Signal Processing for Digital Mode Amateur Radio

David Farrell, CEPD, Inc.
AC0QG@ARRL.NET
www.cepd.com
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Topics

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HF Transmission
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A Few Popular Digital Modes and How They Work
Digital Mode Bands and Frequencies
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Ham Radio Popularity

- At the beginning of 2015, there were over 726,000 licensed operators
- Around 9000 new licenses are issued each year
- Much of the recent growth of ham radio can be attributed to the FCC's 2007 decision to do away with the Morse code requirement for all amateur licenses

How to get your license

The classifications of new licenses are Technician, General and Extra.

Read the free study guides at http://www.kb6nu.com/tech-manual/ , or buy a book at www.arrl.org .

Register on www.QRZ.com and take their practice exams.

Find an exam time and location near you:

http://www.arrl.org/find-an-amateur-radio-license-exam-session .

You can take all three exams in one sitting if you pass. There is a small fee per exam.

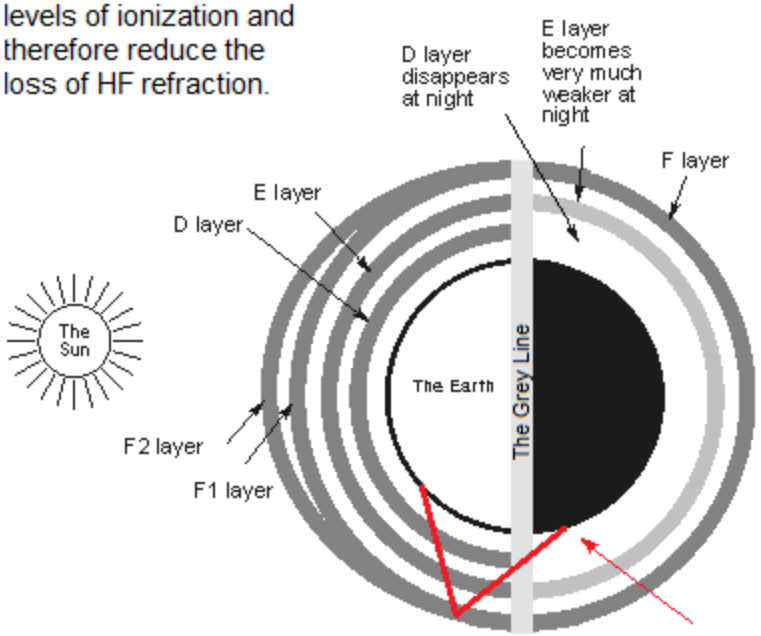
HF Long Distance Transmission

(high frequency bands ~1.8MHZ to 30MHz)

Higher frequencies experience lower loss and penetrate further through the Ionosphere.

F layers refract HF frequencies, 3 to 30MHz.
The D layer absorbs lower frequencies.

Sunspots increase the levels of ionization and therefore reduce the loss of HF refraction.



The ionosphere is less active at night and higher frequencies pass through. The maximum useable frequency, MUF, is higher during the daytime and drops at night.

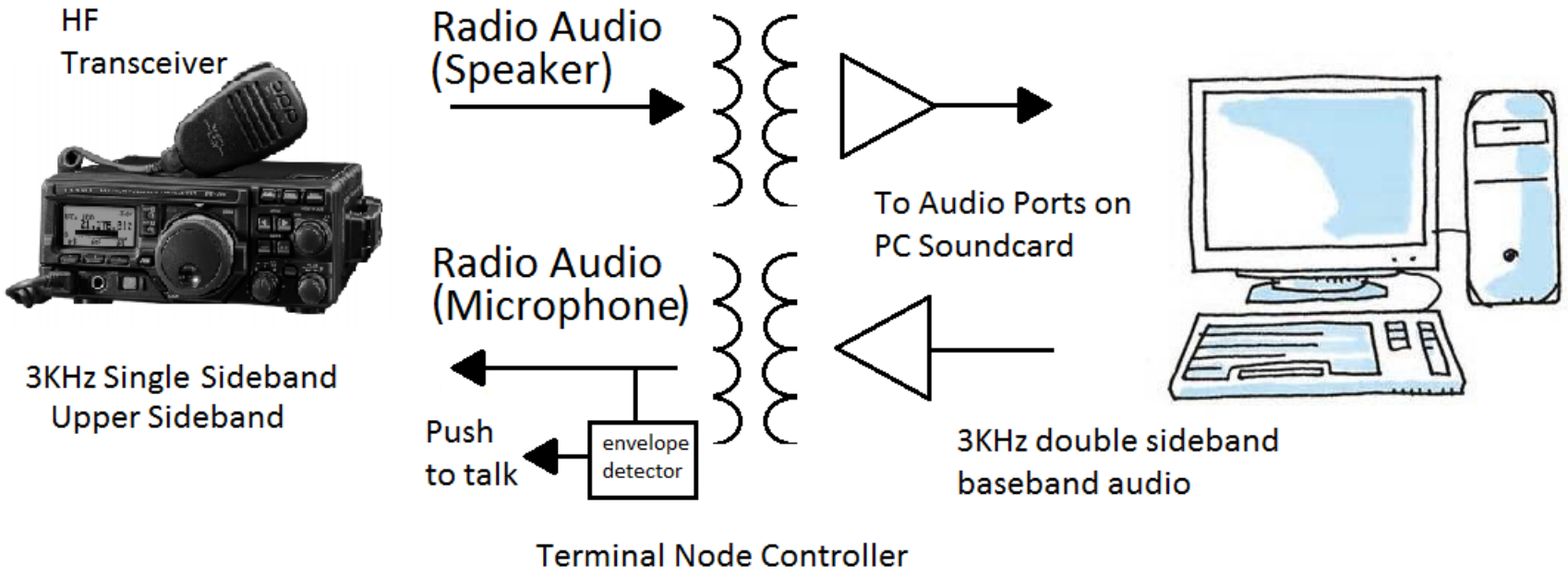
Digital mode operators generally transmit between 1W and 75W of power, using less power than a bright incandescent light bulb.

