AX.25 Part I: Underlying Signals (and comparison to VARA FM)

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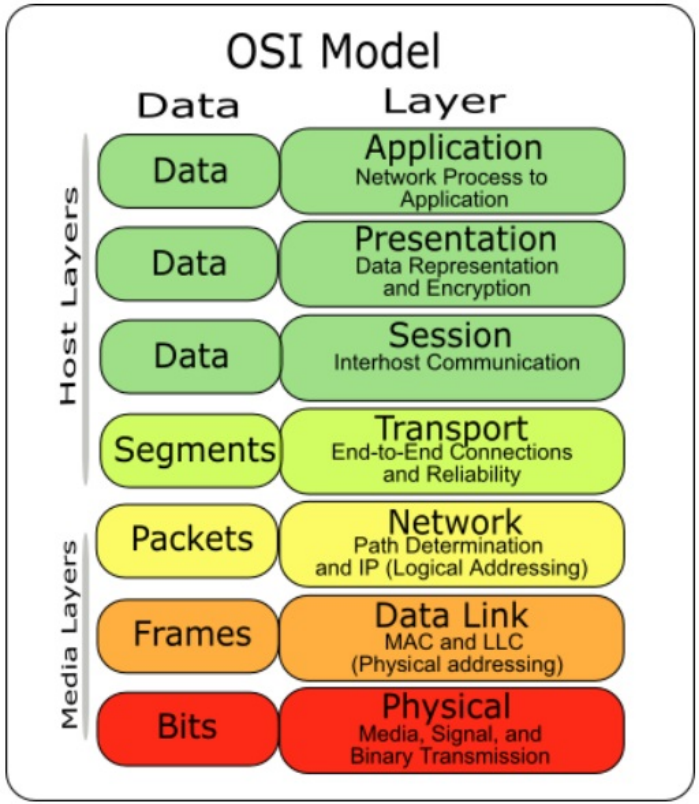
The Layered OSI Model for Networking



REF: https://inst.eecs.berkeley.edu/~ee123/sp17/lab/lab5/Lab5_Part_2-Audio_Frequency_Shift_Keying(AFSK).html

AX.25 preceded this way of layering network protocols.

Early documentation didn't conform to this way of describing.

PHYSICAL LAYER (BITS) and Data Link Layer (FRAMES) are our primary targets tonight…. But AX.25 includes maybe some of Network also.

Timeline

- 1970's: AX.25: Orig. developed in 1970's by hams, standardized in 1984 with version 2.0 specification. "Link layer" development. Multiple "network" implementations developed on top, "tower of Babel" Ref: https://www.ax25.net/
- *Usage decreased after Internet created*.
- Re-popularized by WINLINK using it for VHF/UHF email
- ?2020? VARA-FM: Private development by EA5HVK, Jose Alberto Nieto Ros (https://rosmodem.wordpress.com/) Improvements, addition of digipeating 2021-ish. https://zeroretries.substack.com/p/zero-retries-0006

USE CASE

- AX.25 designed to allow NODES (individual radio stations) to connect to each other, or to create many, many links, to connect to a far distant computer.
- AX.25 has 2 methods of linking:
  - Digipeating: Packets are passed along, where good or bad. Retries must traverse the entire chain all over again
  - Connections: Packets are re-evaluated at each node-node link, and problems are solved right then and there (much more efficient)
  - Using CONNECTIONS, one used to be able to zip from one end of Florida to the other in seconds.

HDLC: High Level Data Link Control

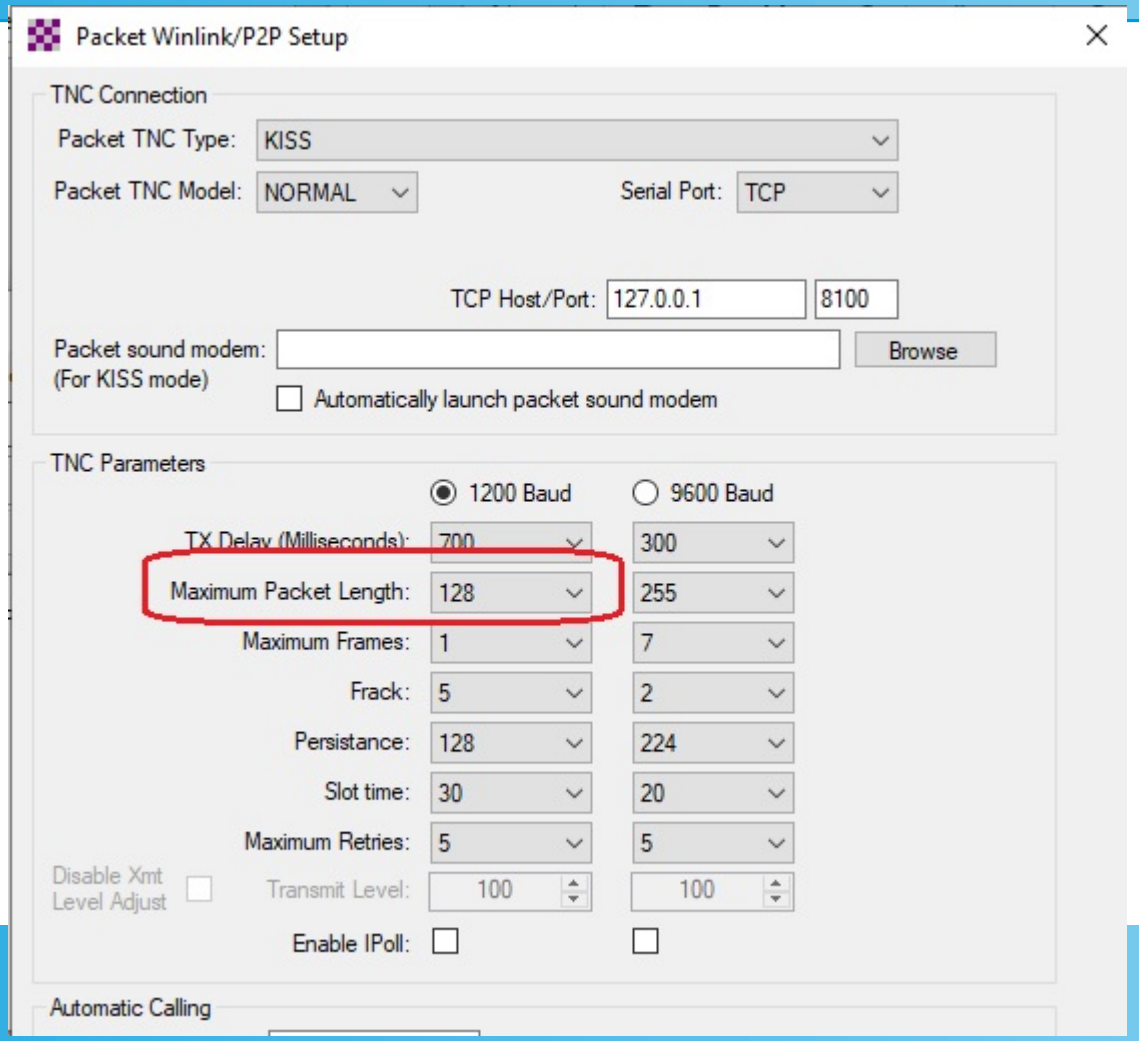
- Group of protocols (“rules”) for transmitting data between network points (“nodes”)
- Fomal standard is a “bit-oriented, synchronous data link layer protocol created by the International Organization for Standardization (ISO) ISO/IEC 13239:2002
- Data organized into units (“frames”) sent, and successful arrival is verified. (+ many more details…..)
- Hams are VERY familiar with communications that have SOME of the features of “HDLC’s”

