

Amateur Radio Service Technician Class

Exam Preparation Class
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Session 2
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These slides are uploaded to my website

<https://k7ojl.com/class-course-materials/technician-class-materials/>

just before class each week.

Depending on how the class goes, they may get updated after the class.

Class Overview

- Questions?
- Quick Review
- Nets and Net Operations
- Propagation
- Antennas and Feed lines
- Let's Go to Space
- Digital Communications
- Modes



A Quick Review

What We Talked About Last Week

- Amateur Radio Service
- Control Operator
- 3rd Party Communications
- Call Signs
- The Exam
- Amateur Bands and Tech Privileges
- Frequency vs Wavelength
- Maidenhead Grid Squares
- ARES and RACES

Amateur Radio Service: FCC, ITU, and IARU; license classes (Technician, General, Amateur Extra)

Control Operator: Station Licensee; Control Point; Automatic Control

Bands: CW frequencies, phone frequencies (only 10 meters on HF)

Repeaters: Split (reverse split); CTCSS

**Questions from Session 1?
Questions about Amateur Radio?**



Nets and Net Operations

What Is a Net?

- Most commonly three types of nets:
 - Traffic Net
 - Casual “birds of a feather” net
 - Emergency practice net
- Conducted on the air
 - Usually at a specific time
 - And on a specific repeater or frequency
- Managed by a Net Control Operator (NCS)
 - Stations check in and then only transmit when invited by the NCS



Message Handling

- Traffic nets relay formal messages from an originator to a destination, kind of like a telegram
 - Local nets collect new messages, deliver received messages
 - Regional nets relay messages to and from other regions and local nets
- The preamble (header) of the radiogram is used to track the message from initiation to reception.
- Note that these messages are third-party traffic

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A key characteristic of traffic handling is passing the message exactly and precisely

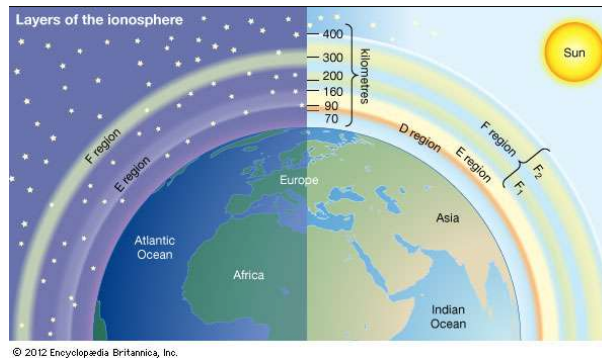
Local WDARC Net

- Held each Thursday evening at 9:00pm on the Tooele County Linked Repeater System
 - The Wendover repeater transmits on 147.200 MHz, positive offset, with a 100.0 Hz CTCSS tone
- Format of the net:
 - A preamble
 - Club officer checkins
 - Club member checkins
 - Any other checkins
 - Traffic handling
 - Postamble

Propagation

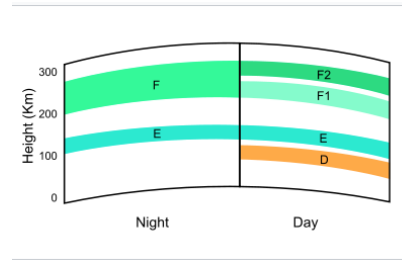
It All Depends on the Sun!

The Ionosphere



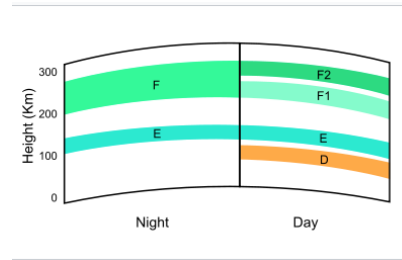
The 'D' Layer

- Appears during daytime
- Closest to the earth (35 to 55 miles above the earth surface)
- Many more neutral molecules rather than ionized molecules
- Significantly attenuates medium frequency and high frequency (below 10 MHz) radio waves