It is not uncommon to reach distances over 9000 miles.

Long distance HF radio communications (DX) utilize skywave, which "skips" off of the ionosphere. The maximum useable frequency generally allows for the longest distance.

Interface between PC and a Standard Transceiver

(to insert the modulated data within a voice channel bandwidth)



The computer does the signal processing

The signal processing consists of encoding and modulation, decoding and demodulation. PCs and SBCs are well suited for the signal processing given the low bandwidths and today's processing power:

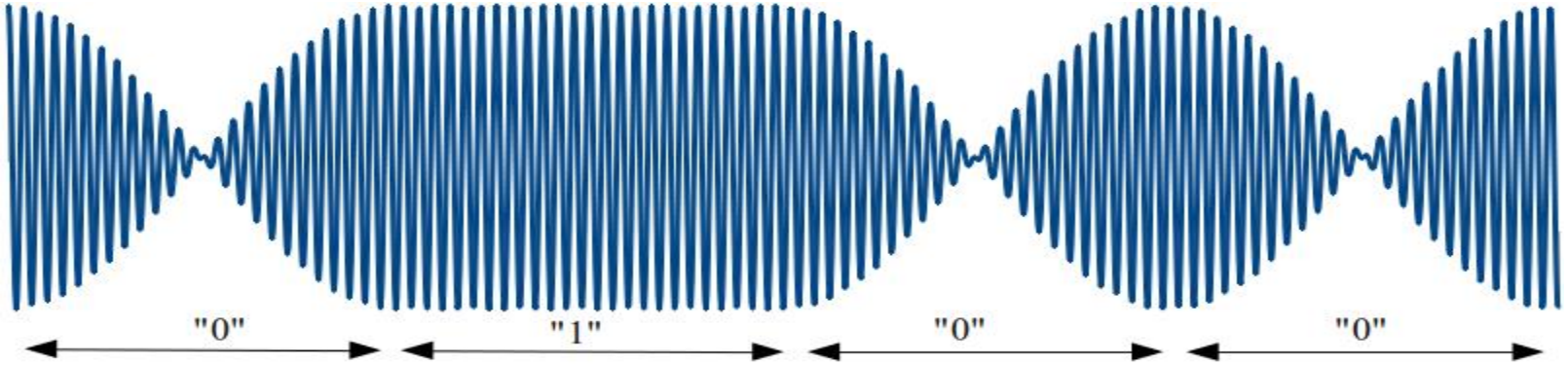
- channels are half duplex
- bandwidth is less than 3KHz
- soundcard sample rates are >8KHz

BPSK Waveform

(binary phase shift keying)

PSK related modes: PSK31 PSK63 PSK125 Q15X25

Binary information is transmitted by imparting a 180-degree phase shift (binary "zero") or no phase shift (binary "one") in each symbol interval. PSK31 signals can be recovered 7 dB below the noise floor. There is no error correction. The bandwidth is approximately equal to the baud rate.