Ham Radio High Level Data Link Control

- Techniques with at least SOME of the features of HDLC:
- Field Day: The EXCHANGE is a frame, and receipt is verified
- Radiograms: Each part of the Radiogram is a frame, and receipt is verified
- PACTOR: data sent in frames (packets) and verified
- AX.25 – same [**AX.25 is a full HLDC compliant protocol**]
- VARA – same
- VARA FM – same
- PSK31 – NOT HDLC no verification
- REF: https://www.techtarget.com/searchnetworking/definition/HDLC#:~:text=HDLC (High-level Data Link Control) is a group,Organization for Standardization (ISO).

Packet Frame SIZES

- Set in the WINLINK Packet Settings
- 64 or 128 typical in our experience
- (Ethernet = 1500 bytes)

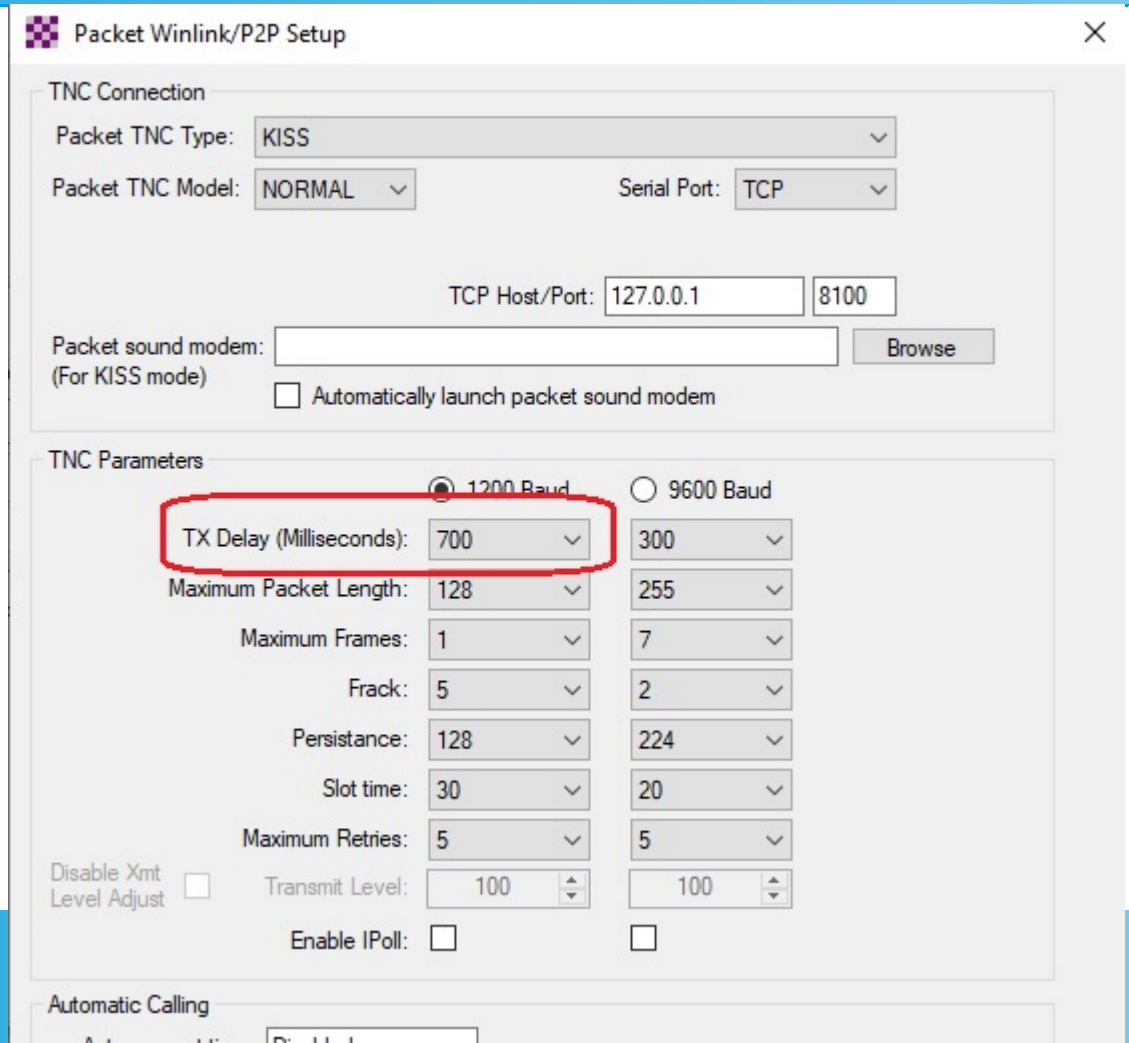


- Real HDLC protocols are more complicated than just receipt
- Frames can be transmitted “clocked” (synchronous) or “uncclocked” (asynchronous)
- Fundamental Frame Types:
  - Information frames (I-frames) data +/- flow/error control
  - Supervisory frames (S-frames): flow / error control without information
  - Unnumbered frames (U-frames) miscellaneous purposes
  - I and S frames are NUMBERED, so receipt and orderly processing can be guaranteed
  -

- Examples of S Frames
  - RR – ready to receive more frames
  - RNR – receive NOT ready
  - REJ – need some frames re-sent!
- HDLC system have STATES
  - Disconnected (not in a connection)
  - Connected (in a connection)

Transmitter / Receiver Slowness

- Real radios are not instantaneous
- Both VARA and AX.25 have a “leeway time” to allow for slowness after PTT is grounded, before real transmission occurs
- **VARA sets it *automatically*!!** COOL!!