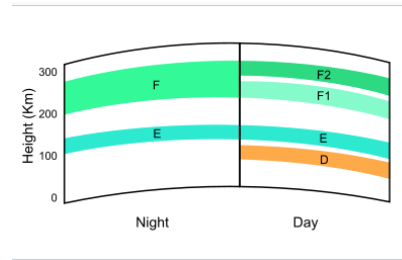
The 'E' Layer

- Appears during daytime
- Middle ionospheric layer (55 to 95 miles)
- Significant amounts of ionized oxygen molecules
- Reflects radio frequencies below 10 MHz and may attenuate higher frequencies
- Occasionally sporadic E events occur where frequencies up to 50 MHz are reflected



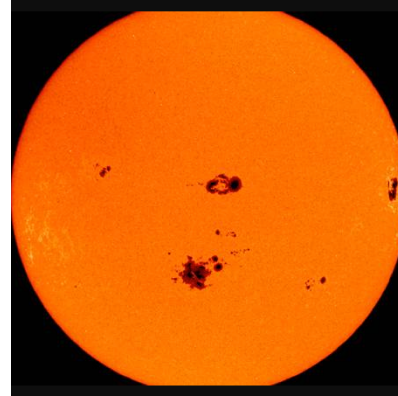
The 'F' Layers

- Splits into the F1 / F2 layers during daytime
- Combines into one F layer during the night
- Highest ionospheric layer (90 to 130 miles)
- Responsible for almost all of the high frequency (above 10 MHz) skywave propagation



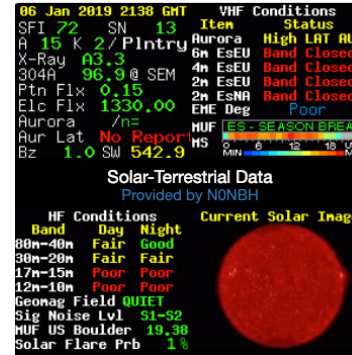
Sunspots Play a Significant Role in Propagation

- Sunspots are dark regions on the face of the sun caused by magnetic field concentrations
- Sunspots emit considerable magnetic and photon activity which is what ionizes the ionosphere
- Sunspots ebb and flow in 11 year cycles. We are currently at a sunspot minimum between cycle 24 and cycle 25
- The Solar Flux Index indicates how ionized the ionosphere is. An index of 70 or less indicates very poor conditions. On the date this slide was prepared, the solar flux was 72



Propagation Forecast

- Propagation forecasts such as the one on the right are commonly available on the Internet
- Notice that on this date there were no sunspots while there was a bright spot sending solar wind degrading propagation
- See <http://qrz.com/>



Propagation Factoids

- VHF and UHF frequencies are generally not affected by the ionosphere, meaning they travel in a straight line forever without being reflected back to the earth
- VHF and UHF radio waves are affected by vegetation — trees and such. In winter these radio waves travel further due to lack of foliage
- VHF radio waves in vertical orientation tend to “bend” over hills or tall buildings. This is called knife-edge diffraction.
- Occasionally (usually in summer) temperature layers may occur opening tropospheric “ducts” which can carry VHF radio waves very long distances of 300 miles or so
- Frequencies below 220 MHz are generally unaffected by fog or rain. Microwave radio waves can be significantly affected by rain and water vapor in the air

More Factoids

- While VHF and higher frequencies are not reflected by the ionosphere, they can be reflected by meteors, aurora, airplanes, and the moon
 - Six and two meter waves reflect off auroras giving a fluttery distorted signal, a characteristic of aurora scatter
 - Six meter frequencies work best with meteor scatter
- The ten meter band is an amazing band during periods of high sunspot activity with very long distance propagation possible from just before sunrise until shortly after sunset. Note that Technicians have phone (SSB) privileges on portions of the ten meter band!
- Sporadic E propagation, mentioned earlier, occasionally occurs during late spring and summer on the 10, 6, and 2 meter bands where propagation of thousands of miles is possible