Mode	Baud	Interval	~wpm
BPSK31	31.25	0.032	50
BPSK63	62.5	0.016	100
BPSk125	125	0.008	200

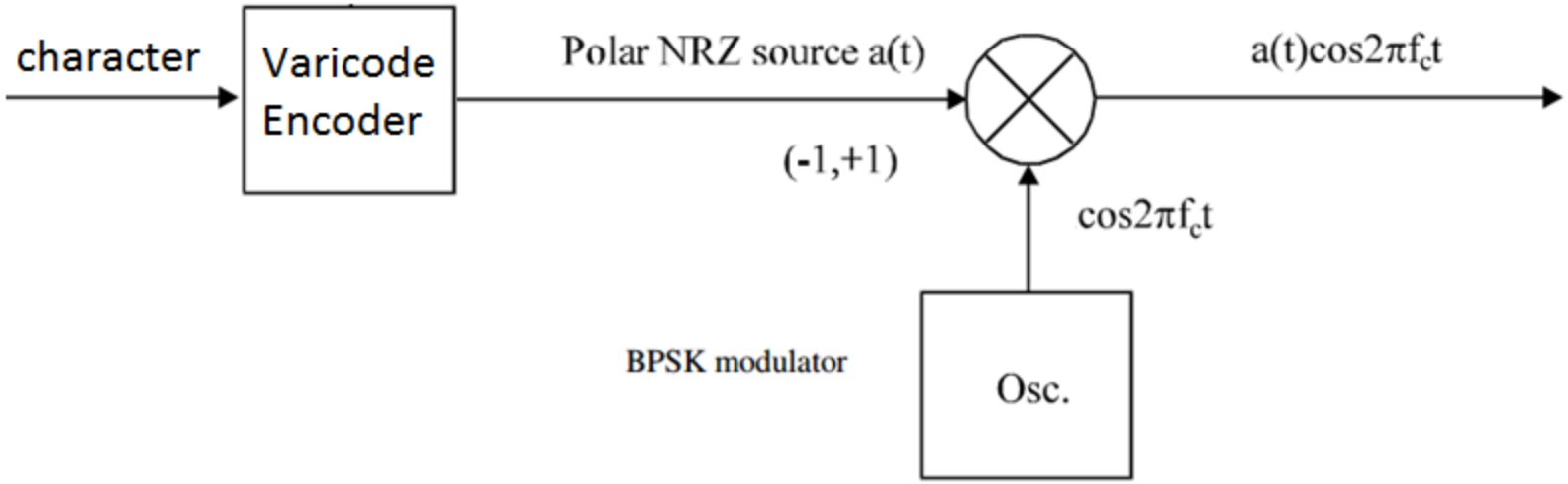
Varicode

Varicode is a Huffman code for use in PSK. It supports all ASCII characters, but the characters used most frequently in English have shorter codes. The space between characters is indicated by a 00 sequence, a variation of Fibonacci coding. [Wikipedia]

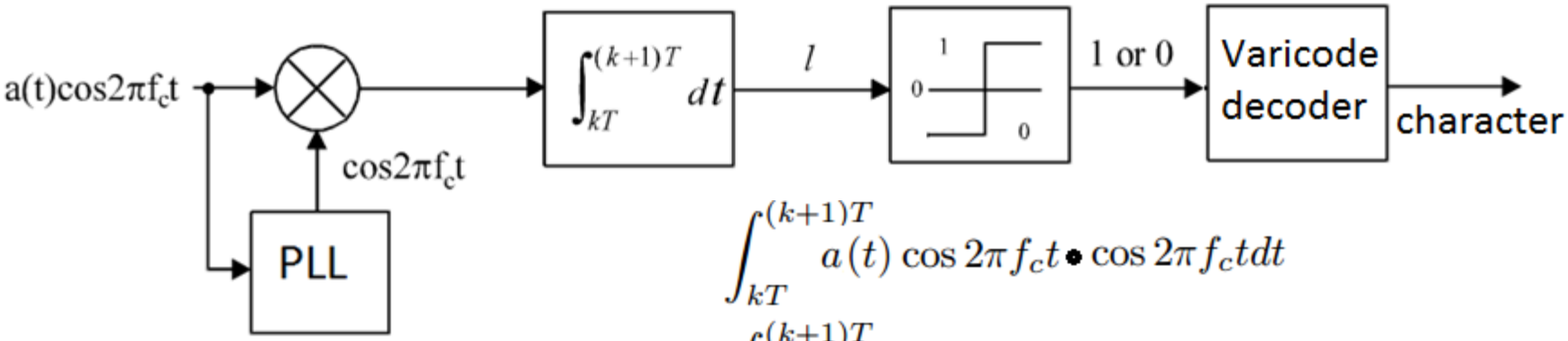
The average character length is 6.3 bits. No Varicode characters can begin or end with a zero.

Varicode was adopted by the ITU in Recommendation ITU-R M.2034.

