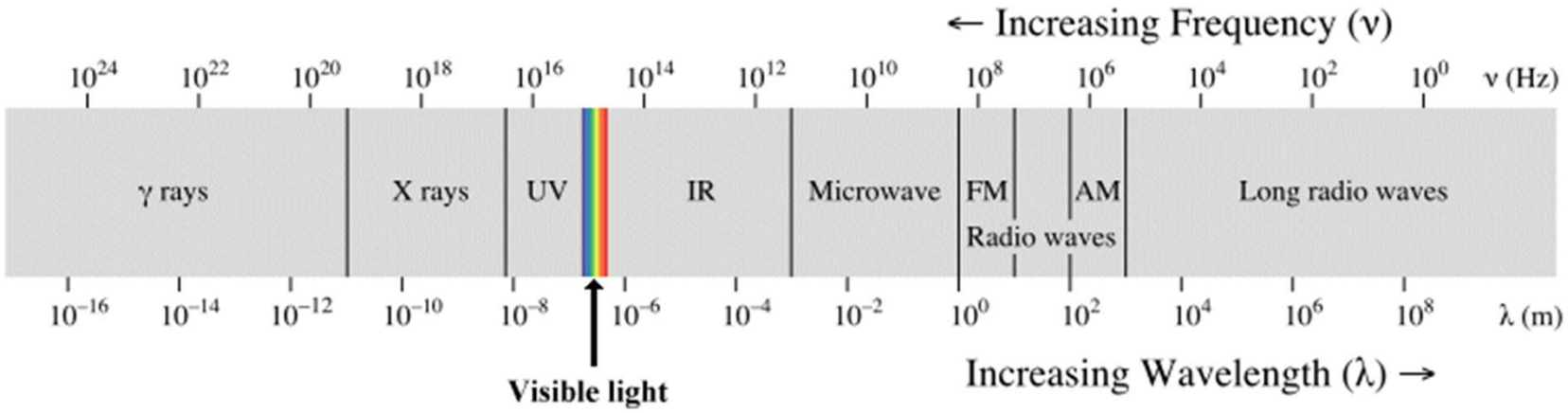
Getting Started & Having Fun on the Microwave Bands

Presented by:
Janice Hoettels, KA9VVQ
Bruce Richardson, W9FZ

What Are Microwaves?

"Microwave" is a term used to identify electromagnetic waves above 10^3 megahertz (1 Gigahertz) up to 300 Gigahertz because of the short physical wavelengths of these frequencies.



What Are the Microwaves Bands?

Amateur radio definition: 900 MHz (33 cm) and higher.

Frequency	Designation*	Amateur Band
902 MHz	9	33 cm
1.2 GHz	E	23 cm
2.3 GHz	F	13 cm
3.4 GHz	G	9 cm
5.7 GHz	H	6 cm
10 GHz	I	3 cm
24 GHz	J	1.2 cm
47 GHz	K	(mm wavelengths)
75 GHz	L	
119 GHz	M	
142 GHz	N	
241 GHz	O	
Light	P	

*Band designation for ARRL contests

Why Operate the Microwaves?

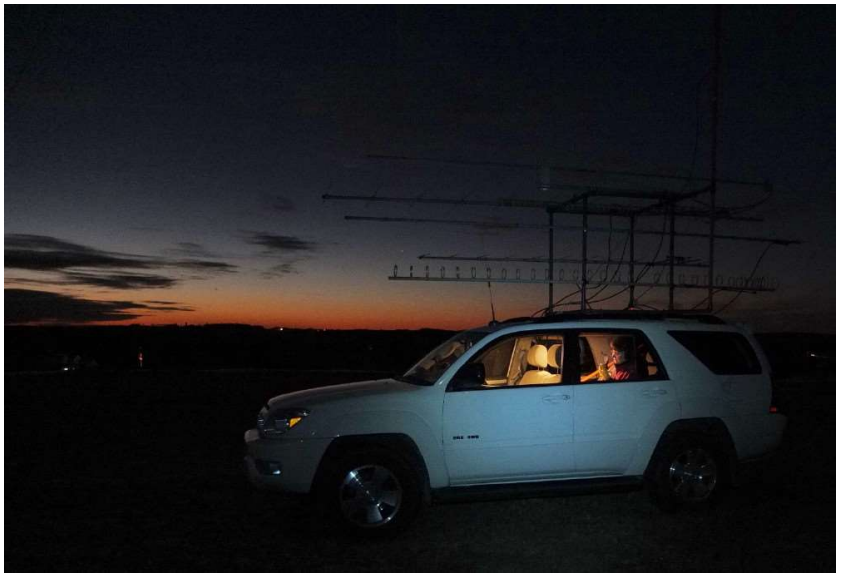
- Experiment with microwave technologies
- Learn about microwave signal propagation
- Set new records or trying new techniques in the field of microwaves
- Provides lots of opportunities for challenging operation
- Camaraderie—microwave operating attracts a great bunch of hams who will go out of their way to give you a hand!
- If you're a contester: extra points in VHF/UHF contests
- Because they're there!...If we don't use them, we'll lose them!

Comparison With VHF/UHF

- Little off-the-shelf equipment to operate the microwave bands directly
- Much weaker signals and narrow beamwidths require accurately pointed, high gain, highly directional antennas
- Higher feedline losses; need for better/different transmission line media
- Unique propagation
- Microwave DX requires locations with a clear path/horizon
- Microwave antennas are much smaller (very portable)

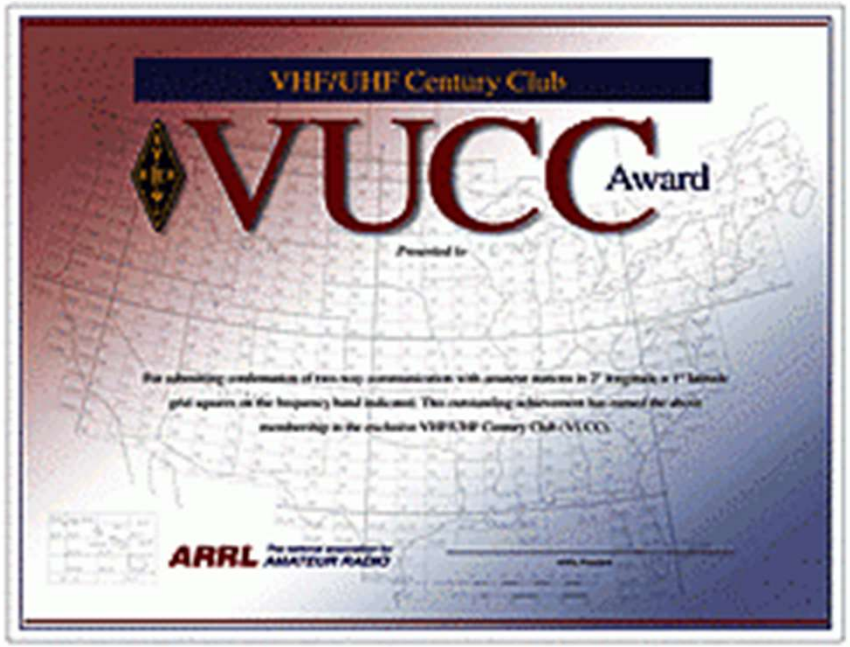
Common Microwave Activities

- ARRL contests
  - January VHF contest
  - June VHF contest
  - ARRL 222MHz and Up Distance Contest
  - September VHF contest
  - 10 GHz & up contest
- Other regional/local contests and sprints
  - CSVHFS Spring Sprints
  - SEVHFS Fall Sprints
- Activity days



Common Microwave Activities

- Award chasing
  - ARRL VUCC
    - 6m, 2m = 100 grids
    - 222 MHz, 432 MHz = 50 grids
    - 902 MHz, 1.2 GHz = 25 grids
    - 2.3 GHz = 10 grids
    - 3.4 GHz and above = 5 grids



Common Microwave Activities

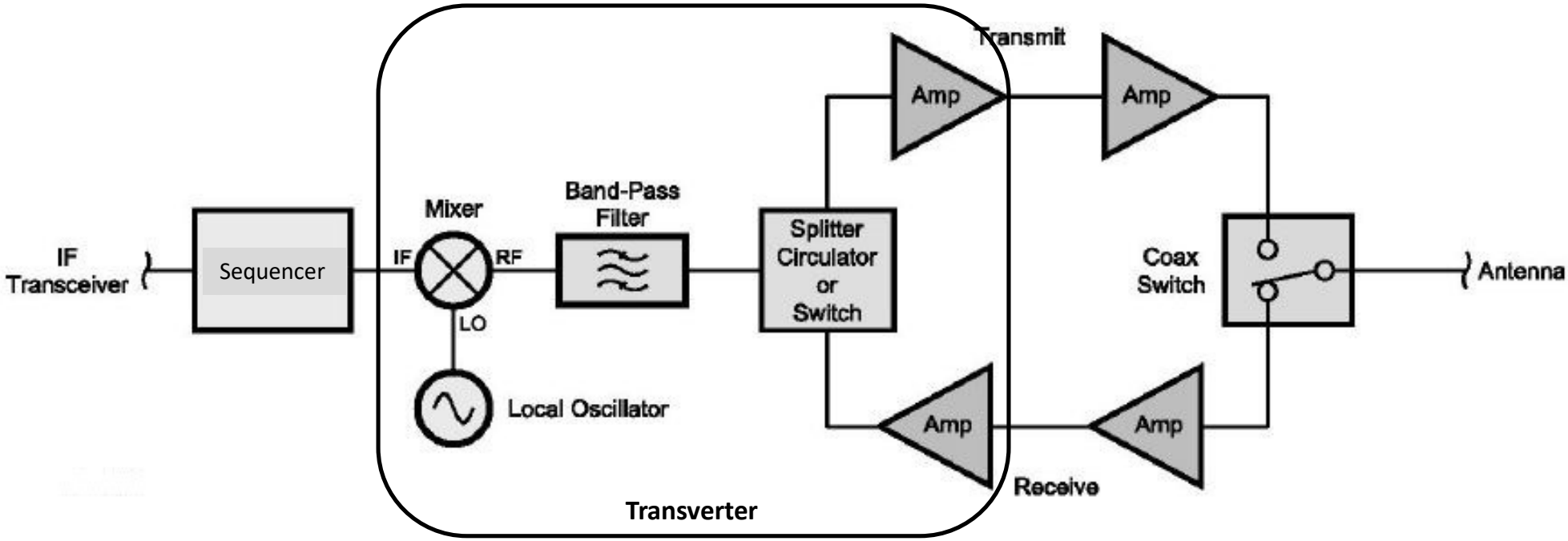
- Terrestrial weak signal DX
- EME (moonbounce)

Getting Started

Microwave Station Components

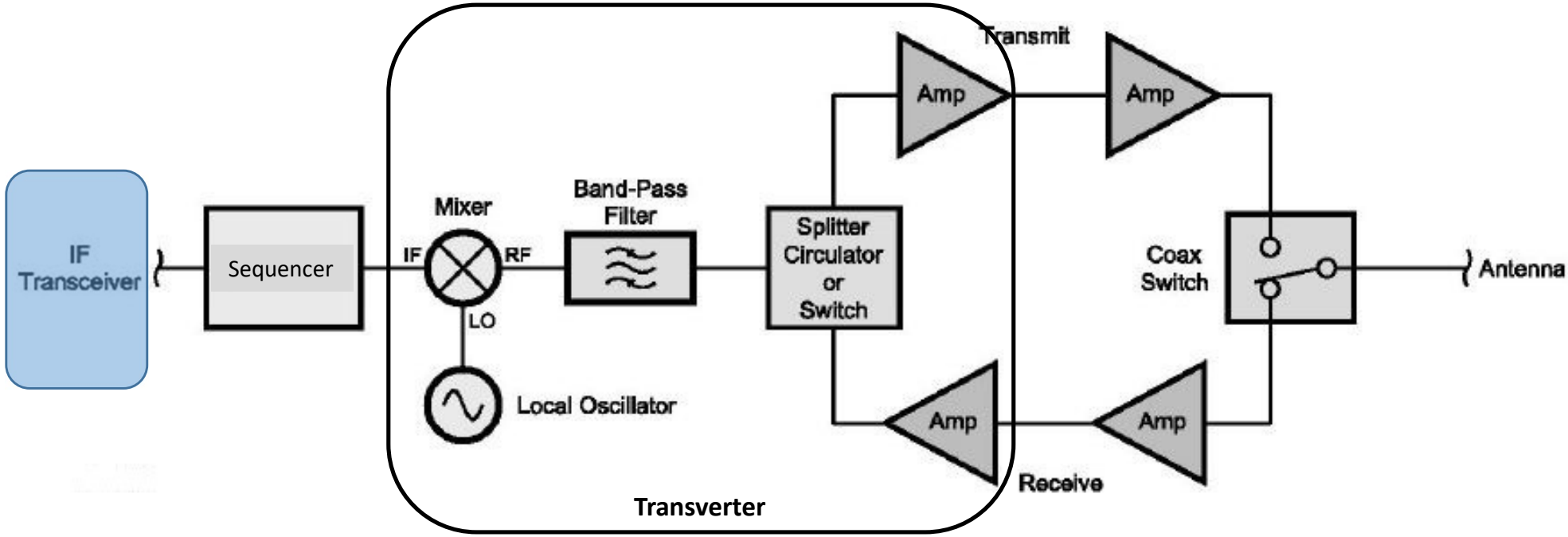
- IF transceiver
- Transverter
- Amplifier
- T/R switch
- Sequencer
- Transmission lines & connectors
- Antennas