Multi-User AX.25

- AX.25 built similarly to wire networks.
- Multiple users on one “channel” can be accomodated
- Stations listen for a clear spot before transmitting
- Accidental “doubles” can occur, and then have to be handled by the software
- Two connection modes:
  - Unconnected: Similar to Internet datagrams: high speed, no error correction
  - Connected: Similar to TCP/IP – 1:1 connections, with full error correction..

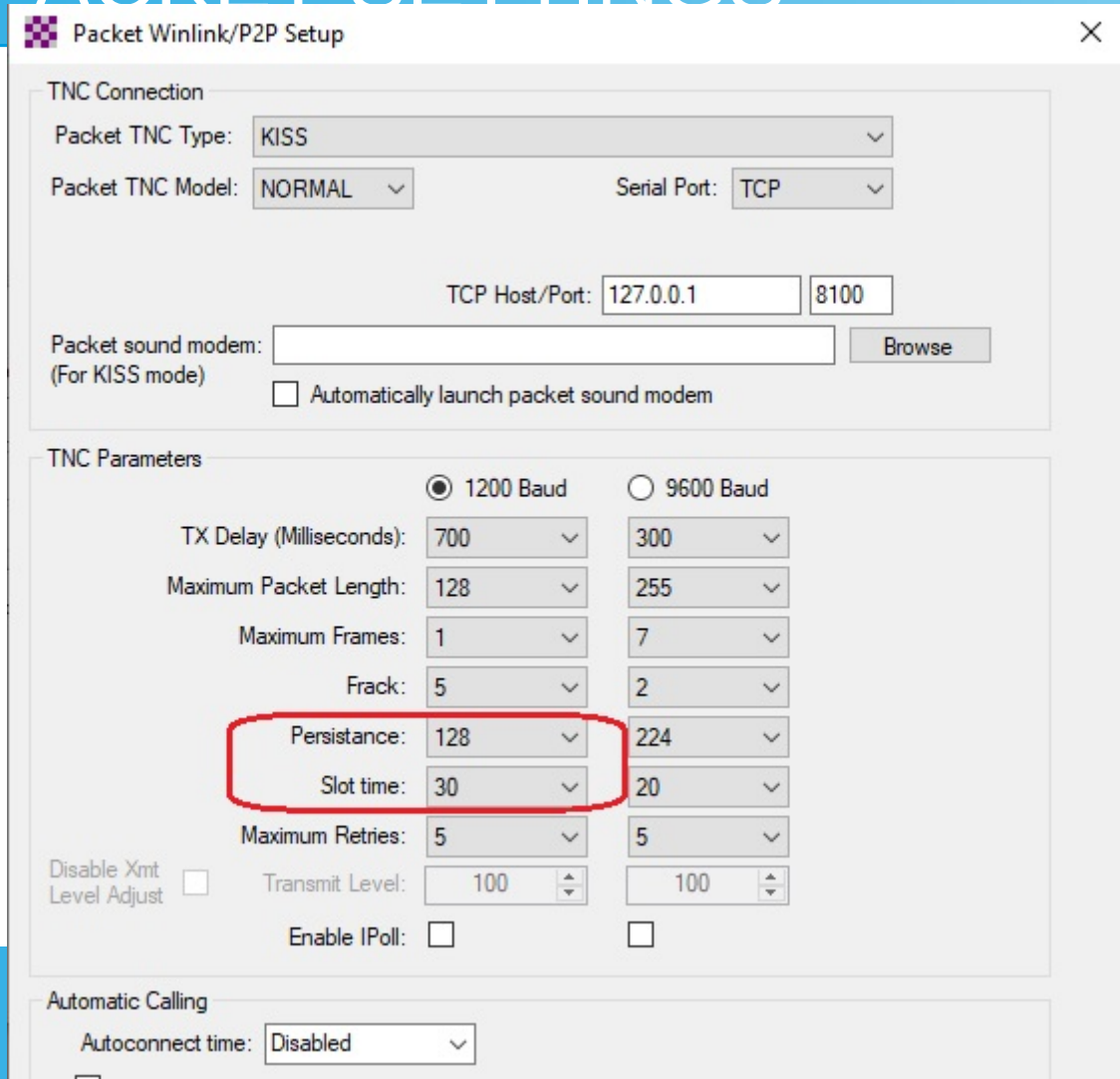
Carrier Sense Multiple Access (CSMA)

- Listen before transmit: P – Persistence (Timer T102)
- P = 0 to 1.0 Probability but scaled to 0 – 255 for 8bit counter
- AX.25 stations LISTEN before transmitting a frame.
- If the channel is EMPTY, they transmit
- If the channel is BUSY, they wait [see later for details]
- Then with probability P, they TRANSMIT (literally create a random number 0-255 and compare to the Stored choice of P-Persistence.
- If you choose a P-Persistence of 192, 224 etc – you are “PUSHY”

- Logically with probability = (1-P) they chose to WAIT.
- They wait a time = “SLOT-TIME” x 10 msec. SLOT-TIME in WINLINK Packet setup can be anywhere from 10 (100 mSec) to 100 (1 second). 20 = 200 mSec is typical.
- Optimal “persistance” (pushy-ness) and SLOT-TIME depend on the usage of your particular channel….