BPSK Modulation



BPSK Demodulation



$$\int_{kT}^{(k+1)T} a(t)\cos 2\pi f_c t \bullet \cos 2\pi f_c t dt$$

$$= \int_{kT}^{(k+1)T} a(t)\cos^2 2\pi f_c t dt$$

$$= \frac{1}{2}\int_{kT}^{(k+1)T} a_k(1+\cos 4\pi f_c t)dt$$

$$= \frac{T}{2}a_k + \frac{a_k}{8\pi f_c}[\sin 4\pi f_c(k+1)T - \sin 4\pi f_c kT]$$

$0 \quad f_c >> 1/T$

FSK Modes

(*multiple* frequency shift keying)

FSK:

RTTY AMTOR / SITOR PACTOR CLOVER2000
Packet radio (Bell 103 Bell 202): APRS

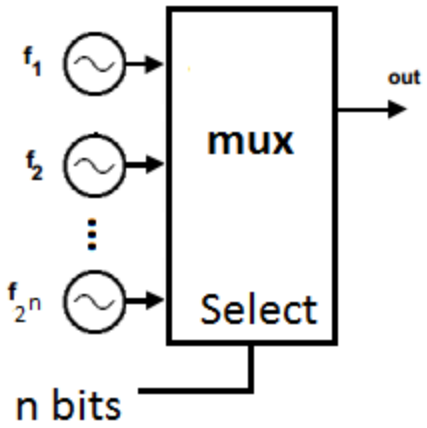
The Automatic Packet Reporting System is popular on VHF/UHF for telemetry and instant messaging.

MFSK:

MFSK Olivia Contestia JT65 FSK441 JT6M WSPR

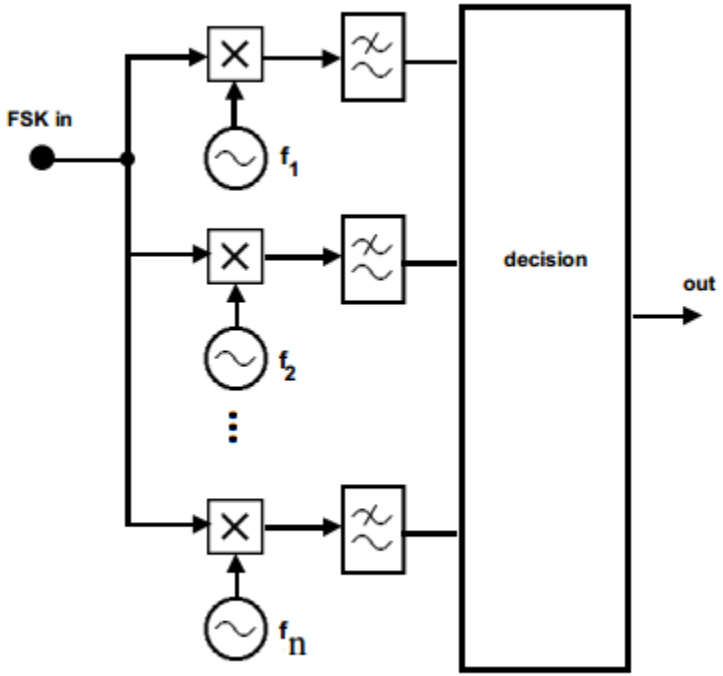
$MFSK_{16}$ Modulation

For $MFSK_{16}$, there are 16 tones, sent one at a time, at 15.625 baud and spaced15.625Hz apart. Each tone represents four binary data bits. The transmission is 316-Hz wide. MFSK signals can be recovered 13.5 dB below the noise floor.