Microwave Station Components



Microwave Station Components

- IF Transceiver ("intermediate frequency (IF) rig")
  - A commercial rig that provides the intermediate frequency to the mixer in the transverter



Microwave Station Components

- IF Transceiver ("intermediate frequency (IF) rig")
  - Most commonly a 2m all-mode (SSB, CW, FM) rig with *low power output* capability (QRP rigs are popular)
    - Only 200 mW-2 Watts output needed to drive transverter
    - Consider attenuator if higher output used
  - Access to the rig's PTT signal

Yaesu FT-817/818 [0.5W]

Yaesu 290 RII [2.5W]

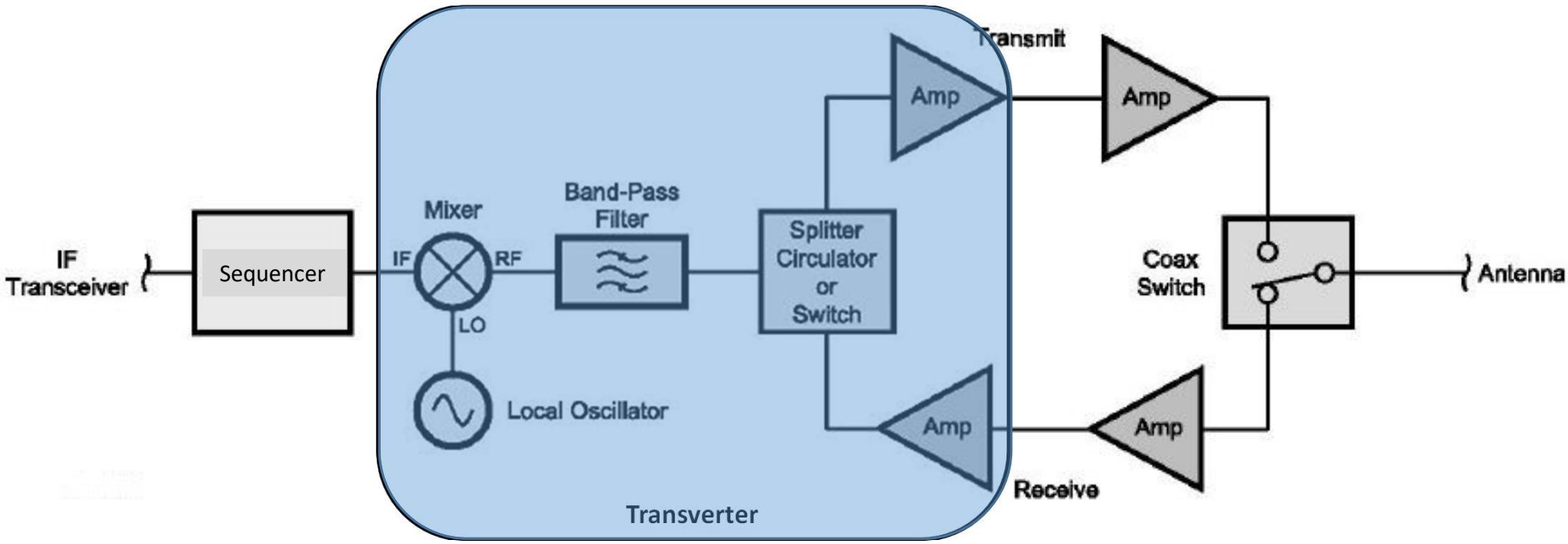
Icom 705 [0.1W]

Kenwood TR-751 [2W]

Icom 706 [2.5W]

Microwave Station Components

- Transverter

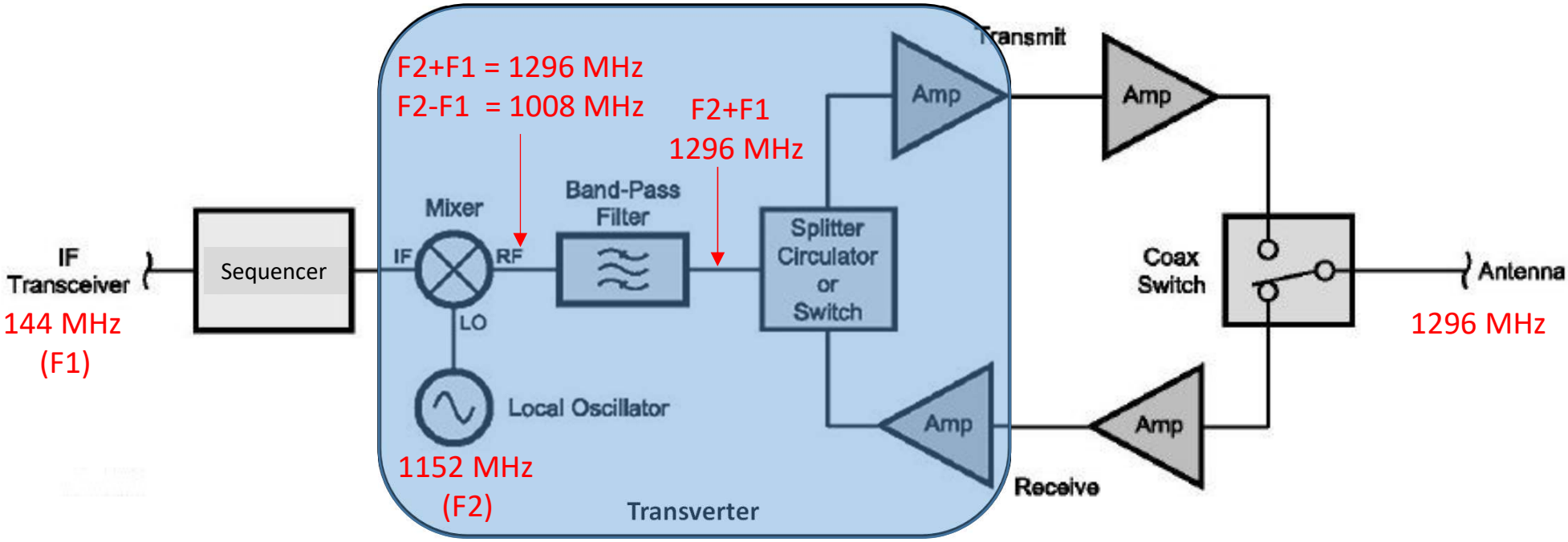


Microwave Station Components

- Transverter
  - It is the crux of a microwave system
  - A transverter consists of a frequency upconverter and a downconverter in one unit. Transverters are used in conjunction with a commercial transceiver (the “IF Rig”) to change the range of frequencies over which the commercial transceiver can communicate.

Microwave Station Components

- Transverter: How does it work?



1.2 GHz Transverter

Microwave Station Components

- Transverter
  - The frequency conversion is totally transparent to the existing IF transceiver.
  - This means that most functions of the IF transceiver will also be the same on the converted band.
    - The transverter may be used in any mode (i.e., SSB, CW, FM) that the transceiver is capable of.

Microwave Station Components

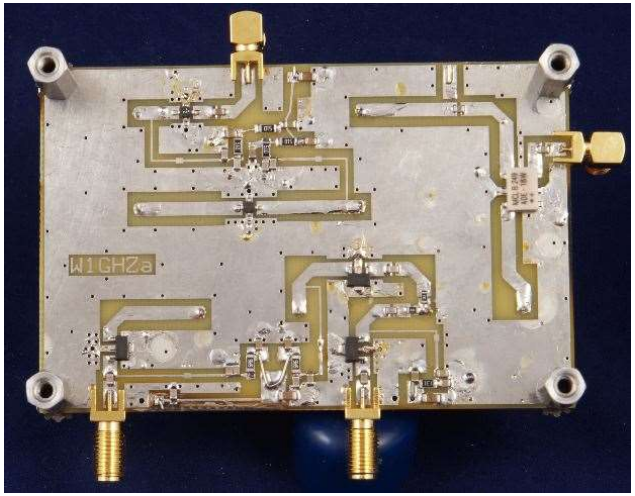
- Transverter
  - There are some things that are not transparent to the transceiver:
    - Power control
      - Power control is addressed in the transverter set-up and can be adjusted in other ways.
    - Frequency readout
      - The frequency read out is a minor inconvenience and becomes less noticeable the more you use your system.

Microwave Station Components

Down East Microwave / Q5 Signal

SG-Lab

Kuhne



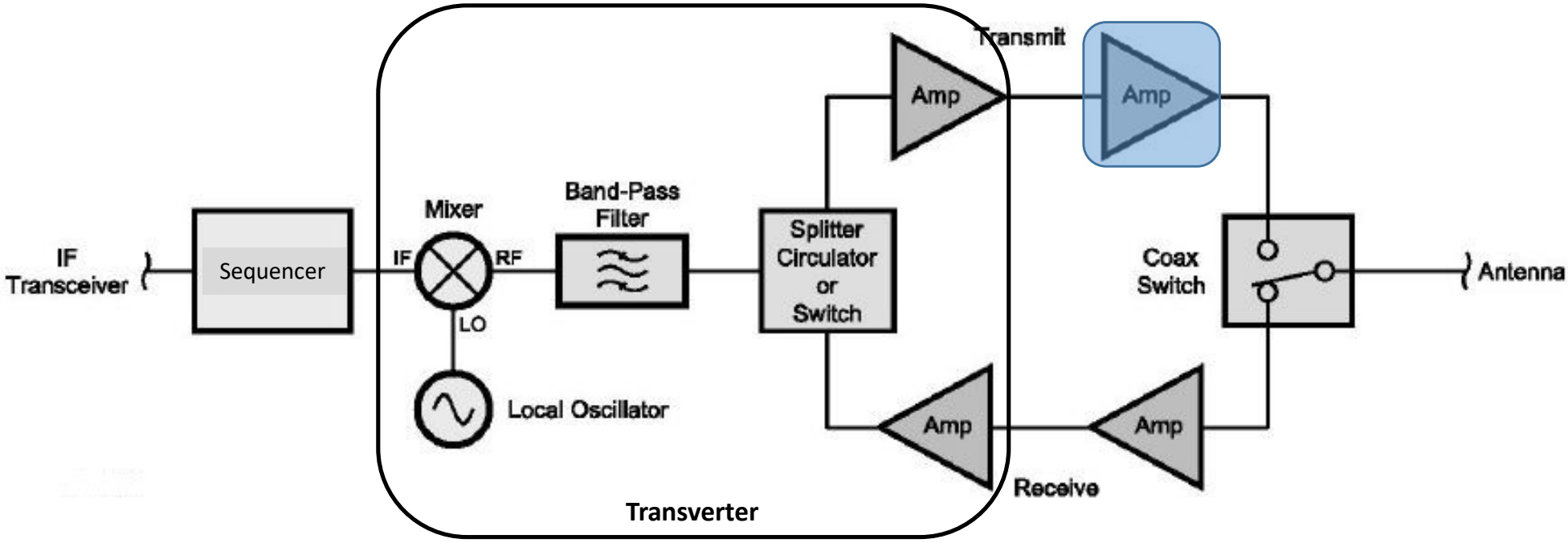
W1GHZ (Boards)

Microwave Station Components

- Transverter
  - Homebrew ($-$$)
  - Circuit Boards (“Kits”) ($-$$)
    - www.W1GHZ.org (Paul Wade)
  - SG Laboratory Ltd., Bulgarian company ($$)
    https://www.sg-lab.com/amateur.html
  - Down East Microwave, Live Oak, Florida ($$$)
    http://www.downeastmicrowave.com/
  - Kuhne, German company ($$$$)
    http://www.kuhne-electronic.de/en/home.html