Space Weather Woman

- Dr. Tamitha Skov
- Produces a weekly propagation forecast published on YouTube
- <https://www.youtube.com/channel/UCkXjdDQ-db0xz8f4PKgKsag>



Important Items

- Technicians have HF phone privileges only on 10 meters
- HF has the advantage over VHF and higher frequencies of long-distance skywave propagation
- Technicians have HF RTTY (teletype) privileges on 10 meters
- The best time for long-distance 10 meter band propagation via the F layer is from dawn to shortly after sunset during periods of high sunspot activity
- “Beacons” are deployed by other amateurs around the world to help identify when communications between two points might be possible and to perform similar experimental activities

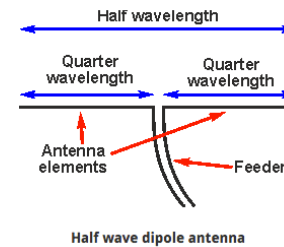
Antennas and Feed Lines

Antenna Polarization

- Antenna polarization is important at VHF and higher frequencies.
 - The position of the antenna determines the electrical polarization: vertical, horizontal, or circular
 - A signal from a horizontally polarized antenna will be significantly attenuated by a vertical receiving antenna
 - VHF and UHF FM radios are standardized around vertical polarization (including repeaters), so how you hold your HT makes a difference
 - VHF and higher SSB and Digital modes are generally horizontally polarized
- HF frequencies are usually unaffected by polarization and the ionosphere often reverses the polarization anyway

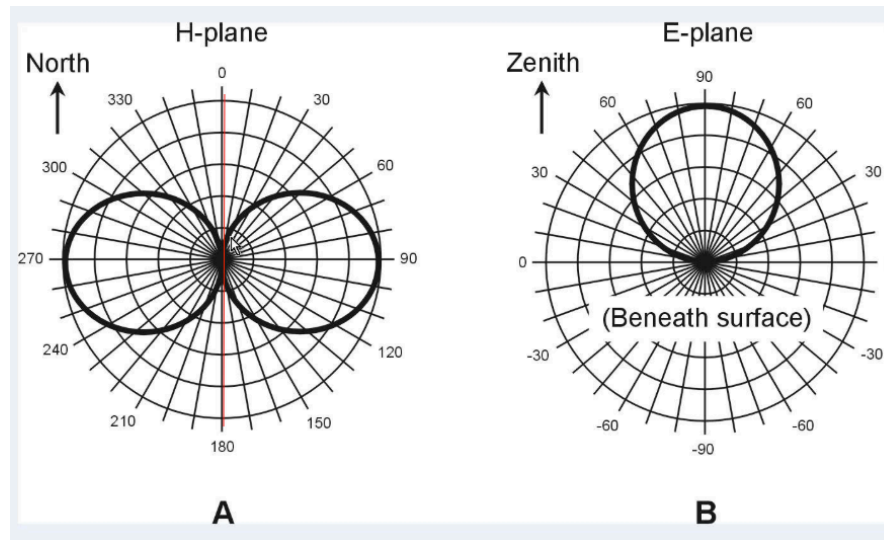
Dipole Antennas

- Most common type of antenna
- Radiates well broadside to the antenna
- Length of the antenna wire determines the resonant frequency
 - Shorten to go higher
 - Lengthen to go lower
- Height above ground affects the radiation angle
 - Works best $\frac{1}{2}$ wavelength or more above ground



Takeoff angle

Dipole Radiation Pattern



How Long Should A Dipole Be?

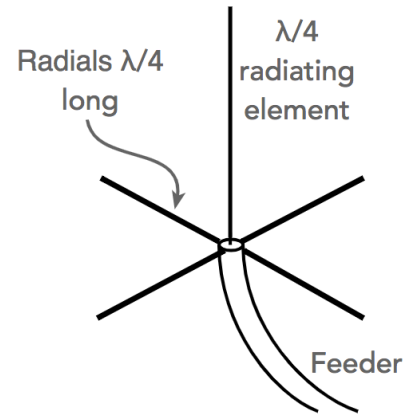
- Length in feet = $468 / \text{frequency in MHz}$
 - Remember the formula to convert wavelength into frequency
- A 6 meter half-wave dipole?
 - 6 meters = 50 MHz ($300/6$)
 - length = $468 / 50 = 9.36$ feet = 112.3 inches

How to remember the formula? Think 2-4-6-8 ... Who do we appreciate?