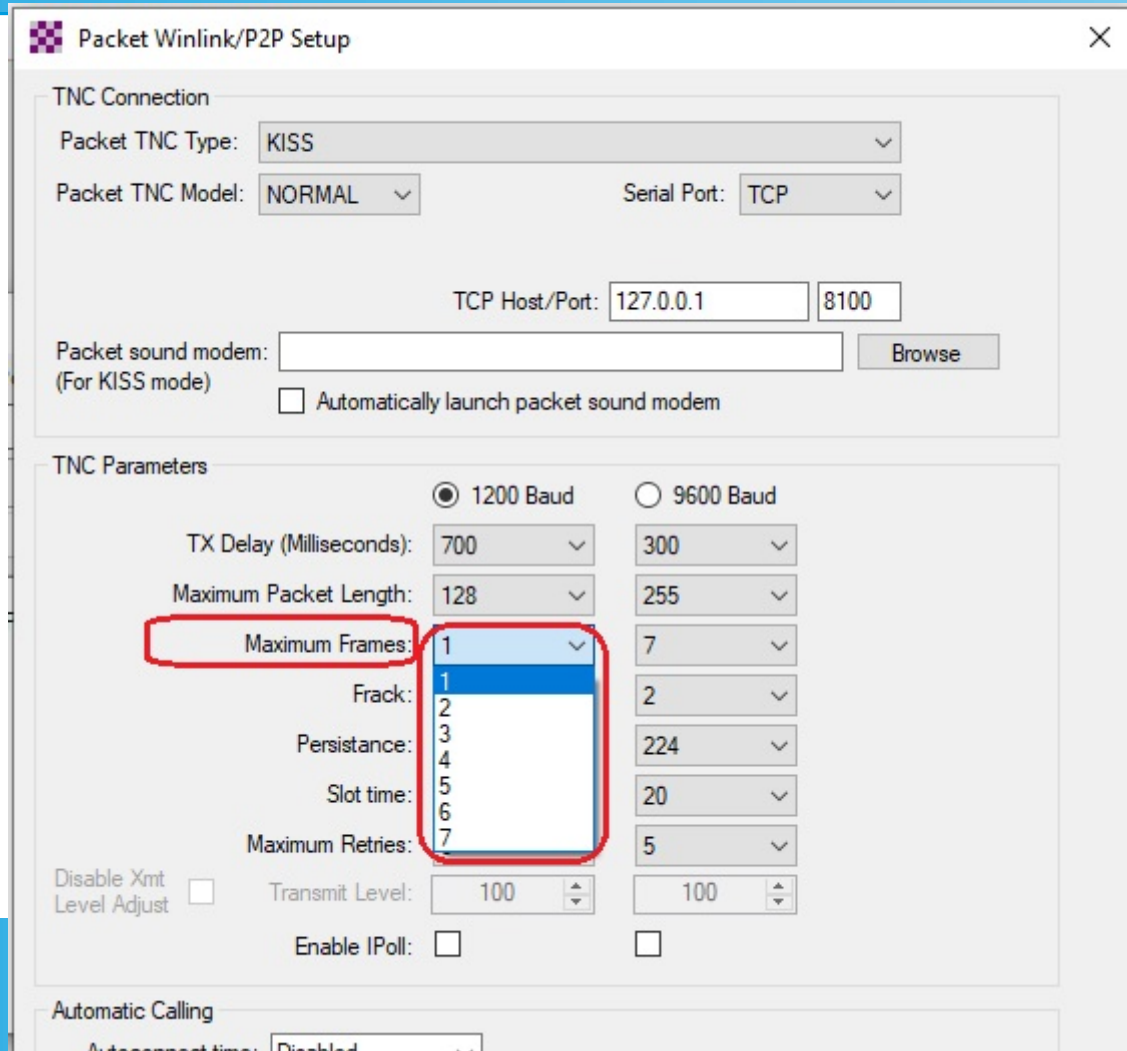
Set in WINLINK PACKET SETTINGS

- P-Persist = 128 = 50% chance of transmitting on empty channel
- SLOT TIME = 20 = if not transmit, wait 0.2 seconds before considering it again.
-
- REF: https://www.ax25.net/kiss.aspx



