply inlcuding prohibition of encription. ***[E1F09]***

KC Mesh (ARDEN based) is the local KC group/network - https://km3sh.org/ or at https://groups.io/g/KCmesh/topics
ARDEN web site: https://www.arednmesh.org/

KC Mesh Network Map

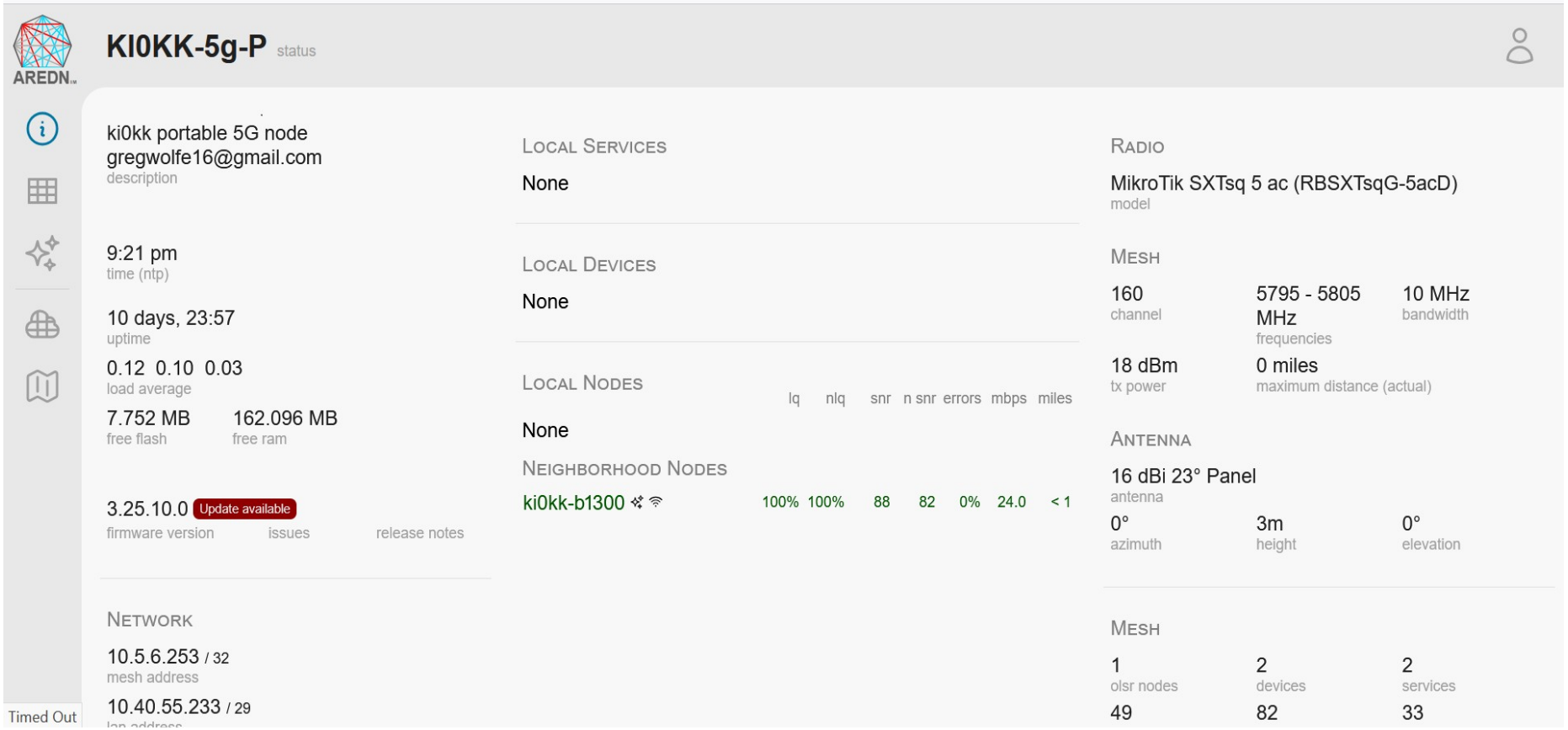


AREDN Map

Band	Nodes
HaLow	2
2.4 GHz	13
5 GHz	27
Supernode	2
No RF	18
Total	62

Last updated 2/6/2026, 2:11:08 PM

KIØKK Mesh Node



Error Detection and Correction

Pg 8-19

* ***Error detection*** helps to determine that an error has occurred in a received signal.
  - ***Parity bit***, single bit errors
  - ***Cyclical redundancy check*** (CRC) can detect multiple bit errors
* ***Error correction*** tries to fix the error
* Two types of error correction:
  - Automatic Repeat Request (ARQ), NAK ACK messages ***[E8C08]***
  - Forward Error Correction

Error Detection
Parity

Pg 8-19

Remember, an ASCII character consists of 8 symbols:

* ASCII letter "A" : __ 1000001
  - Insert a zero 01000001 for *Even Parity*
* ASCII letter "C" : __ 1000011
  - Insert a one 11000011 for *Even Parity*
* If this is received: 11001011
  - An error is declared

Error Correction

Pg 8-19

Two types of error correction:

* ***Automatic Repeat Request*** **(ARQ)**
  - If the receiving system detects and error, it requests a retransmission of the corrupted packet or message.
  - Done by sending a ***NAK*** **(Not Acknowledged message)** ***[E8C08]***

* ***Forward Error Correction*** **(FEC)**
  - Sends some extra data about the information in the message so the receiving station can correct some of the errors .
  - FEC data and the algorithm by which errors are detected and corrected is called an **FEC Code.**
    - MFSK 16_sends all data twice
    - Common FEC codes; Reed-Solomon, Hamming, BCH and Golay codes.

Section 8-2

Questions

What is the definition of symbol ratein a digital transmission?

[E8C02]

A. The number of control characters in a message packet
B. The maximum rate at which the forward error correction code can make corrections
C. The rate at which the waveform changes to convey information
D. The number of characters carried per second by the station-to-station link

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Which of the following HF digital modes uses variable-length character coding?