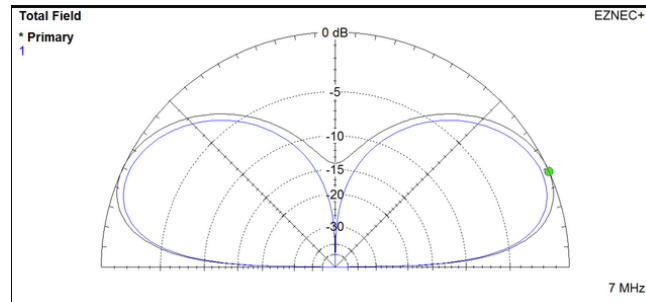
This is the 2nd of four formulas needed for the Technician Exam.

Vertical Antennas

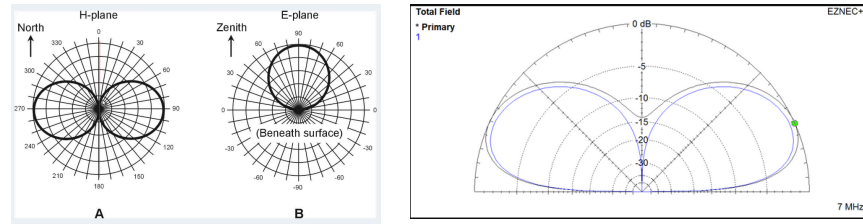
- Vertical antennas have a vertical element ($\lambda/4$ wavelength) and several radials, also $\lambda/4$ wavelength, along the ground
- They have a very low takeoff angle (good for distant contacts)
- More susceptible to noise than horizontal dipoles



Vertical Antenna Radiation Pattern



Horizontal vs Vertical Antennas



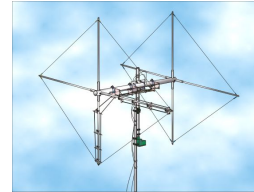
Vertical antenna has a lower take-off angle

Vertical antenna has no “lobes”

Vertical antenna has less radiation on the broadside (evenly distributed)

Directional Antennas

- Yagi, Quad, and Dish are all types of directional antennas
- Directional means that the radiation pattern is more focused than a dipole or a vertical antenna
- Directional antennas have more “gain” and a higher “front to back ratio”

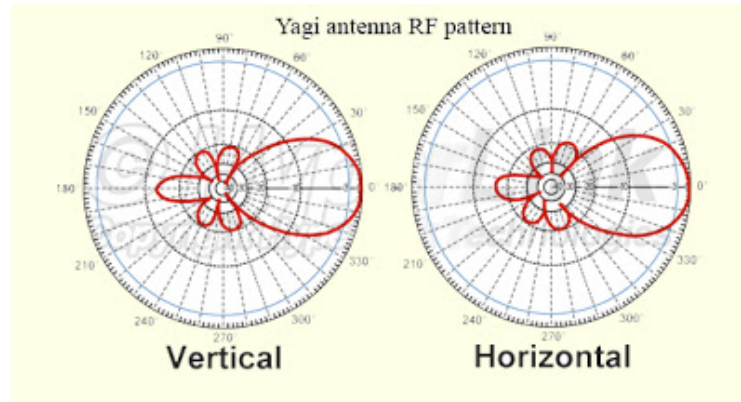


Gain: a process of taking RF energy and focusing it in an intended direction. An antenna cannot “amplify” a signal, it can only “shape” a signal thus focusing the radiation

Front to Back Ratio: The relative signal strength at the front of the antenna vs the relative signal strength at the back of the antenna