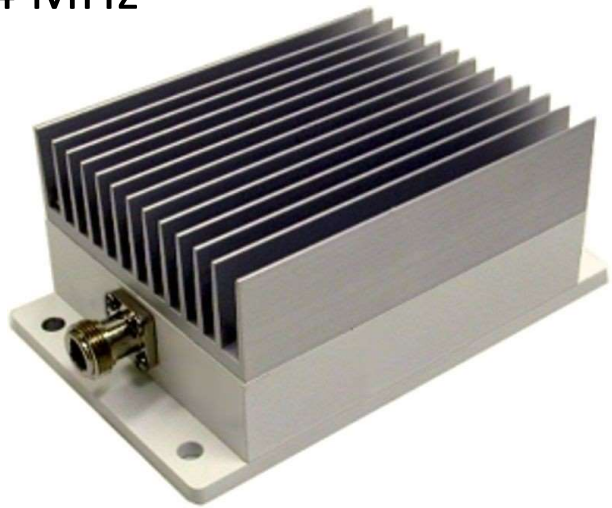
Microwave Station Components

- Transmit Amplifier



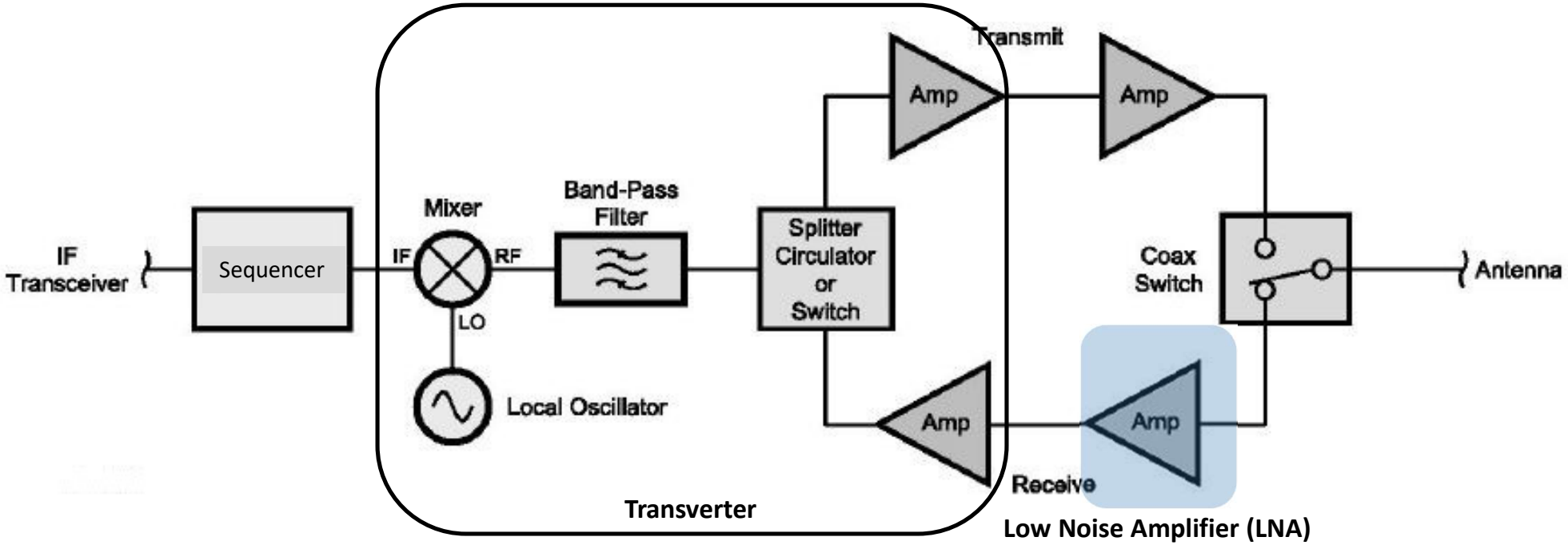
Microwave Station Components

- Transmit Amplifier
  - 12 V or 24 V
  - Band specific
  - Surplus an option
    - AML PCS amps (from WA2AAU)-2304 MHz
    - Spectran amps (Ebay: “pyrojoseph”)-2304 MHz
    - Ebay
  - Output:
    - 3-150 W for 900 MHz – 1.2 GHz
    - 1-30 W for 2.3 – 10 GHz



Microwave Station Components

- Receive Amplifier (LNA)

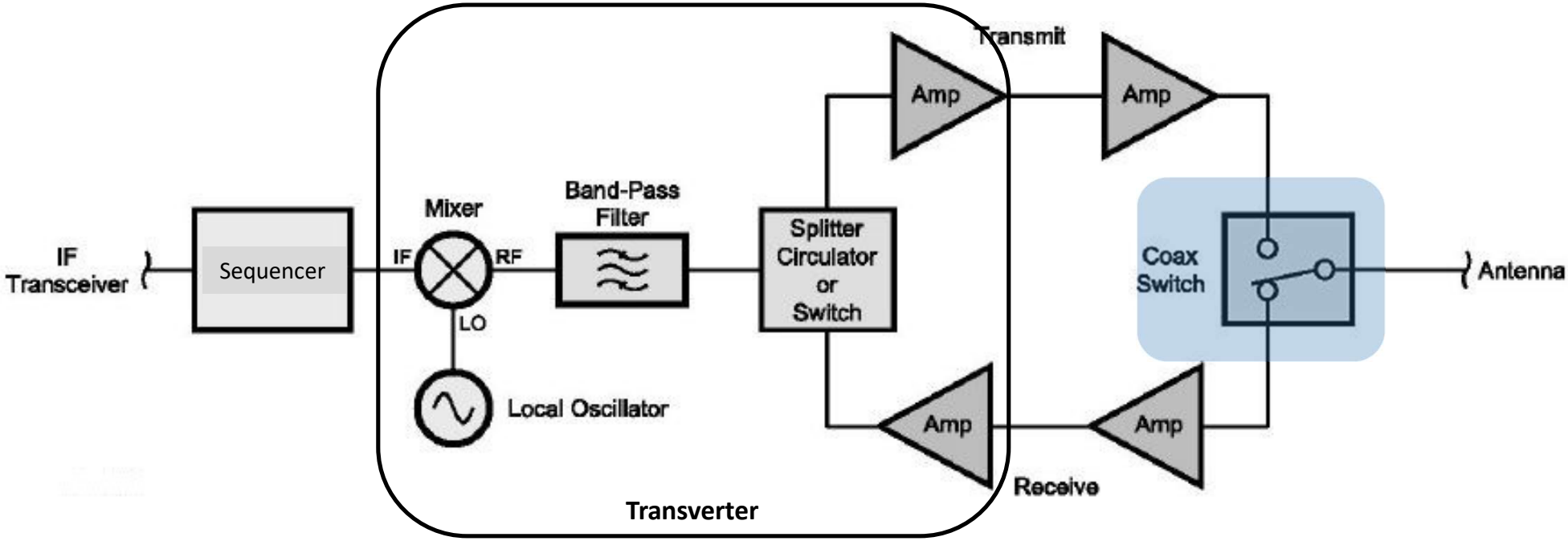


Microwave Station Components

- Low Noise Amplifier (“LNA”, Receive)
  - Remember, we’re talking weak signals here!
  - A typical amplifier increases the power of both the signal and the noise present at its input, whereas LNAs are designed to amplify a signal while minimizing additional noise.
  - Down East Microwave
  - Kuhne
  - W1GHZ (boards)

Microwave Station Components

- Transmit/Receive Coaxial Switch

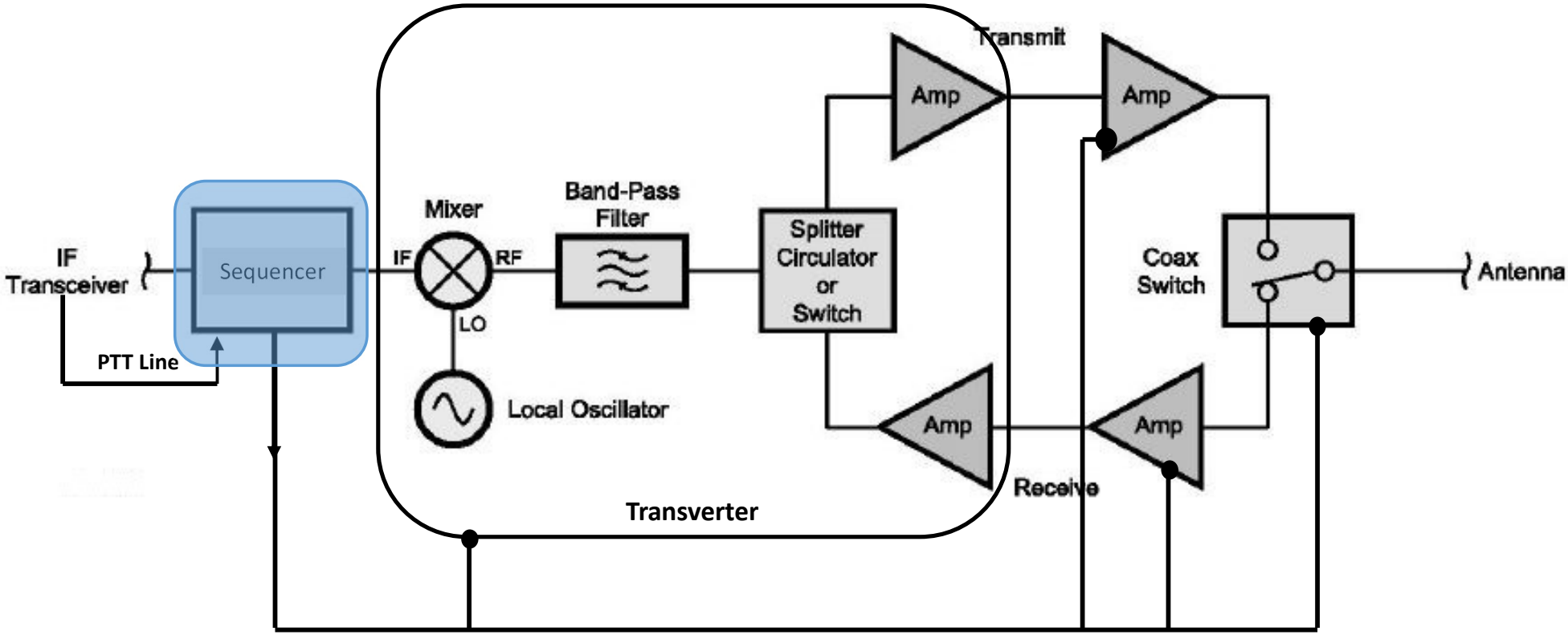


Microwave Station Components

- Coaxial T/R Relay Switch
  - Used in switching signals from the antenna to either the transmit receive chain.
  - Look for 12V T/R Relay
  - Expensive new, but common surplus item ($15-$25)