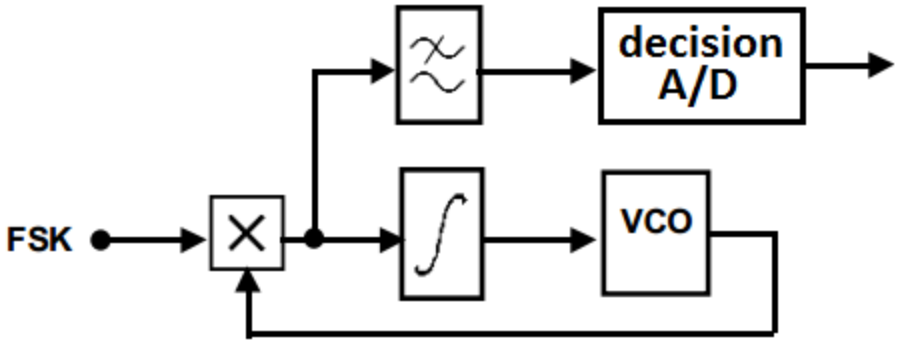


$$v_{fsk}(t) = V_c \cos\{2\pi[f_c + v_m(t)\,\Delta f]t\}$$

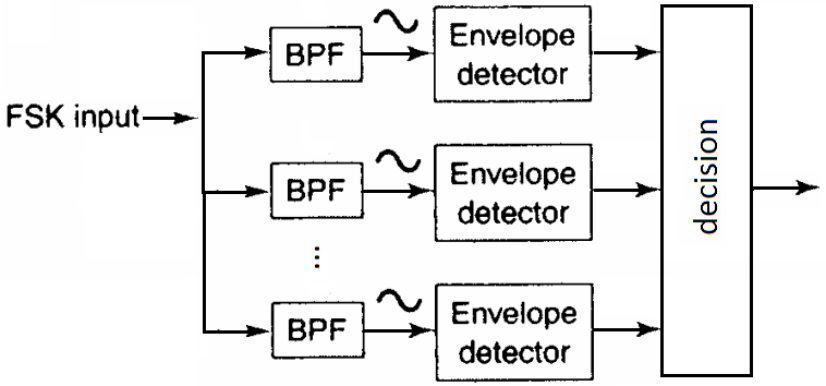
MFSK Demodulation



Synchronous Detection



PLL Method



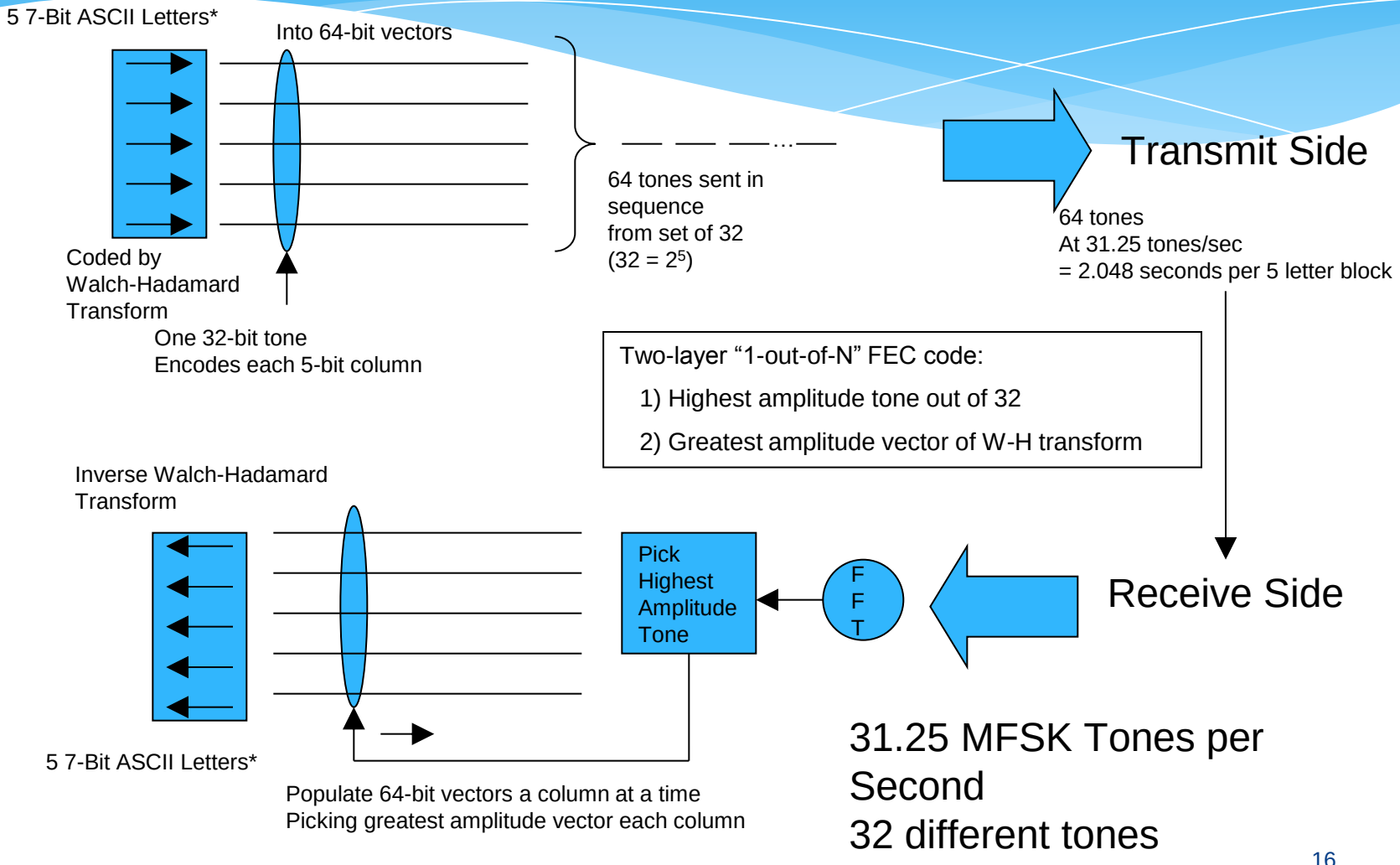
Non-coherent

Olivia

Olivia transmits a stream of ASCII (7-bit) characters. The characters are sent in blocks of 5. Olivia has 40 formats (modes) based upon different values for bandwidth and the number of tones (bit-rate = Bandwidth / tones).
Tones: 2, 4, 8, 16, 32, 64, 128, 256
Bandwidths (Hz): 125, 250, 500, 1000, 2000
For example, Olivia 16/500 is 16 tones and 500Hz bandwidth.
Olivia signals can be recovered 17 dB below the noise floor. Olivia utilizes error correction.