Directional antennas are very useful for radio direction finding

Yagi Antenna Radiation Patten

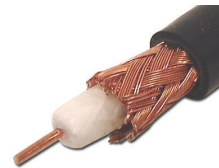
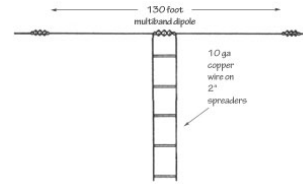


To focus the beam in the vertical: add elements to the beam

To focus the beam in the horizontal: stack another yagi

Feed Lines

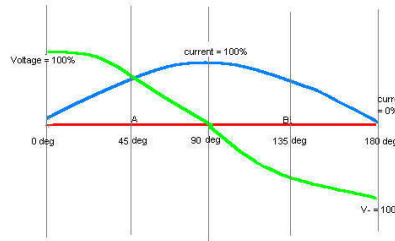
- Two main types: ladder line (aka window line) and coax
- Coax is used most often because of ease of use and no stand-off need
- Ladder line has the lowest loss
- Each type of feed line has differing characteristic impedance



The antenna connector on the back of the transmitter / receiver expects to see an impedance (resistance) of 50 ohms
Coax generally has either 50 ohms or 75 ohms of impedance (50 ohms ... amateur; 75 ohms ... TV)

Antenna Impedance

- The impedance at the feed point varies across the length of the antenna
- If the impedance of the antenna at the feed point varies much from the impedance of the feed line, some of the energy is reflected back towards the transmitter rather than going into the antenna
- If the mismatch is greater than 3:1 (150 ohms at the feed point from 50 ohm coax), then the transmitter may “fold back” the power to reduce chance of damage to the final amplifier



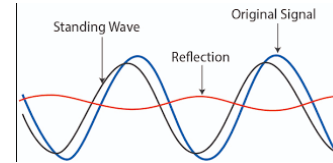
The method to address the mismatch is to insert a “transmatch” (short for transformer match) between the feed line and the antenna

Alternatively, a transmatch is often inserted between the transmitter and the feed line to be sure that the transmitter always sees 50 ohms regardless of the mismatch

Another name for the trans match is an “antenna tuner” ... which doesn’t tune anything

Standing Waves

- The amount of power reflected back to the transmitter varies with the mismatch
- The returning wave combines with the transmitted wave to cause a “standing wave” on the feed line. The ratio between the transmitted wave and the reflected wave is called the “Standing Wave Ratio”
- Eventually the energy not getting into the antenna goes up in heat in the coax. The greater the SWR, the more heat



Antenna / Feed Line

Factoids

- A $5/8$ wave vertical antenna has higher gain and a “squashed” signal pattern vs a $1/4$ wave antenna
 - Often used for mobile antennas
- Inductance coils are used to electrically lengthen shorter antennas. These coils are often located in the center of the vertical antenna
- All feed lines have loss. The longer the feed line, the more loss. Coax has significantly more loss than window line but is easier to use
 - The difference between RG-8 and RG-58 is the latter has more loss than the former
- Coax must be protected against moisture incursion. The copper braid will disintegrate
- Air-insulated hardline: lowest loss, hardest to use, install, and maintain

Coax Cable Loss per 100 Feet

Coax Type	Size	Loss at HF 100 MHz	Loss at UHF 400 MHz
RG-58U	Small	61% (39 W)	90% (10 W)
RG-8X	Medium	66% (34 W)	61% (39 W)
RG-8U	Large	20% (80 W)	48% (52 W)
RG-213	Large	20% (80 W)	40% (60 W)
Hardline	Large, Rigid	6% (94 W)	16% (84 W)

If the transmitter output were 100 Watts, the amount that reaches the antenna is in parentheses. For example using RG-8X, 100 watts in at 100 MHz would result in 34 watts getting to the antenna.