Microwave Station Components

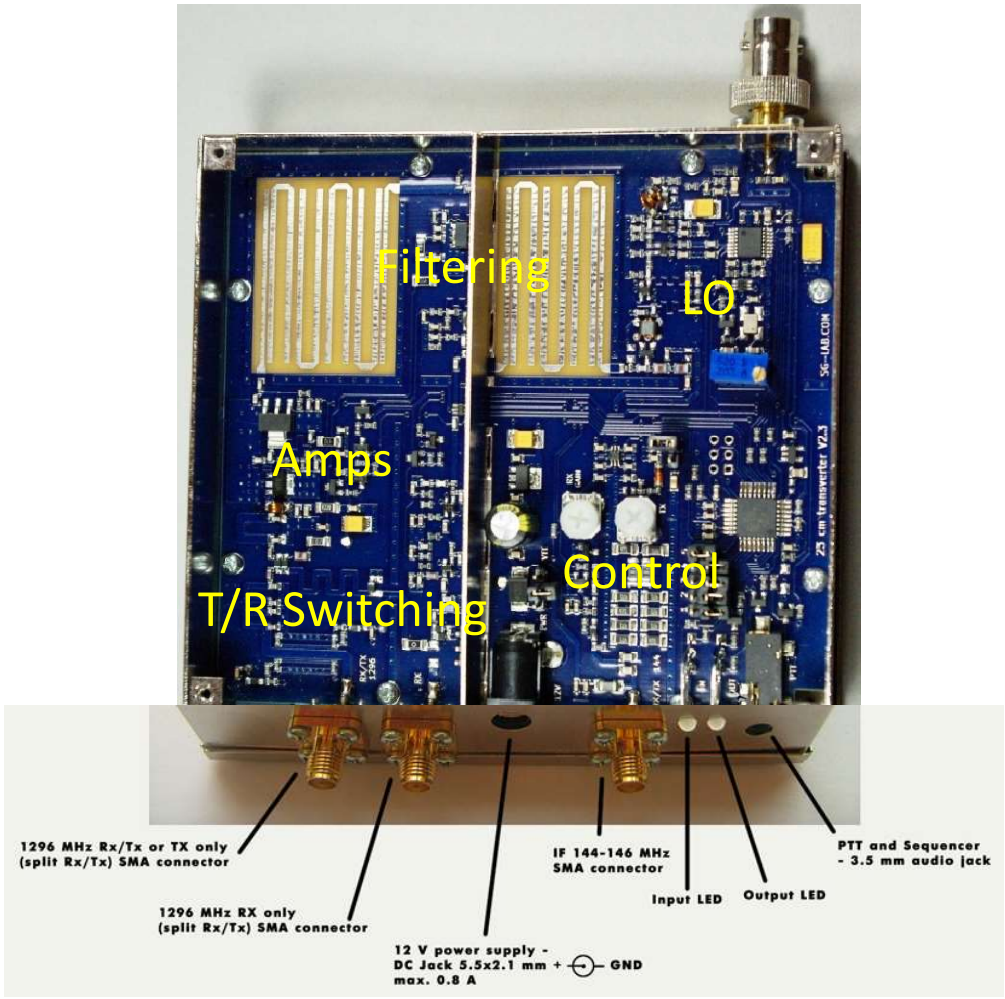
- Sequencer

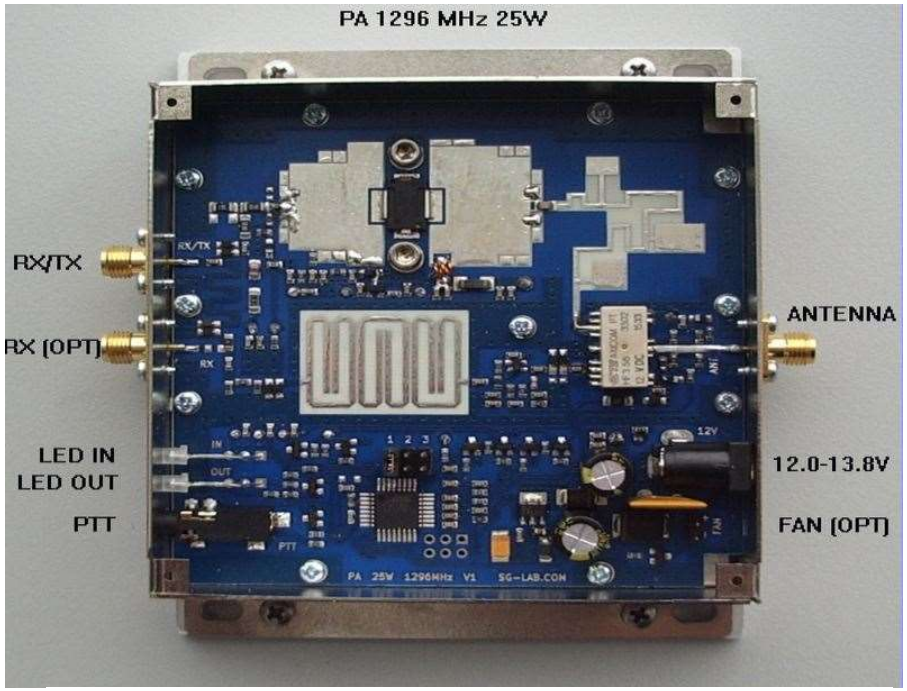


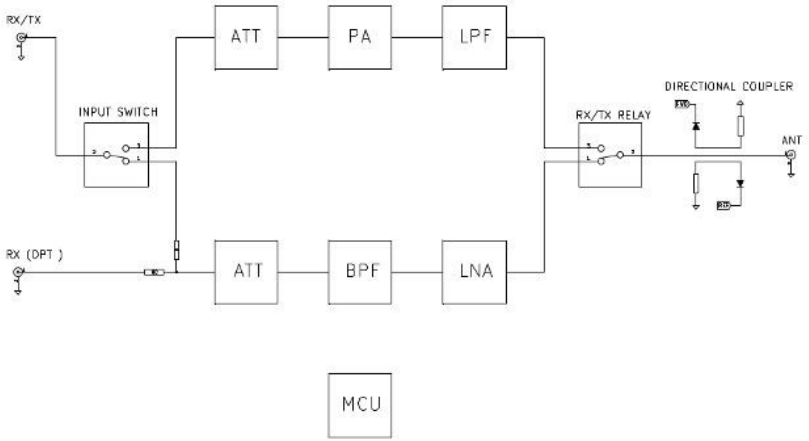
Microwave Station Components

- Sequencer
  - Turns the various stages of a microwave system on and off in the correct sequence when going from receive to transmit mode…and the reverse when going from transmit to receive mode.
  - By triggering the various system components to come online or go offline at precisely the right time, issues with “hot switching”—where the RF signal or voltage are already on the line that is being switched into the circuit--are avoided
  - Hot switching causes arcing, heating, and ultimately contact erosion and failure of relay switches and can damage or destroy the sensitive input circuitry in the LNA and amplifiers.

Microwave Station Components



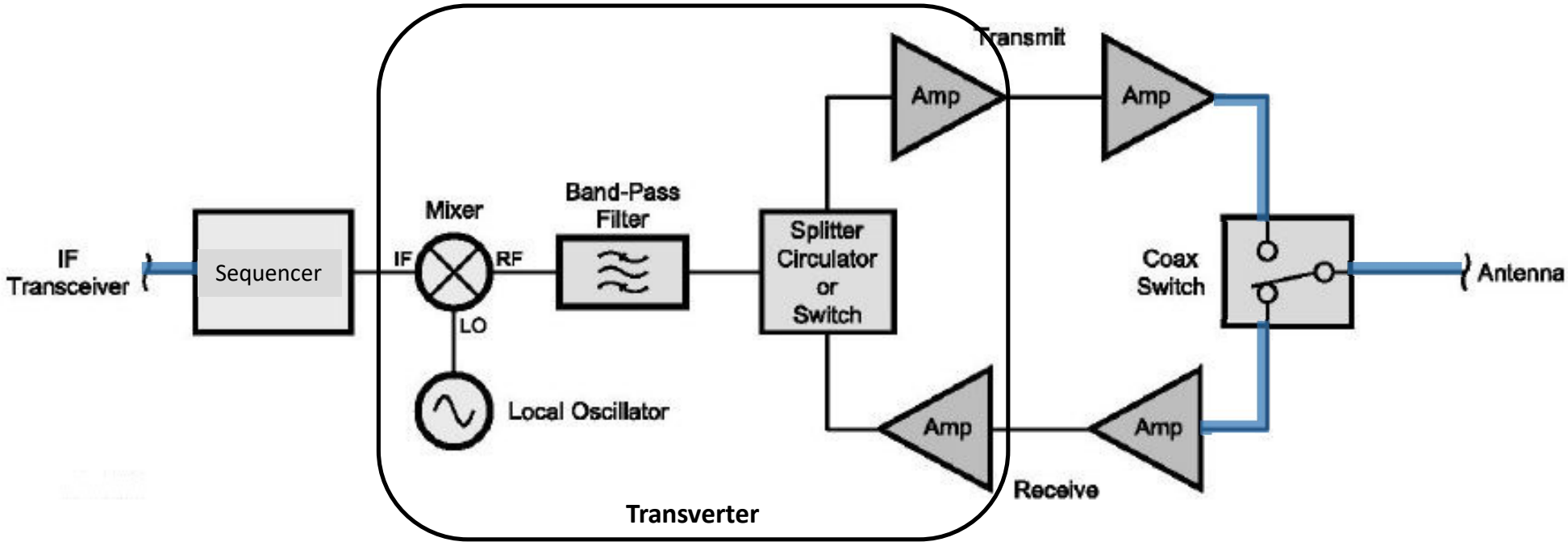




SG Labs 1296 MHz Transverter (2W) and Amplifier (25W)

Microwave Station Components

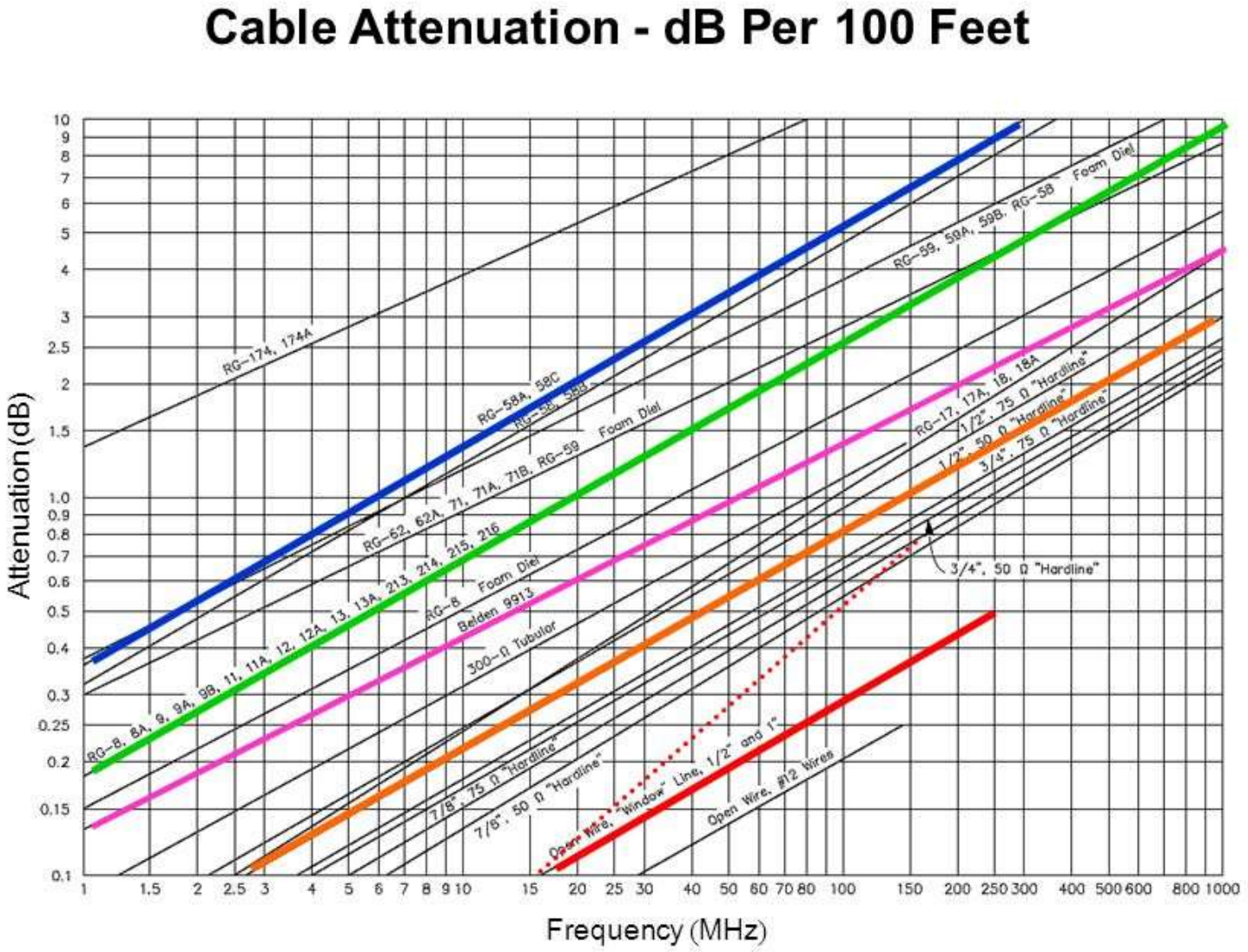
- Transmission Lines and Connectors



Microwave Station Components

- Transmission lines & connectors
  - Commonly used coax types at HF/VHF/UHF (e.g., RG-8 and RG-58) cannot be use for microwaves due to excessive attenuation losses, “leakage”, and impedance bumps.
  - Similarly, standard PL-259 coax connectors have poor performance at microwave frequencies.