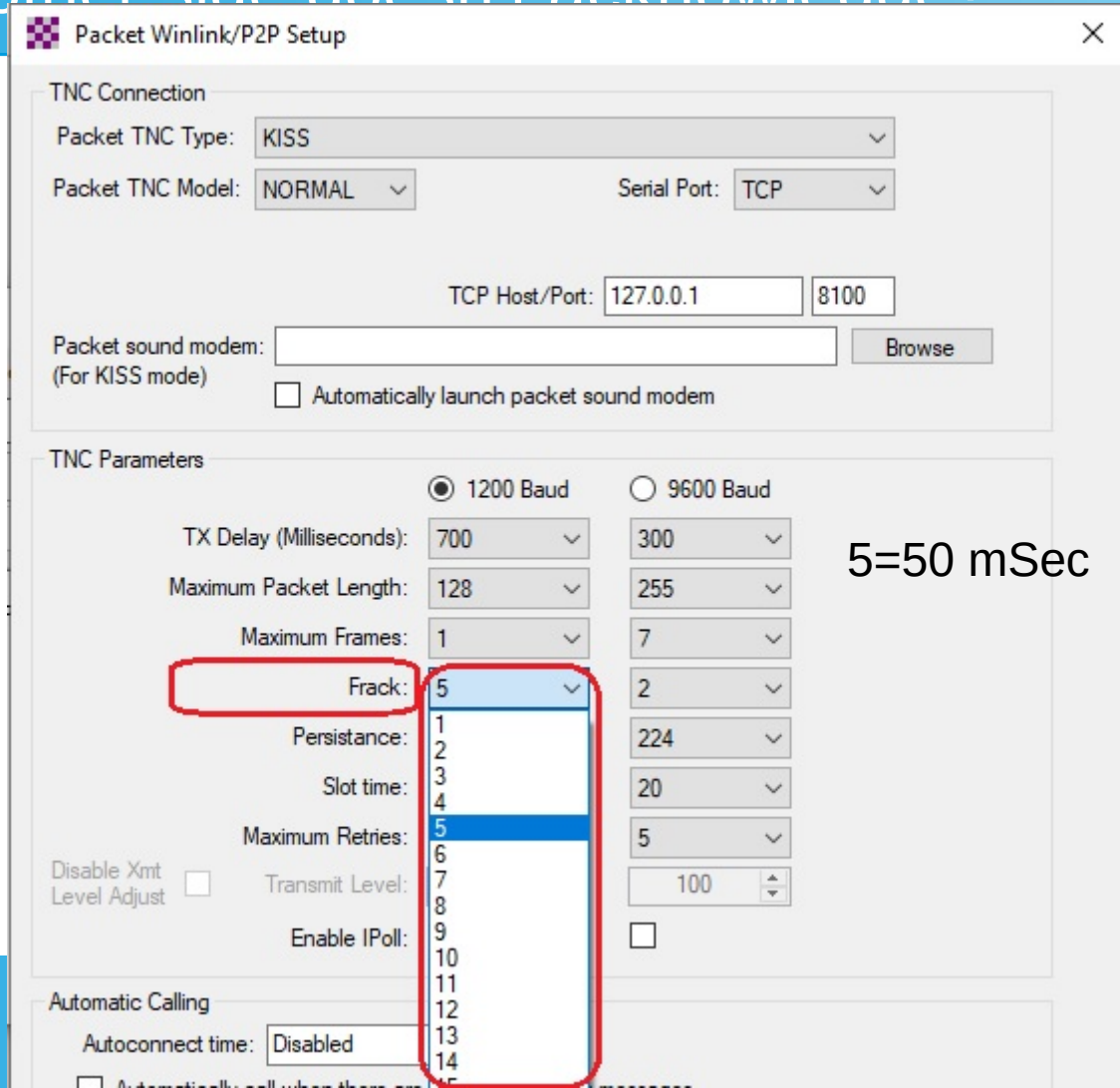
When cleared to Transmit

- You can set how many frames get sent – sending many frames is being optimistic
- Max frames possible is 7 because the numbering system rolls over….



How long do you wait if the other side doesn't acknowledge?

- FRACK: FailuRe to Acknowledge… the other guy went dormant…
- Kinda depends on how busy your channel is.
- Once you've waited them out, you start resending stuff if it wasn't acknowledged.



VARA

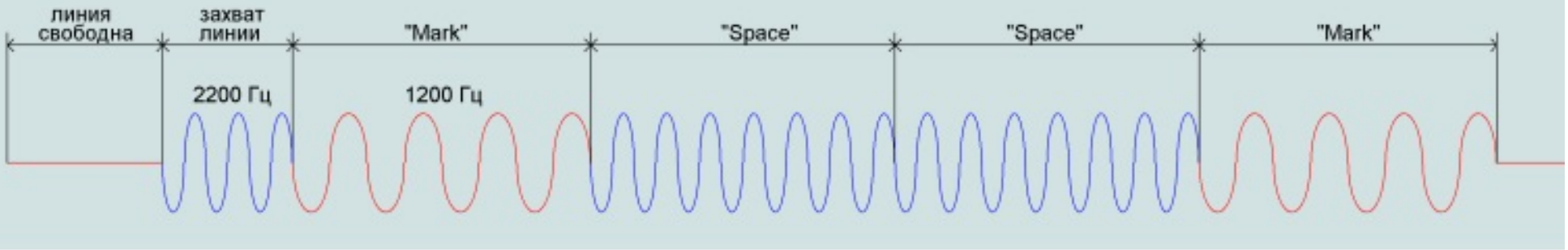
- Designed for single-connection channels (2 stations connected)
- Apparently no “listen before transmit”
  - Hence, no P-Persistence
  - No Slot Time
- 3rd user will cause havoc [Requires cooperation!]
- TXDelay set AUTOMATICALLY. (Huge benefit)
- Suspect 1 Frame at a time (then acknolwedge ACK or NACK)
- Unkown FRACK time (repeat if no acknowledgement)
-

2021 – digipeating added

- Digipeating added (HUGE improvement) – *don't know* if errors are fixed at each node or require transmit across entire system
- OFDM – enormously FAST!
-

Bell 202 Modem: 1200/2200 Hz (center 1700)

Figure 1 A binary sequence of 1001 modulated by FSK



REF: http://www.softelectro.ru/bell202_en.html

- BELL 202 MODEM Detection: simple frequency discriminator.
- Not difficult to do with 1970’s hardware.
- Lots of tedious detail about “non return to zero” / “Inverted” – have to do with how it represents 1’s and 0’s
- AX.25 normally uses a NRZI technique that seems weird and not that important to us to know about.

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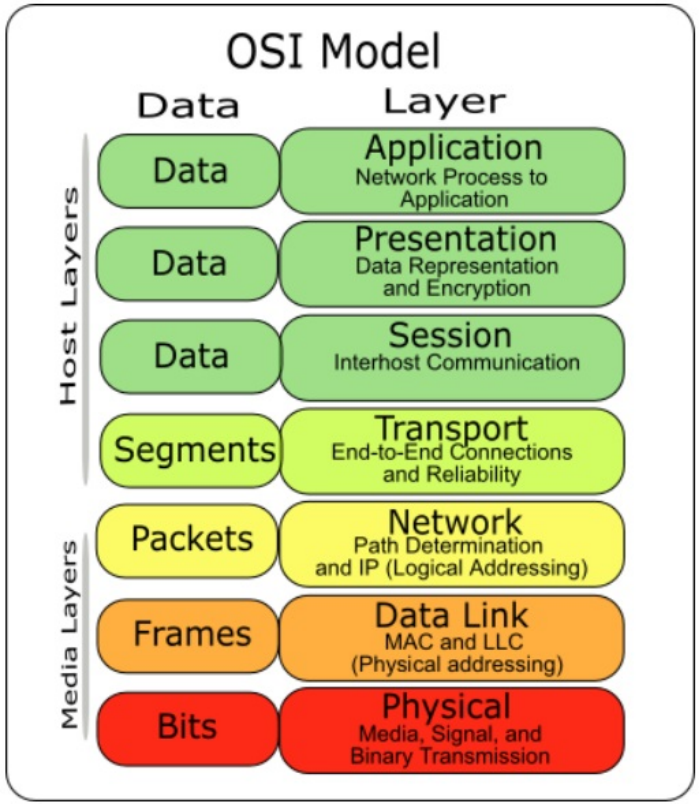