A Few More Factoids

- An antenna analyzer can be used to measure the SWR of an antenna system
- A perfect impedance match (1:1) is achievable (??). A match of 1.5:1 and lower is considered a good match. Higher than 3:1 is a problematic match and likely will cause the transmitter to “fold back”
- Loose connections (at the transmitter, the trans match, or the feed point) will cause erratic SWR readings
 - Deteriorating coax due to water damage will also exhibit strange SWR readings
- A “dummy load” is very useful when testing a radio but don’t want anything to be transmitted
 - A dummy load is simply a set of resistors giving an impedance of 50 ohms to the transmitter but sized large enough to handle the heat produced as the resistors use up the transmitted energy

Analyzer Demo

- Device transmits a low-power signal at the designated frequency
- Device then measures the reflected power and calculates the SWR and impedance
- Device has several other functions available, including testing coax cable, determine coax velocity factor, and more



Let's Go to Space!

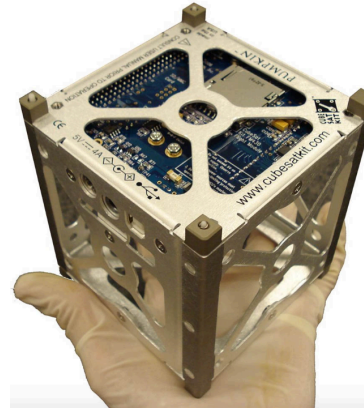
Many Amateur Radio Satellites Are Waiting for You

- A “space station” is any amateur station located 50km above the earth’s surface
 - Most amateur satellites are in low earth orbit (LEO)
- In order to talk with or through a “space station” you need to know the satellite’s real position, azimuth, elevation from start to finish of the pass, frequencies to use
 - The “Keplerian Elements” are the critical time, azimuth, and elevation data needed to compute the satellite’s position



Satellites Continued

- Most amateur satellites have a beacon: continuous faint transmission that carries digitized telemetry about the health and status of the satellite itself
 - Anyone can receive and decode the telemetry. Once a radio signal has been transmitted it becomes public domain
- Almost all transmission modes are used, CW, Data, SSB, FM with FM being the most popular with Technicians
- Satellites usually are spinning to reduce overheating of the solar panels. The spin may cause signals to fade in and out
- As the satellite passes the frequency will change ... Doppler Shift
- It is important to use the lowest power setting needed to successfully complete the transmission to or through the satellite
 - Too high power will block other users or saturate the signal to make it unintelligible
 - Your signal strength on the uplink should match the signal strength on the downlink



And Finally, Space Stations Modes

Most amateur radio satellites operate as “repeaters” ... receiving a signal on one frequency and transmitting it simultaneously on another.

Since there is limited space and power, the input frequency (uplink) is on one band and the output frequency (downlink) is on a different band

The “mode” of the satellite indicates where the uplink and downlink are located. For instance, Mode U/V means uplink on the 70cm band and downlink on the 2meter band

Band	Freq Range	Mode
HF	21-30 MHz	H
VHF	144-148 MHz	V
UHF	435-438 MHz	U
L band	1.26-1.27 GHz	L
S band	2.4-2.45 GHz	S
C band	5.8 GHz	C
X band	10.4 GHz	X
K band	24 GHz	K

A Satellite Contact Video

- https://www.youtube.com/watch?v=XCdvCbjK_zo&t=81s



SO-50

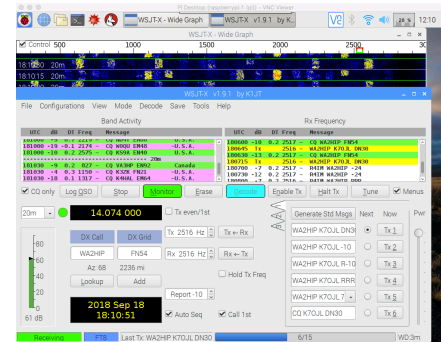
Digital Communications

- The original digital mode is CW (international morse code)
 - CW frequencies are from 50.0-40.1 MHz (10 meter band) and 144.0-144.1 MHz (2 meter band)
 - Many hams use an electronic keyer when sending CW
- A computer is used to generate and decode many other digital modes
 - The computer's sound card is used to send audio to the radio's microphone input, generate the PTT signal, and converts audio from the radio's speaker output into digital form
 - The physical connection from the radio is to the computer's microphone or line input