Microwave Station Components

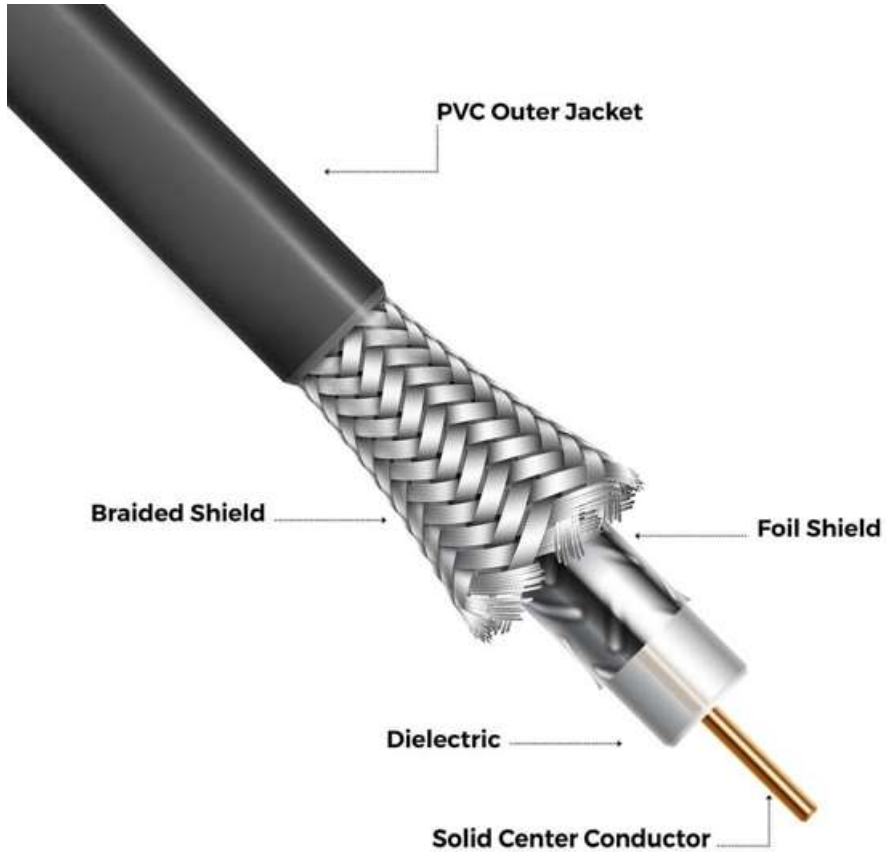


Microwave Station Components

- Transmission lines & Connectors
  - Common types of microwave transmission line:
    - Coax
      - Flexible (LMR-400, LMR-600)
      - Hardline (“Heliax”)
      - Semirigid
    - Waveguide

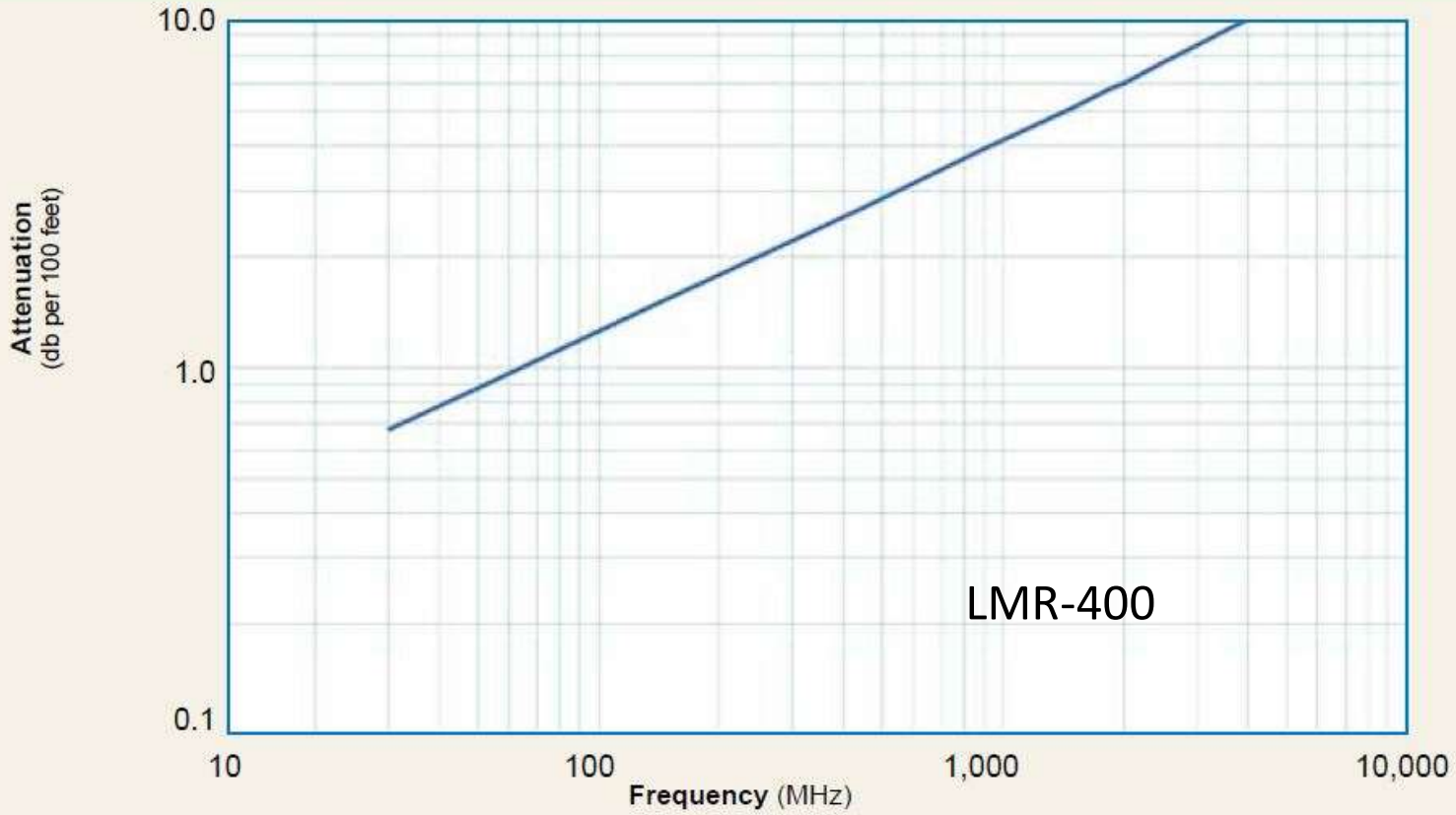
Microwave Station Components

- Transmission lines & Connectors
  - Flexible coax: “LMR” series
    - Acceptable attenuation loss up to 2-3 GHz
    - Still reasonably flexible
    - Extra shielding in construction



Microwave Station Components

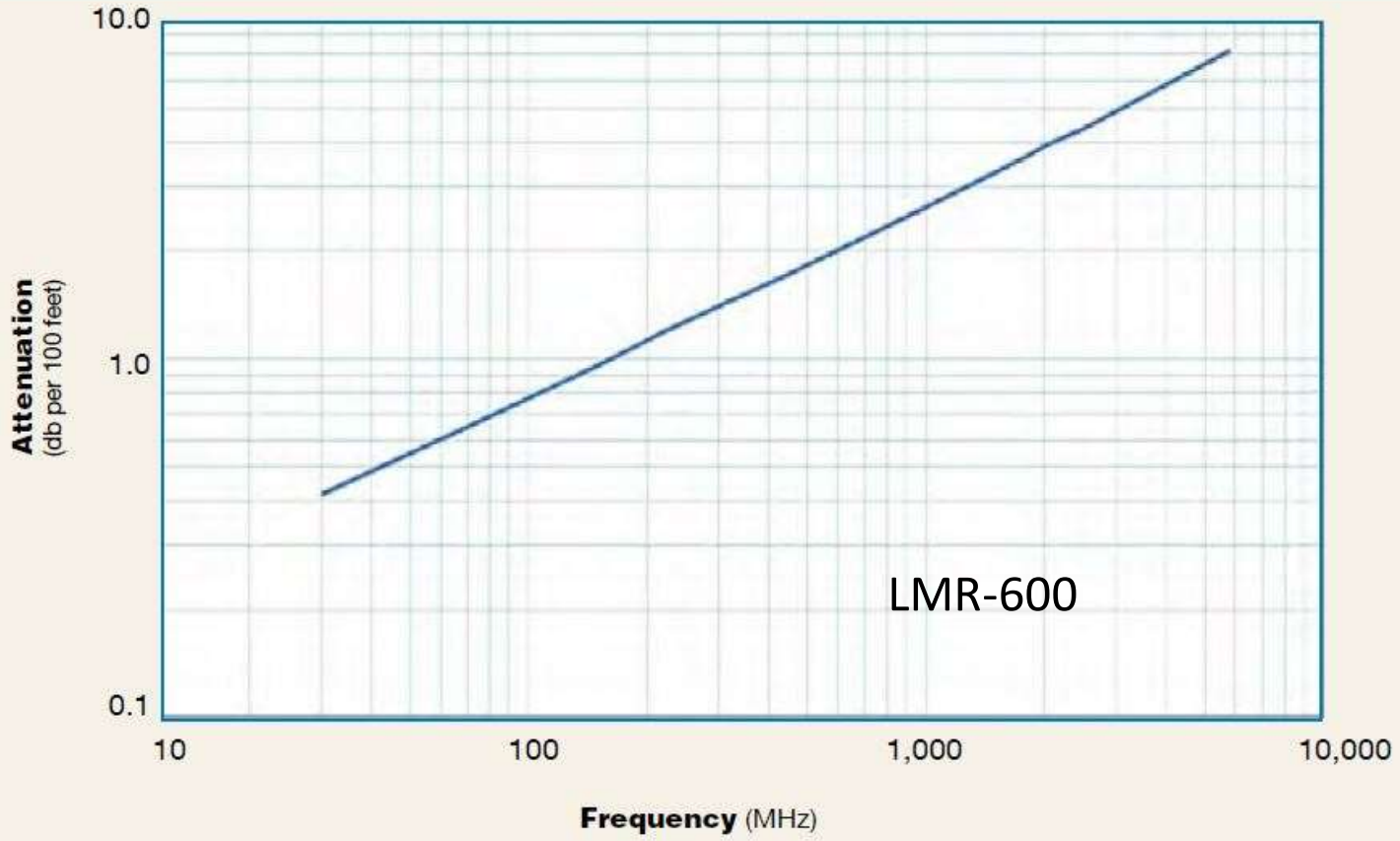
Attenuation vs. Frequency (typical)



Frequency (MHz)	30	50	150	220	450	900	1500	1800	2000	2500	5800
Attenuation dB/100 ft	0.7	0.9	1.5	1.9	2.7	3.9	5.1	5.7	6.0	6.8	10.8
Attenuation dB/100 m	2.2	2.9	5.0	6.1	8.9	12.8	16.8	18.6	19.6	22.2	35.5
Avg. Power kW	3.33	2.57	1.47	1.20	0.83	0.58	0.44	0.40	0.37	0.33	0.21

Microwave Station Components

Attenuation vs. Frequency (typical)



Frequency (MHz)	30	50	150	220	450	900	1500	1800	2000	2500	5800
Attenuation dB/100 ft	0.4	0.5	1.0	1.2	1.7	2.5	3.3	3.7	3.9	4.4	7.3
Attenuation dB/100 m	1.4	1.8	3.2	3.9	5.6	8.2	10.9	12.1	12.8	14.5	23.8
Avg. Power kW	5.51	4.24	2.41	1.97	1.35	0.93	0.70	0.63	0.59	0.52	0.32

Microwave Station Components

- Transmission lines & connectors
  - Hardline (“Heliax”)
    - Has a corrugated solid outer conductor and foam dielectric to allow it to flex more easily. Still pretty stiff though!
    - Used for frequencies up to several GHz.

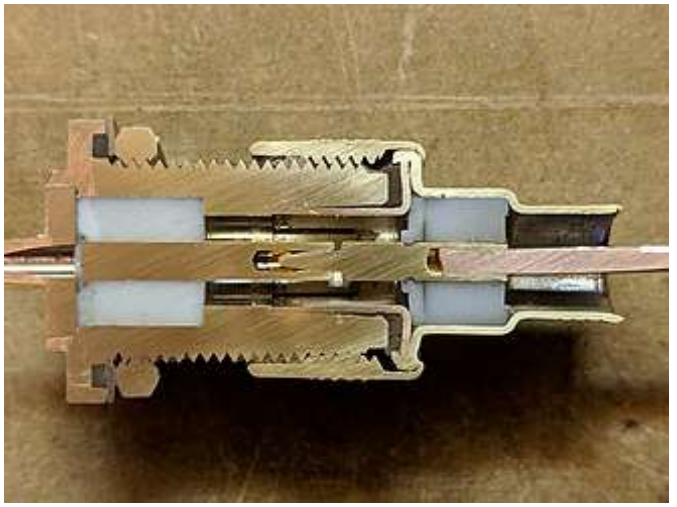
Microwave Station Components

Hardline: Attenuation (dB/100 ft) vs. Frequency

Hardline	30 MHz	50 MHz	150 MHz	220 MHz	450 MHz	900 MHz	1500 MHz	1800 MHz	2000 MHz	2500 MHz	5800 MHz
7/8”	0.195	0.254	0.449	0.529	0.808	1.2	1.58	1.75	1.861	2.15	3.5
1 5/8”	0.105	0.137	0.293	0.293	0.439	0.543	0.865	0.962	1.024	1.169	~~