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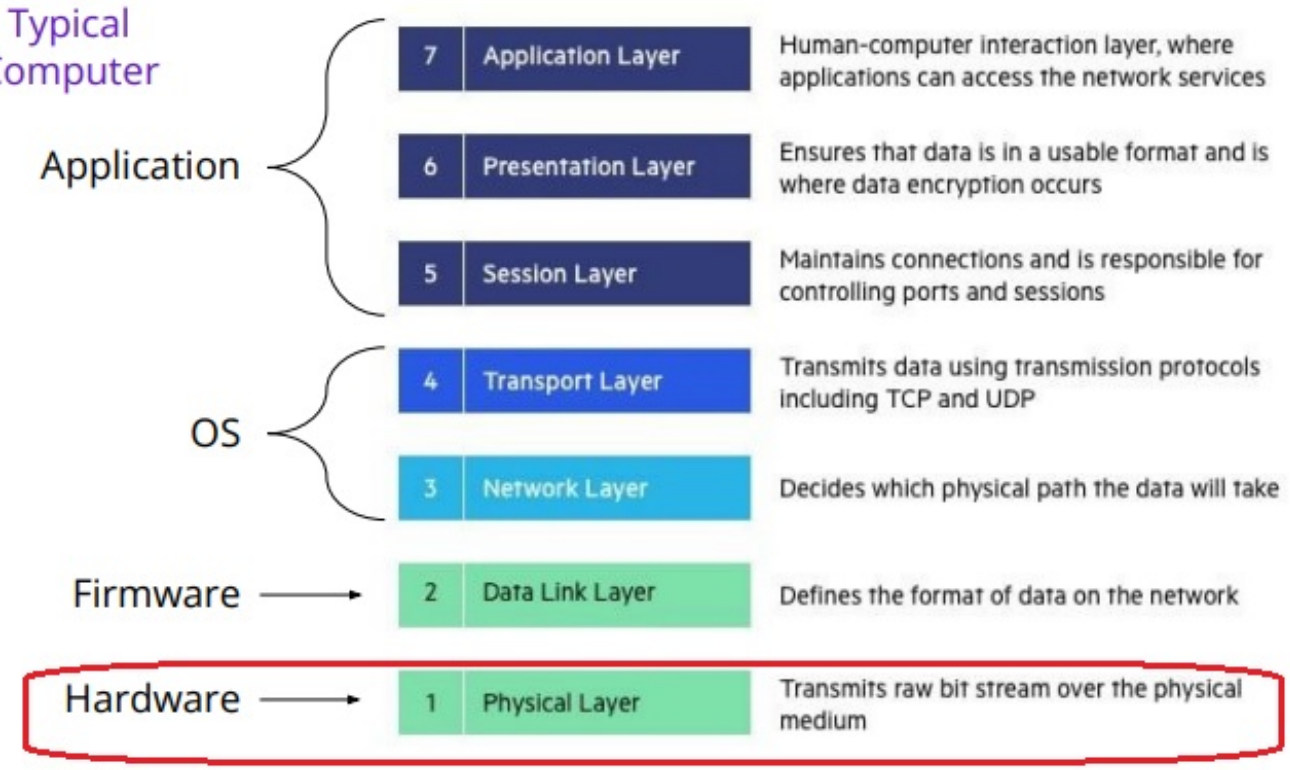
AX.25 preceded this way of layering network protocols.

Early documentation didn't conform to this way of describing. So AX.25 is mostly the bottom two layers, but maybe some of Network? Includes some path determination – subject for Part 2.

VARA seems to be even more just the bottom two layers: the PATH is specified by the users.

OSI 7-layer model



Word processors / Winlink

https://

Port numbers

UDP; TCP;