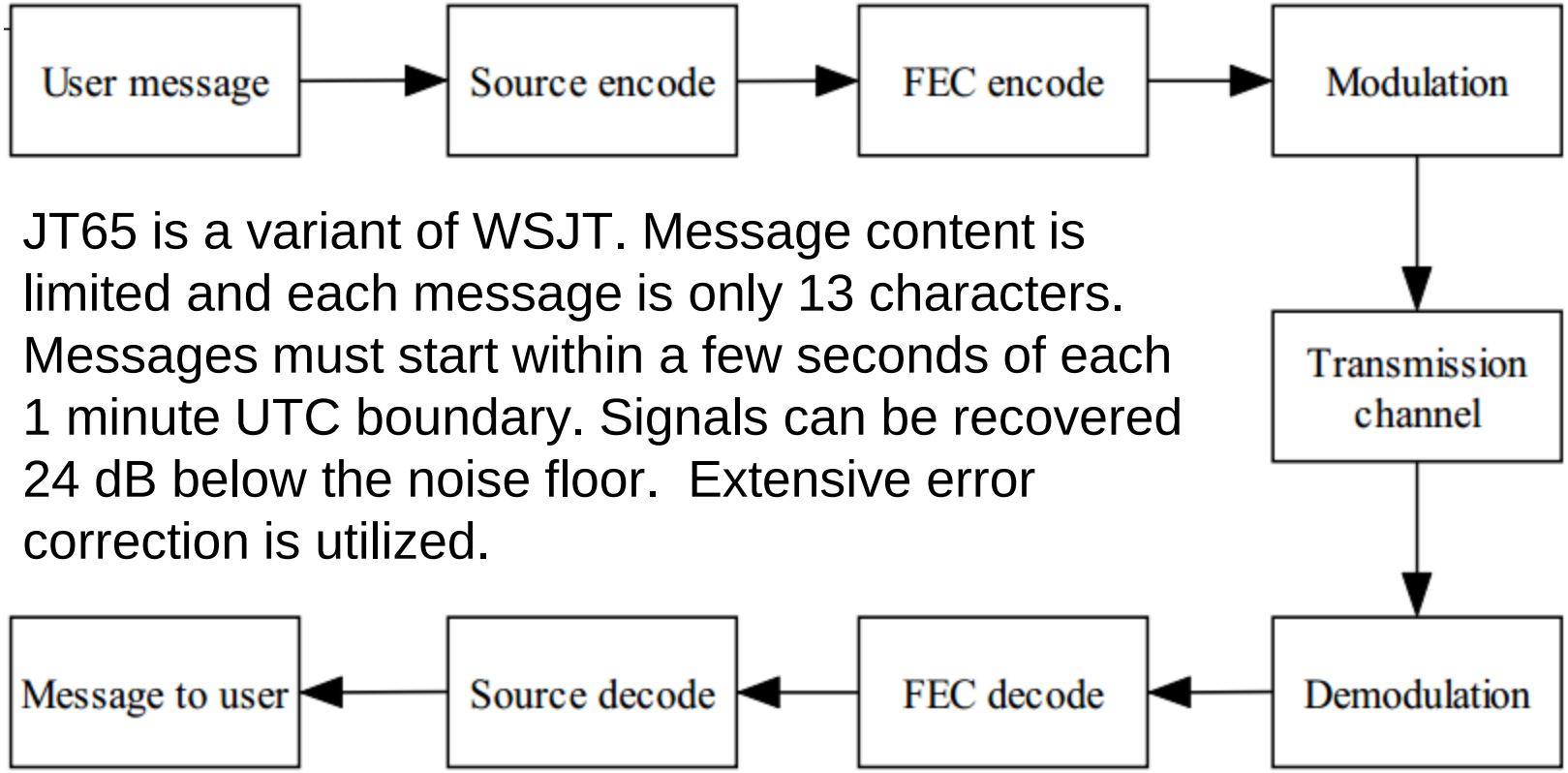
Olivia 32/1000 Signal Flow

[http://www.k4lrg.org/Projects/Digital_Modes/Digital_Presentation_2009_11_21_By_AI4IN.ppt]



* Scrambled to minimize false lock with pseudo-random sequence
xE257E6D0291574EC

JT65 HF



JT65 is a variant of WSJT. Message content is limited and each message is only 13 characters. Messages must start within a few seconds of each 1 minute UTC boundary. Signals can be recovered 24 dB below the noise floor. Extensive error correction is utilized.

More detail on JT65

JT65 uses the Reed Solomon code RS(63,12). After being compressed into 72 bits, a JT65 message is augmented with 306 uniquely defined error-correcting bits. JT65 Transmission uses 64-tone MFSK, with each symbol value corresponding to a distinct tone. It is divided into 126 contiguous time intervals, each of length 0.372 s (4096 samples at 11025 samples per second). Within each interval the waveform is a constant-amplitude sinusoid at one of 65 pre-defined frequencies, and frequency changes between intervals are accomplished in a phase-continuous manner. The synchronizing tone is at frequency 1270.5 Hz and is normally sent in each interval having a “1” in the pseudo-random sequence.