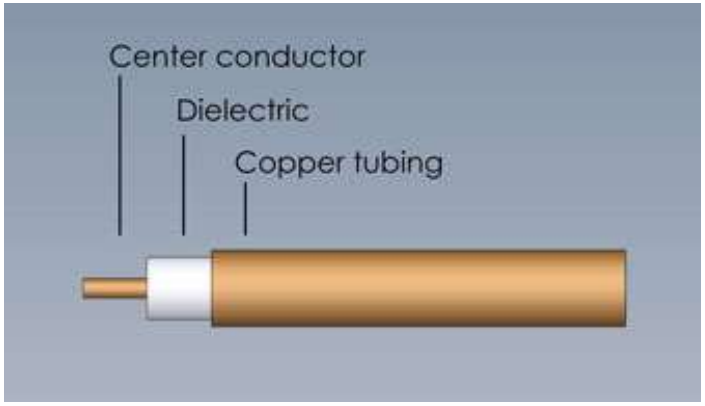
Microwave Station Components

- Transmission lines & connectors
  - Type N connectors
    - Screw locking connector
    - Precision types usable up to 18 GHz!
    - Very common
    - Available for almost all types of cable
    - Waterproof
    - Widely used in many lower frequency microwave systems, where ruggedness and/or low cost are needed



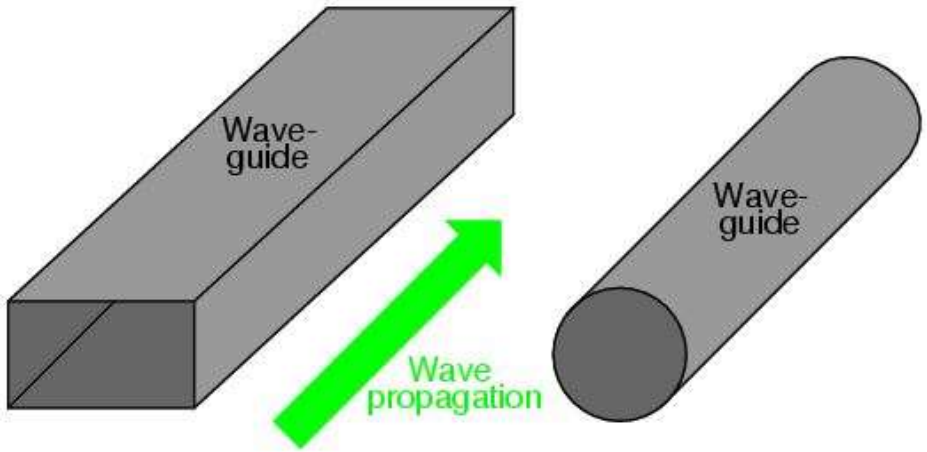
Microwave Station Components

- Transmission lines & connectors
  - Semirigid cable
    - Copper tube for outer conductor
    - Teflon dielectric for lower loss
    - Solid copper inner conductor, usually silver plated
    - Excellent performance 1 GHz – 24 GHz
    - Major disadvantage is that it is not very flexible
    - Watch for buckles/kinks when bending
    - Great for short run interconnects between pieces of equipment
    - SMA connector



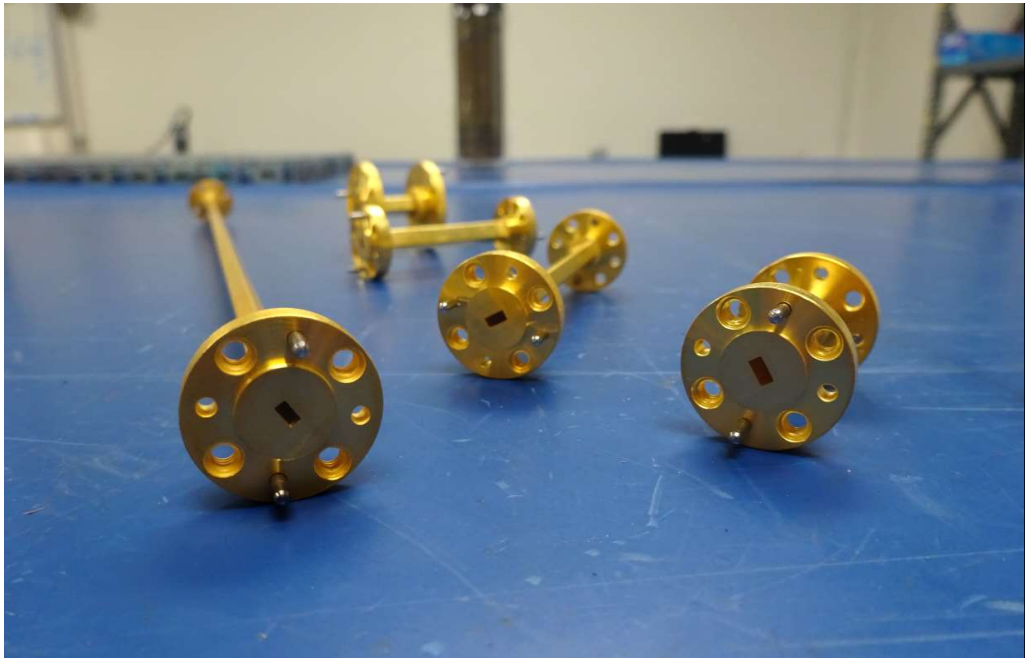
Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - A waveguide is a special form of transmission line consisting of a hollow metal tube.
    - Waveguide conducts microwave energy at significantly lower loss than coaxial cables.



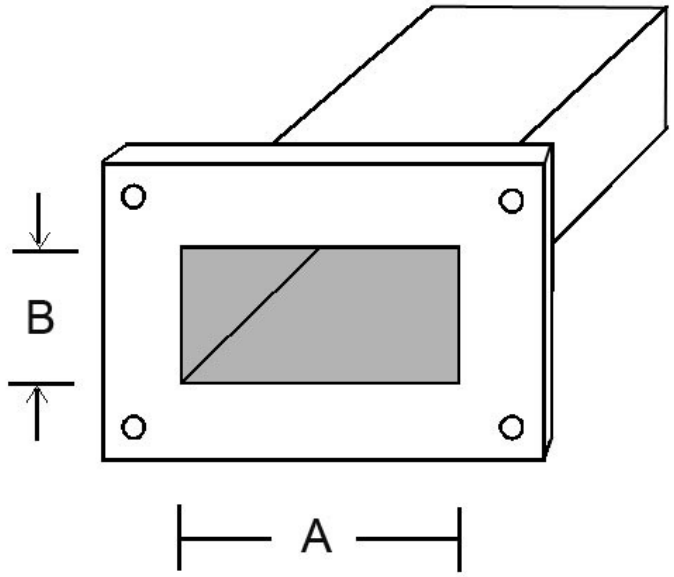
Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - Many types, shapes, and sizes
    - Heavy, expensive, mounting challenges



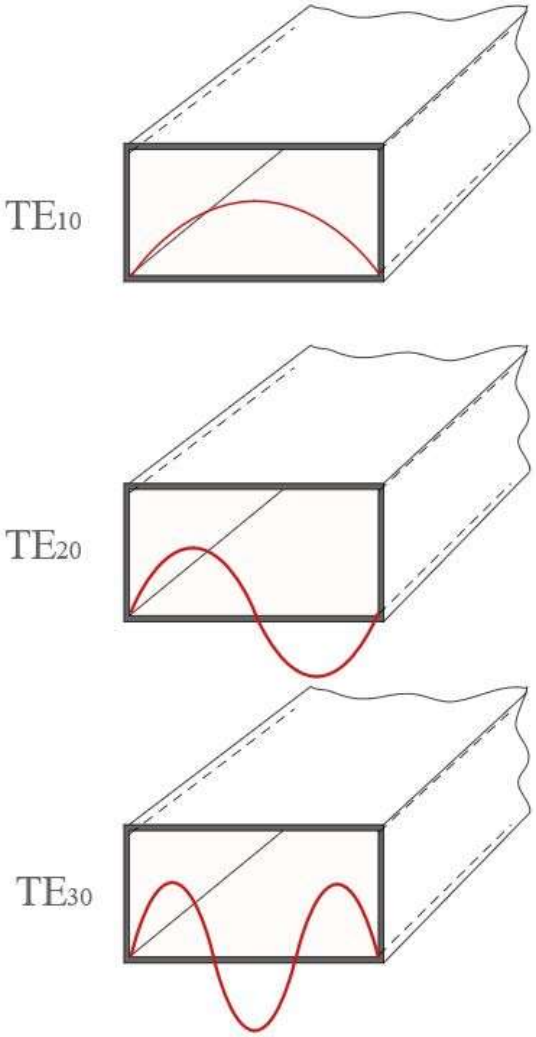
Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - The widest dimension of a waveguide is called the "a" dimension and determines the range of operating frequencies of the waveguide.
    - The narrowest dimension is called the “b” dimension and determines the power-handling capability of the waveguide



Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - Waveguide is practical only for signals of extremely high frequency, (5 GHz +) where the wavelength approaches the cross-sectional dimensions of the waveguide.
    - Below such frequencies, waveguides are useless as electrical transmission lines.

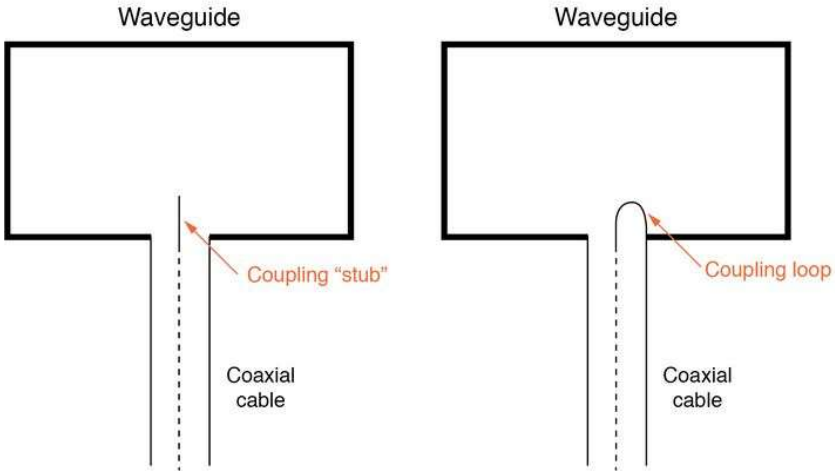


Microwave Station Components

WR WAVEGUIDE DIMENSIONS, SIZES AND WAVEGUIDE CUT-OFF FREQUENCIES FOR RIGID RECTANGULAR RF WAVEGUIDES			
WR DESIGNATION	WG EQUIVALENT	STANDARD FREQ RANGE GHZ	INSIDE DIMENSIONS (INCHES)
WR340	WG9A	2.20 - 3.30	3.400 x 1.700
WR284	WG10	2.60 - 3.95	2.840 x 1.340
WR229	WG11A	3.30 - 4.90	2.290 x 1.150
WR187	WG12	3.95 - 5.85	1.872 x 0.872
WR159	WG13	4.90 - 7.05	1.590 x 0.795
WR137	WG14	5.85 - 8.20	1.372 x 0.622
WR112	WG15	7.05 - 10.00	1.122 x 0.497
WR90	WG16	**8.2 - 12.4**	**0.900 x 0.400**
WR75	WG17	10.0 - 15.0	0.750 x 0.375
WR62	WG18	12.4 - 18.0	0.622 x 0.311
WR51	WG19	15.0 - 22.0	0.510 x 0.255
WR42	WG20	**18.0 - 26.5**	**0.420 x 0.170**
WR28	WG22	26.5 - 40.0	0.280 x 0.140
WR22	WG23	33 - 50	0.224 x 0.112
WR19	WG24	40 - 60	0.188 x 0.094
WR15	WG25	50 - 75	0.148 x 0.074
WR12	WG26	60 - 90	0.122 x 0.061

Microwave Station Components

- Transmission lines & connectors
- Waveguide “transition”
- Signals are typically introduced to and extracted from waveguides by means of small antenna-like coupling devices inserted into the waveguide.
- Sometimes these coupling elements take the form of a dipole, which is nothing more than two open-ended stub wires of appropriate length.
- Other times, the coupler is a single stub (a half-dipole, similar in principle to a “whip” antenna, 1/4λ in physical length), or a short loop of wire terminated on the inside surface of the waveguide.