?Mac Number

Packets / checksums etc

Voltages, tones, carriers

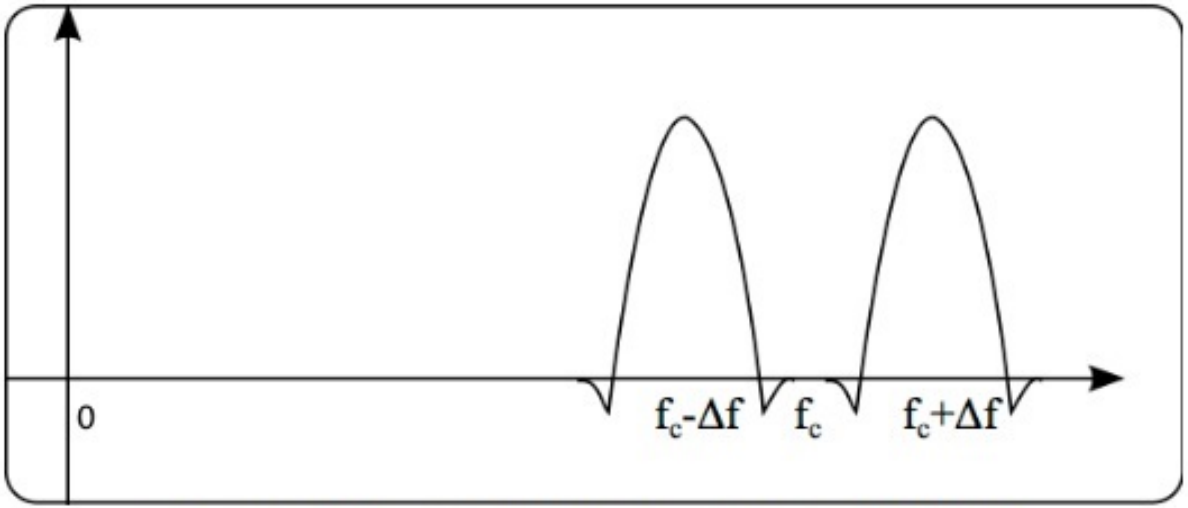
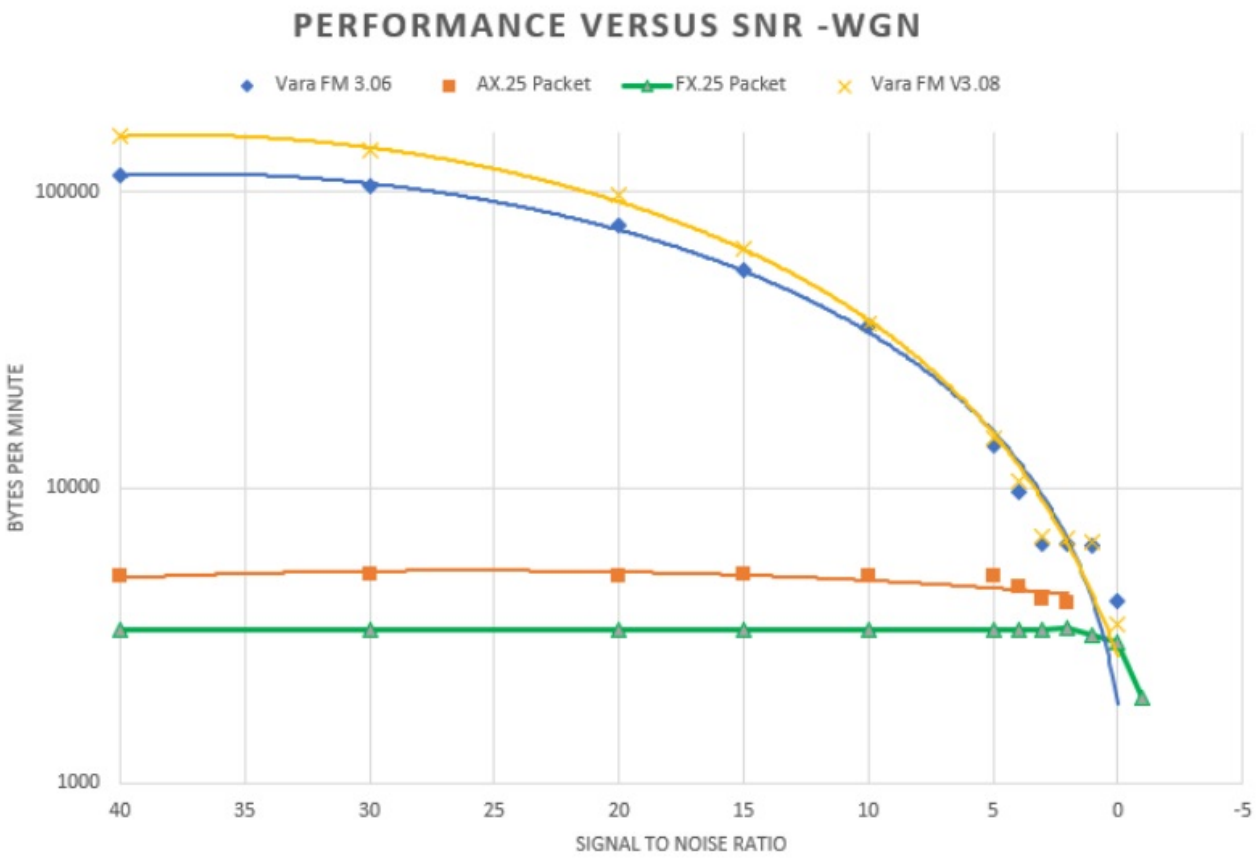


Figure 1: Approximate spectrum of AFSK

~ee123/sp17/lab/lab5/Lab5_Part_2-Audio_Frequency_Shift_Keying(AFSK).html

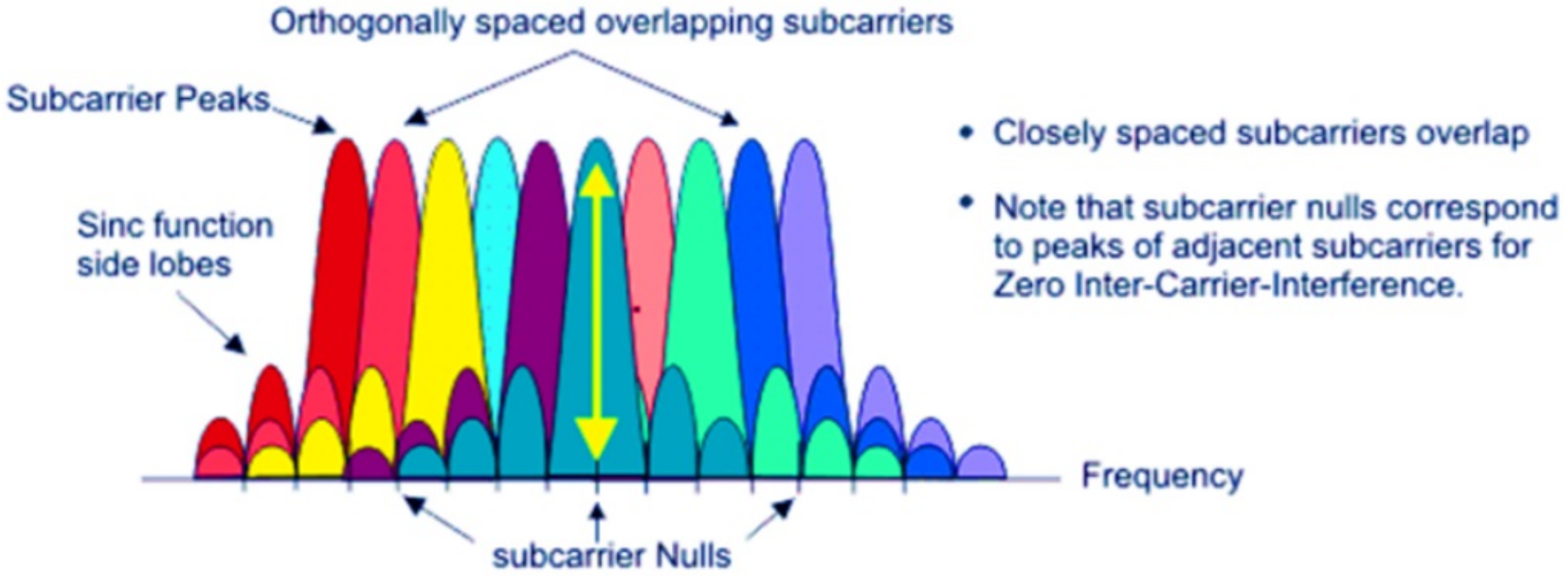
AX.25 vs VARA Performance



Research by Tom Whiteside N5TW (big winlink official)
https://winlink.org/sites/default/files/a_winlink_digital_mode_performance_comparison_based_on_the_ionis_sim_hf_vhf_channel_simulator_-_july_5_2020_0.pdf

This is FM. Note that we don't get much performance BELOW 0dB SNR
(We're already using the entire bandpass.)