[E2E09]

A. RTTY
B. PACTOR
C. MT63
D. PSK31

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What is one advantage of using the ASCII code for data communications?

[E8D11]

A. It includes built-in error correction features
B. It contains fewer information bits per character than any other code
C. It is possible to transmit both upper and lower case text
D. It uses one character as a shift code to send numeric and special characters

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What factors affect the bandwidth of a transmitted CW signal?

[E8C12]

A. IF bandwidth and Q
B. Modulation index and output power
C. Keying speed and shape factor (rise and fall)
D. All these choices are correct

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B. Direct FSK occupies less bandwidth
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What technique minimizes the bandwidth of a PSK31 signal?

[E8C04]

A. Zero-sum character encoding
B. Reed-Solomon character encoding
C. Use of sinusoidal data pulses
D. Use of linear data pulses

What type of packet frame is used to transmit APRS beacon data ?

[E2D08]

A. Acknowledgment
B. Burst
C. Unnumbered Information
D. Connect

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What is the length of an FT8 transmission cycle ?

[E2E06]

A. It varies with the amount of data
B. 8 seconds
C. 15 seconds
D. 30 seconds

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What describes orthogonal frequency division multiplex (OFDM) ?

[E8B08]

A. A frequency modulation technique that uses non-harmonic related frequencies
B. A bandwidth compression technique using Fourier transforms
C. A digital mode for narrow-band, slow speed transmissions
D. A digital modulation technique using sub carriers at frequencies chosen to avoid inter-symbol interference

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C. Frequency response of the signal stream
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What type of equipment is commonly used to implement an amateur radio mesh network ?

[E2C09]

A. A 2 meter VHF transceiver with a 1200 baud modem
B. A computer running echo link to provide interface from the radio to the internet
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