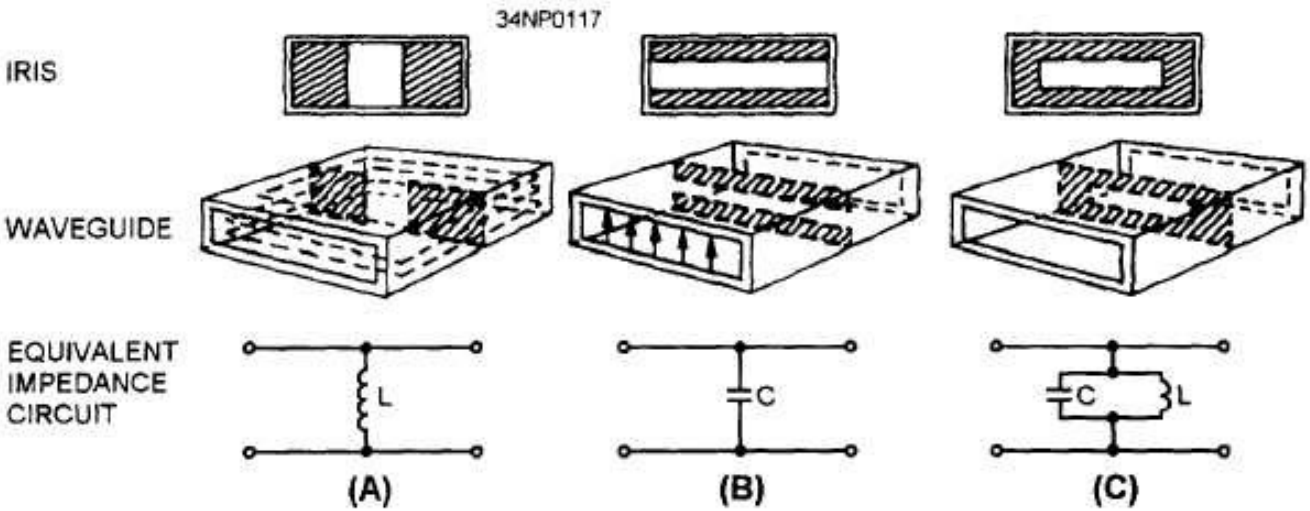


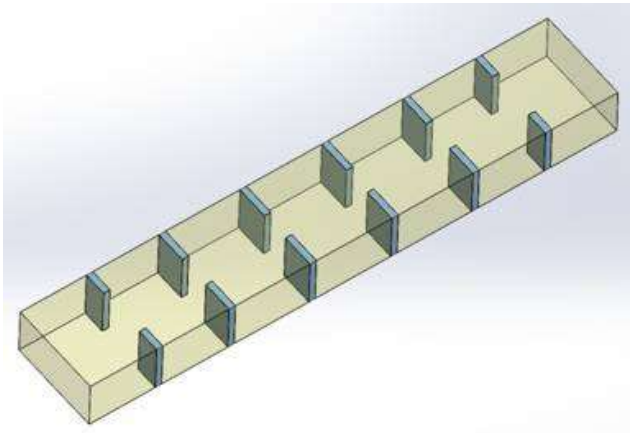
Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - Impedence Matching
      - Small devices are placed into the waveguide close to the point where the matching is needed to change its characteristics.
      - There are a number of ways in which waveguide impedance matching can be achieved:
        - Use of a waveguide iris
        - Use of a waveguide post or screw
        - Use of gradual changes in dimensions of waveguide.

Microwave Station Components

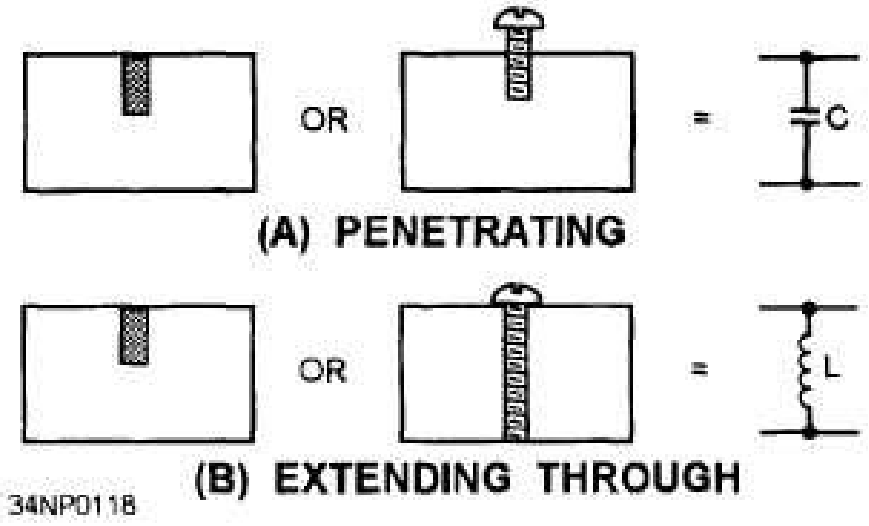
- Transmission lines & connectors
  - Waveguide
    - Impedence Matching
      - Waveguide iris





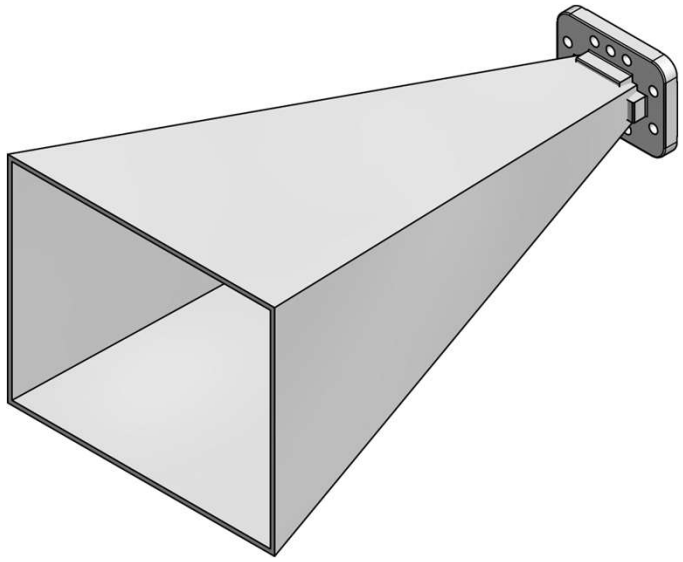
Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - Impedence Matching
      - Waveguide post or screw



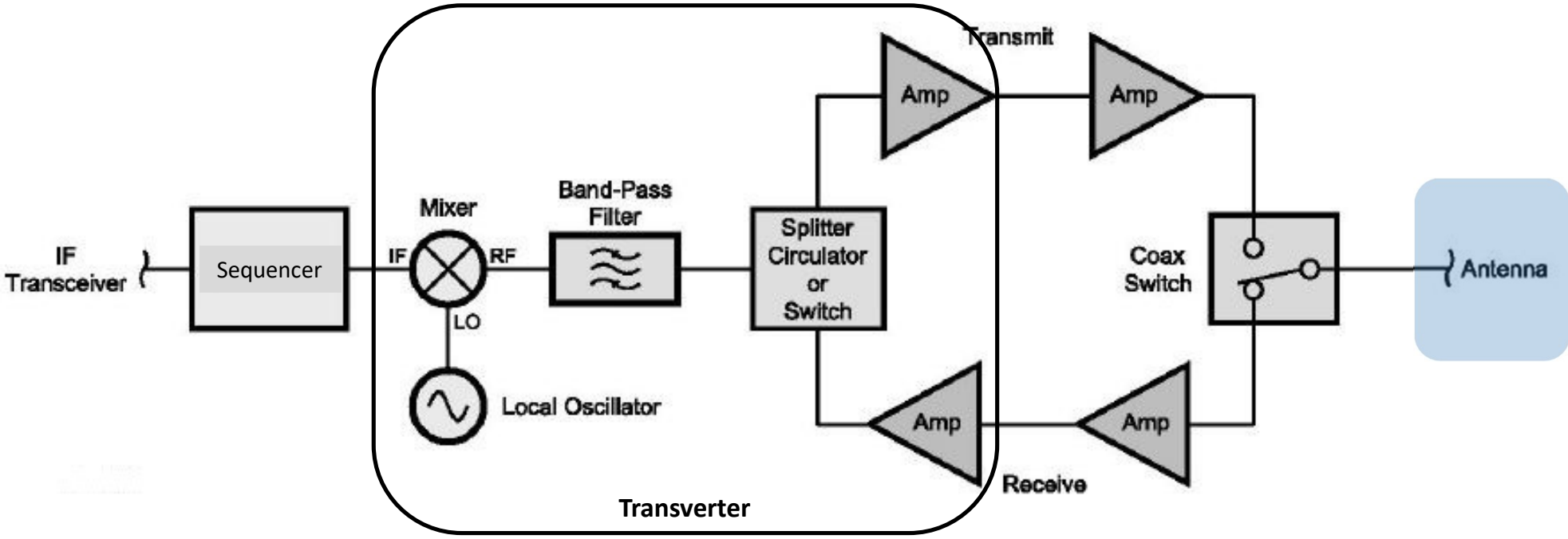
Microwave Station Components

- Transmission lines & connectors
  - Waveguide
    - Impedence Matching
      - Gradual changes in dimensions of waveguide



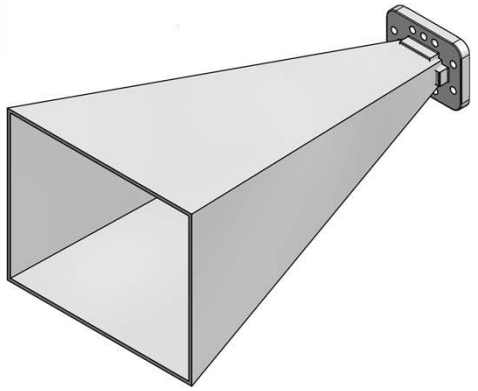
Microwave Station Components

- Antennas



Microwave Station Components

- Antennas
  - Many types; choices depend on band/frequency
    - Yagi
    - Horn
    - Parabolic dish

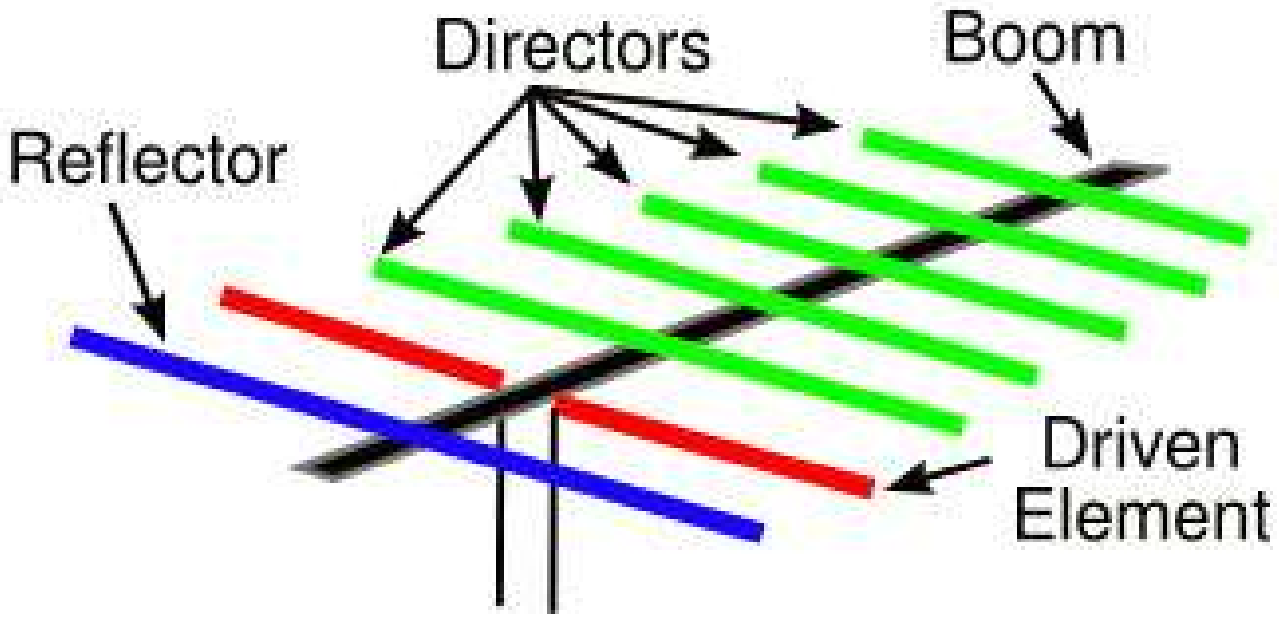


Microwave Station Components

- Antennas: Importance of gain
  - High gain (thus highly directional) antennas are essential to compensate for much weaker signals at microwave frequencies.
  - Antenna gain is achieved by concentrating the radiated energy within angular confines to form a beam.
  - Smaller the angle of the beam, higher the gain.
  - By increasing the gain of the antenna, the effective power of the transmitter or the sensitivity of the receiver is increased, but at the expense of needing to more precisely align the antenna in the desired direction.