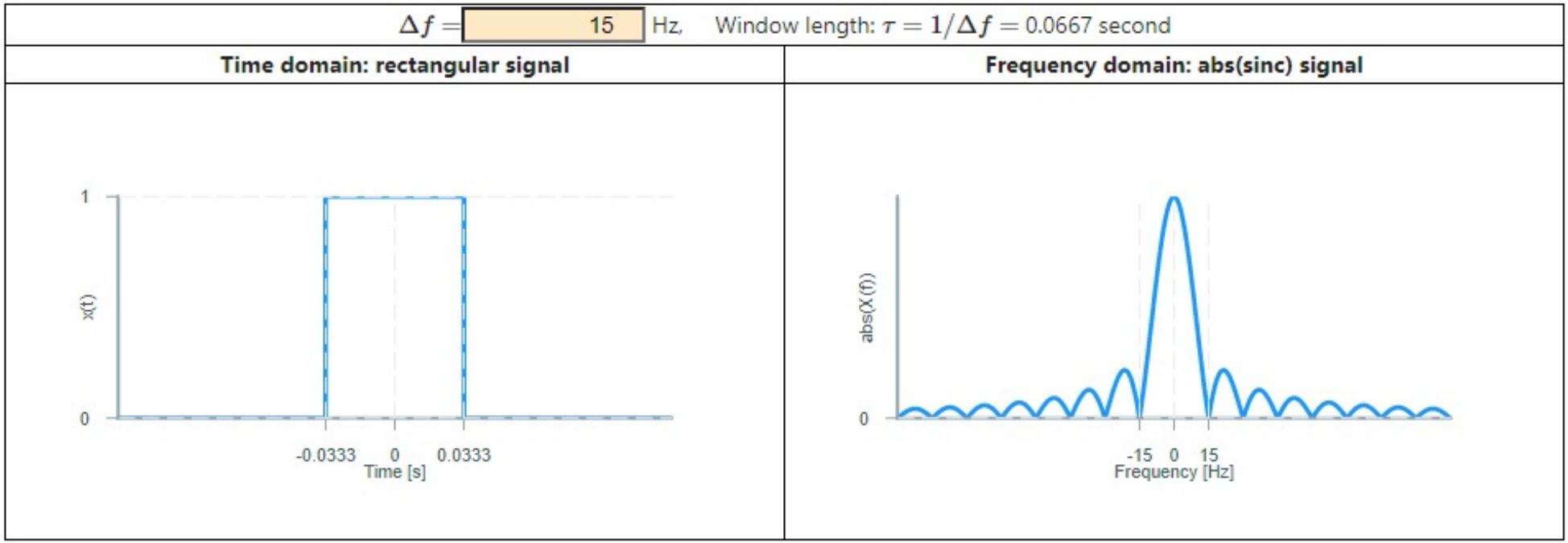
Orthogonal Frequency Division Multiplexing (OFDM)



REF: https://rosmodem.wordpress.com/2017/09/03/vara-hf-modem/

Clever choices of subcarrier audio tones

$\Delta f =$ 15 Hz, Window length: $\tau = 1/\Delta f = 0.0667$ second



On a single “subcarrier” audio tone, sending that audio tone for a small slice of time [symbol rate] (a rectangle in the time domain) causes it to have “sidelobes” that look like the right hand graph – a sinx/x type (sinc) function. That subcarrier has a strong point, and many NULLS. We position the surrounding audio frequency subcarriers cleverly at the NULLS of their brethren.

VARA FM v4.0.0
Speed Levels

	VARA FM WIDE				VARA FM NARROW			
Level	Symbol Rate	Carriers	Mod.	Net Rate (bps)	Symbol Rate	Carriers	Mod.	Net Rate (bps)
1	42	14	4PSK	566	42	14	4PSK	549
2	42	29	4PSK	1188	42	29	4PSK	1181
3	42	58	4PSK	2390	42	58	4PSK	2390
4	42	98	4PSK	4040	42	58	4PSK	3188
5	42	98	4PSK	5387	42	58	8QAM	4252
6	42	98	8QAM	7185	42	58	16QAM	5668
7	42	98	16QAM	9580	42	58	32QAM	7087
8	42	116	16QAM	11340	42	58	64QAM	8505
9	42	116	32QAM	14144	42	58	64QAM	9567
10	42	116	64QAM	16932	42	58	128QAM	11162
11	42	116	64QAM	19003	42	58	256QAM	12750
12	42	116	128QAM	22102				
13	42	116	256QAM	25210				

VARA FM NARROW			
Symbol Rate	Carriers	Mod.	Net Rate (bps)
42	14	4PSK	549
42	29	4PSK	1181
42	58	4PSK	2390
42	58	4PSK	3188
42	58	8QAM	4252
42	58	16QAM	5668
42	58	32QAM	7087
42	58	64QAM	8505
42	58	64QAM	9567
42	58	128QAM	11162
42	58	256QAM	12750

4PSK = phase shift keying, 4 different phases (90, 180, 270 0)

QAM = combination of both Phase Shifts + Amplitude Changes. Uses I & Q signals (90 degrees out of phase) and adds various amounts of each.

256QAM has 256 possible (8bit) transmissions, in this case done 42 times per second, on each of 58 carriers.

8 bits x 42/second x 58 carriers = raw data rate = 19488 bits per SECOND
(similar waveforms used on cell phones, cable)

Some Summaries of Part 1

- Different protocols for different use models.
- Ax.25 developed during limited hardware/software.
- Made to work with simultaneous stations
- Not yet discussed: AX.25 can do BROADCAST 1:many with Unnumbered Packets. (Run nets)
- VARA developed with far more hardware / software power
- VARA only two stations can use it at a time.
- VARA much faster!