New Digital Modes

- Digital modes include Packet Radio, IEEE 802.11, JT65, FT8, PSK (phase shift keying), and may more
- FT8 (pictured to the right) is one of the newest enabling communications in very low signal-to-noise conditions transmitting and receiving in 15-second windows
- Joe Taylor K1JT has developed a suit of low SNR applications used for moon bounce (EME), weak-signal propagation, meteor scatter, and others
- Some modes include check sums for error detection, automatic repeat requests in case of error, header records containing metadata about the transmission
- Multipath signals will seriously degrade reception and increase error rates



Automatic Packet Reporting System

- APRS is an application capable of providing real-time tactical digital communications together with a map showing the location of stations
 - Requires a GPS receiver to provide position information to the transmitting application
- Popular mobile text messaging application
- Many amateur weather stations use APRS to send their weather information to various weather data systems
- <https://aprs.fi/#!addr=salt%20lake%20city%20C%20ut>



Other RF Digital Modes

- Digital Mobile Radio (DMR)
 - Two “time multiplexed” conversations on a 12.5 kHz channel
 - Users connect to “talkgroups” which are conference rooms for like interests
 - Inexpensive cost to play
- D-Star
 - Developed in Japan, supported by ICOM, Kenwood, and Elecraft
 - Has very fast data transfer capability
- System Fusion
 - Developed by Yaesu and proprietary to Yaesu
 - Growing in popularity
- DMR, D-Star, and System Fusion are all incompatible with each other

Mesh Networking

- Commercial WIFI gear (part 90 equipment) repurposed to work on amateur frequencies (part 97)
- Several WIFI channels are within amateur radio bands
- Makes a self-healing, multi-path routing, high-speed data network
- Amateur Radio Emergency Data Network (ARDEN) is where the firmware and additional information is available

The screenshot shows the ARDEN VK2IUW-A mesh status page. It displays a table of local mesh nodes, remote nodes, current neighbors, and previous neighbors. The table includes columns for Node ID, Name, and Status. The local mesh section shows nodes like VK2IUW-A, VK2IUW-B, and VK2IUW-C. The remote nodes section shows nodes like VK2IUW-D, VK2IUW-E, and VK2IUW-F. The current neighbors section shows nodes like VK2IUW-G, VK2IUW-H, and VK2IUW-I. The previous neighbors section shows nodes like VK2IUW-J, VK2IUW-K, and VK2IUW-L.

Local Mesh	Remote Nodes	Current Neighbors	Previous Neighbors
VK2IUW-A	VK2IUW-D	VK2IUW-G	VK2IUW-J
VK2IUW-B	VK2IUW-E	VK2IUW-H	VK2IUW-K
VK2IUW-C	VK2IUW-F	VK2IUW-I	VK2IUW-L

Some Other Digital Mode Information

- PSK (phase shift keying) is a very popular keyboard to keyboard protocol as well as the ability to transfer files
- IRLP (internet radio linking project) is a technique to connect amateur radio systems, such as repeaters, using Voice Over Internet Protocol (VOIP). A popular IRLP repeater in our area is on 449.425(-) connected to the Western Reflector
 - DTMF (dual-tone multi-frequency) tones, similar to the touch tones on a phone) tones are used to connect and disconnect reflectors
- Echolink is another VOIP system. There are Echolink applications that can run on your laptop or smart phone. Registration is required before using Echolink (to prove you are a licensed amateur).
- There are online services, printed directories, and subscription services to find repeaters and VOIP services

And Finally, Amateur TV

- Slow scan tv as well as fast scan systems are available
 - Analog only at the moment. Hams are working on a non-patented digital codec
- NTSC is the standard for fast scan color analog signals
- Typically used on the 70cm band and higher frequencies.
- Fast scan tv has a bandwidth of about 6 MHz (that's why they're on the higher frequencies!)