Commonly used HF digital mode frequencies (kHz)

These vary with region and mode, and are published on several sites. Check Google for HF frequencies for the mode you are using.

160 meters

1807 – 1810

80 meters

3580 – 3583

40 meters

7035 – 7038

7070 - 7073

30 meters

10130 - 10140

20 meters

14070 - 14073

17 meters

18100 - 18103

15 meters

21070 – 21073

12 meters

24920 - 24923

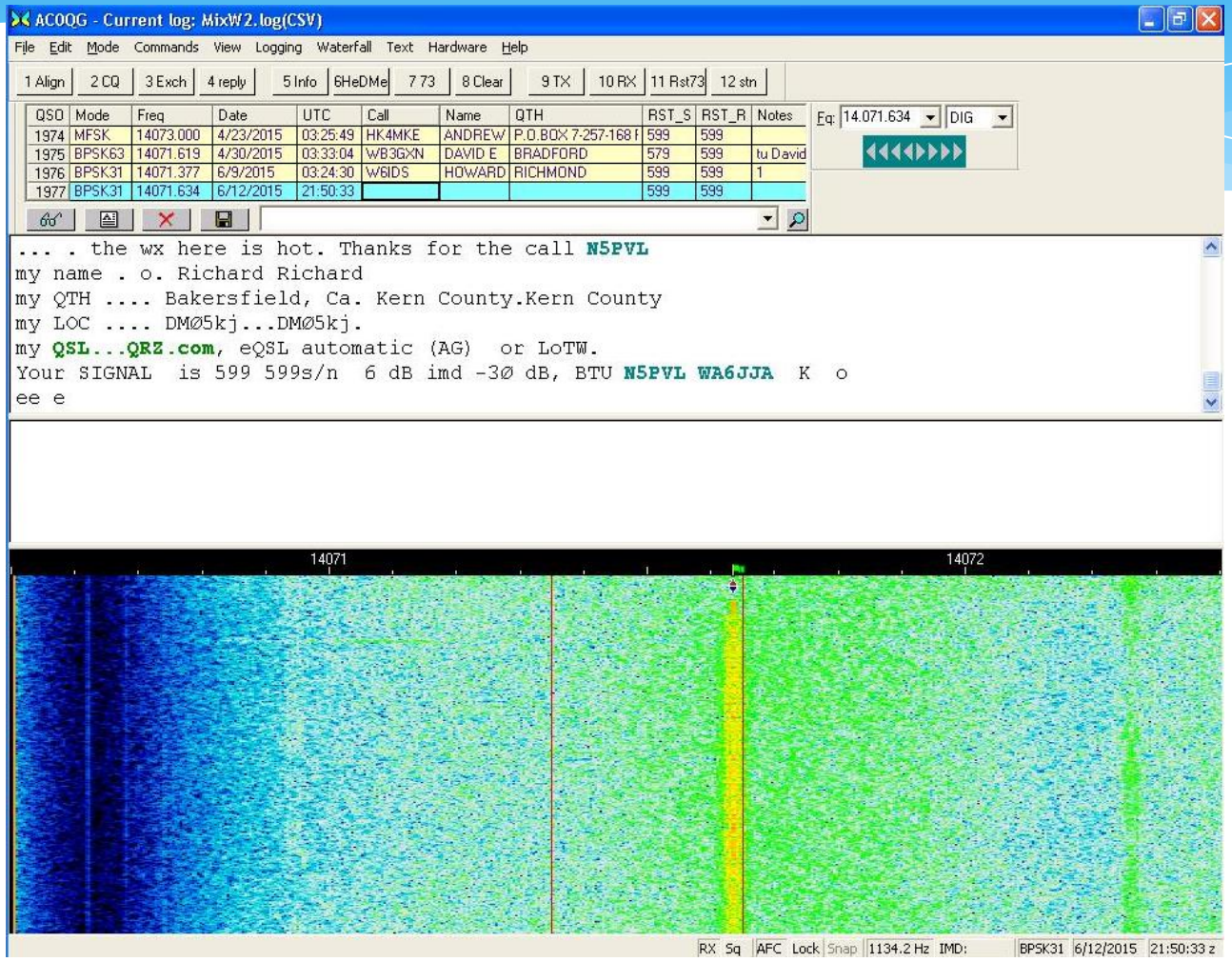
10 meters

28120 - 28123

Where to find source code

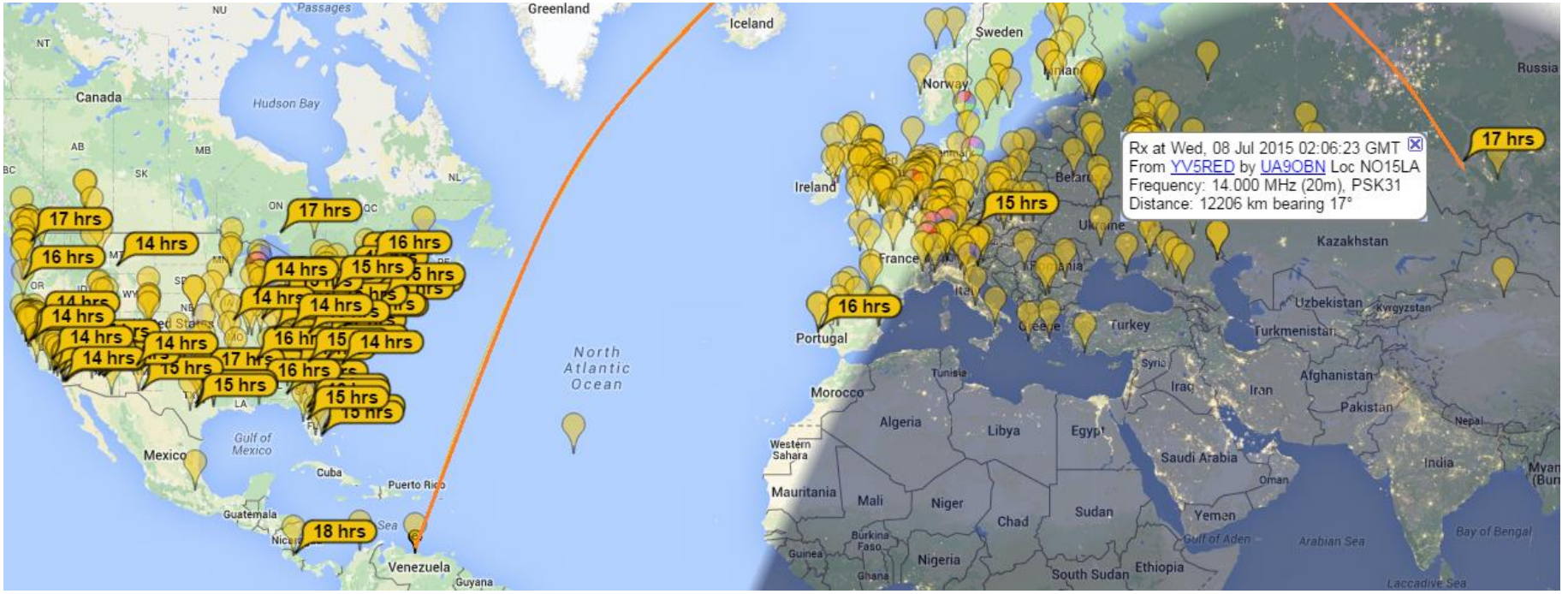
- FLDigi
- Olivia on Linux
- sourceforge links
- West Mountain Radio's links
- JT65
- PSK31 DLL

Example


ACOQG - Current log: MixW2.log(CSV)
File Edit Mode Commands View Logging Waterfall Text Hardware Help
1 Align 2 CQ 3 Exch 4 reply 5 Info 6HeDMe 7 73 8 Clear 9 TX 10 RX 11 Rst73 12 stn
QSO Mode Freq Date UTC Call Name QTH RST_S RST_R Notes
1974 MFSK 14073.000 4/23/2015 03:25:49 HK4MKE ANDREW P.O.BOX 7-257-168 599 599
1975 BPSK63 14071.619 4/30/2015 03:33:04 WB3GXN DAVID E BRADFORD 579 599 tu David
1976 BPSK31 14071.377 6/9/2015 03:24:30 W6IDS HOWARD RICHMOND 599 599 1
1977 BPSK31 14071.634 6/12/2015 21:50:33 599 599
Fq: 14.071.634 DIG
... . the wx here is hot. Thanks for the call N5PVL
my name . o. Richard Richard
my QTH .... Bakersfield, Ca. Kern County.Kern County
my LOC .... DMØ5kj...DMØ5kj.
my QSL...QRZ.com, eQSL automatic (AG) or LoTW.
Your SIGNAL is 599 599s/n 6 dB imd -3Ø dB, BTU N5PVL WA6JJA K o
ee e
14071
14072
RX Sq AFC Lock Snap 1134.2 Hz IMD: BPSK31 6/12/2015 21:50:33 z

Determining your range
(directivity and effectiveness of your antenna)

- Perform a CQ call or contact with your call sign.
- After several minutes, but within 24 hrs, check the map at to https://pskreporter.info/pskmap.html and enter your call sign, to see which monitoring stations received your signal.
- Digital Master 780 (part of Ham Radio Deluxe) and FLDigi have built in monitoring capabilities, if you wish to become a monitoring station.



References

(this presentation can be found at https://app.box.com/IeeeSPS-ham)

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