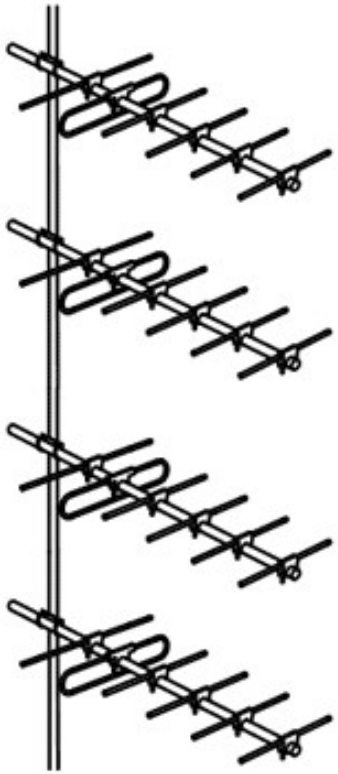
Microwave Station Components

- Antennas: Yagi



Microwave Station Components

- Antennas: Yagi
  - Popular and good choice for lower microwave bands (902/1296/2304 MHz)
  - For working DX – use horizontal polarization
  - More than one Yagi may be stacked to achieve extra gain
  - Buy
    - Directive Systems https://directivesystems.com
  - Build
    - Kent Britain, WA5VJB “Cheap Yagis” http://www.wa5vjb.com/yagi-pdf/cheapyagi.pdf

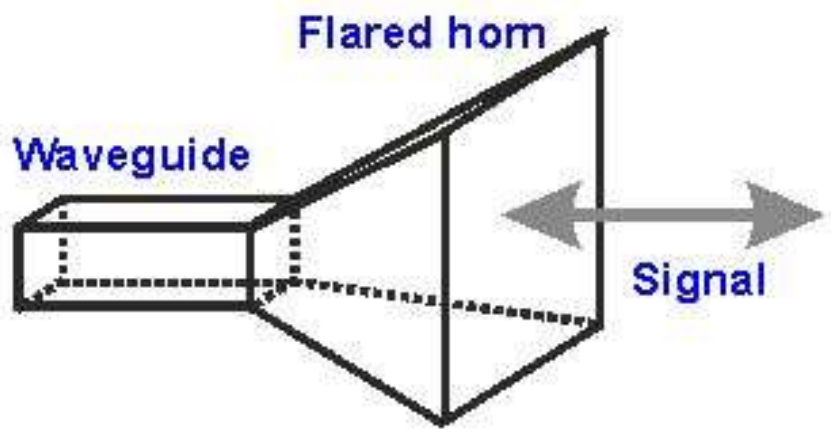


Microwave Station Components

- Antennas: Horn
  - The horn antenna is used in the transmission and reception of RF microwave signals.
  - The horn antenna is normally used in conjunction with waveguide feed line.

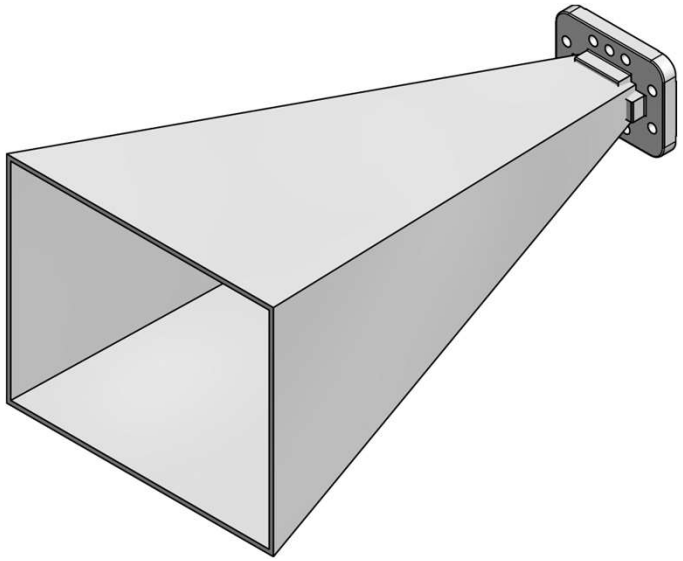
Microwave Station Components

- Antennas: Horn
  - The horn antenna may be considered as an RF transformer or impedance match between the waveguide feeder and free space (~377 ohms).
  - The tapered or a flared end to the waveguide allows the impedance to be matched. Although the waveguide will radiate without a horn antenna, this provides a far more efficient match.



Microwave Station Components

- Antennas: Horn
  - Features
    - Directivity
    - Gain
      - Larger aperture --> greater gain
      - Gain levels for a horn antenna may be up to 20 dB



  - Benefits
    - Simple construction (homebrew an option!)
    - Easy to interface to waveguide
    - Portable

Microwave Station Components

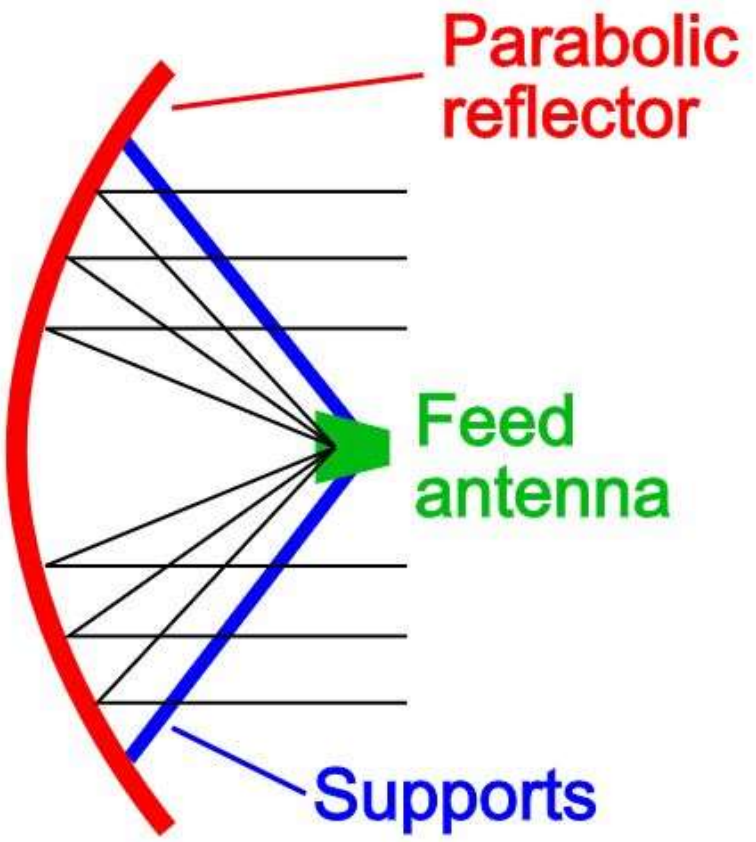
Jon Platt, W0ZQ, 10 GHz Horn Rig, 3 Watts Output, Buck Hill, 2014, ~150 mi QSO

Microwave Station Components

- Antennas: Parabolic Dish
  - Consists of a metal parabolic reflector (dish) with a small feed antenna (commonly a feed horn) suspended in front of the reflector at its focus, pointed back toward the reflector.

Microwave Station Components

- Antennas: Parabolic Dish
  - Transmitting and receiving



Microwave Station Components

- Antennas: Parabolic Dish
  - The reflector can be sheet metal, metal screen, or wire grill construction, and it can be either a circular "dish" or various other shapes to create different beam shapes.
  - A metal screen reflects radio waves as well as a solid metal surface as long as the holes are < 1/10 of a wavelength.
  - For maximum gain, dish shape must be accurate within a fraction of a wavelength to ensure the waves from different parts of the antenna arrive at the focus in phase.

Microwave Station Components

- Antennas: Parabolic Dish
  - Provide extremely high gain at microwave frequencies, but only with very sharp beamwidths
  - Gain is only limited by the size of the dish
  - Most important type of antenna for bands above 5.7 GHz

Microwave Station Components

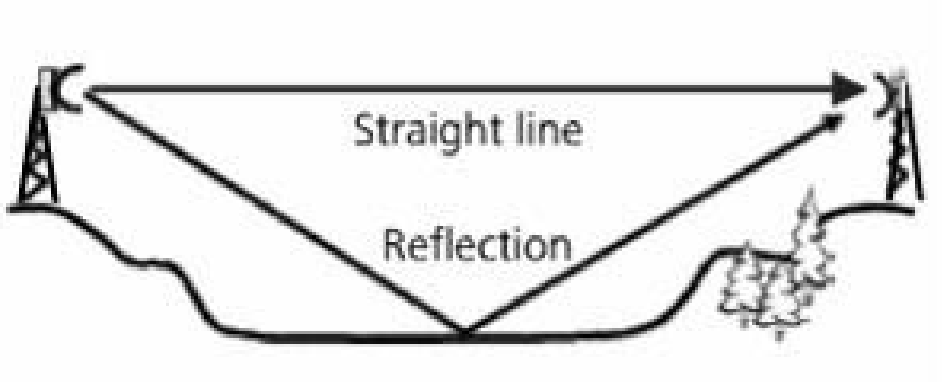
- Antennas: Parabolic Dish
  - Readily available
  - Surplus
  - Inexpensive (sometimes free!)
  - Finicky
    - Assembly/alignment of feed/dish system
    - Narrow beamwidth can make searching for weak signals frustrating and time consuming
  - Awkward to transport

Microwave Propagation

- Direct path
- Reflection
- Diffraction
- Scatter (e.g., tropospheric scatter, rain scatter)
- Ducts

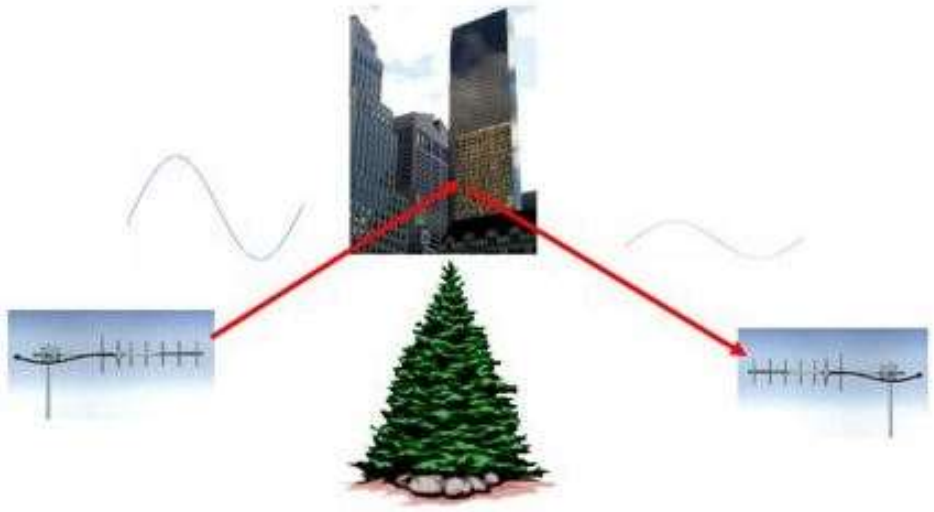
Microwave Propagation

- Direct path
  - Simplest propagation mode
  - No obstructions between the transmitting and receiving antenna
  - Reference mode against which path losses associated with other propagation modes is usually judged.

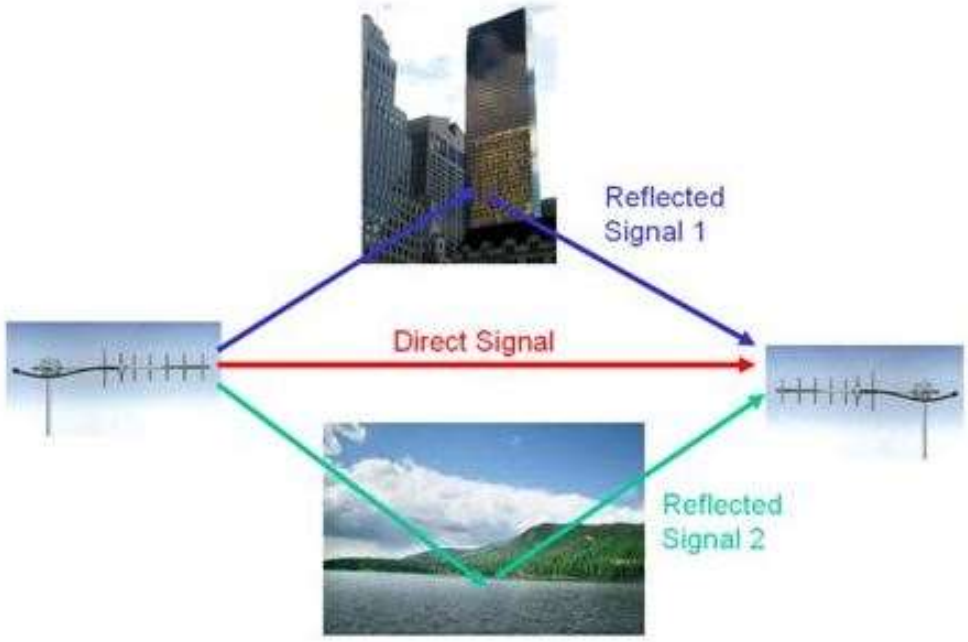


Microwave Propagation

- Reflection
  - Contact achieved by reflecting signals off an object in between both ends of the path.



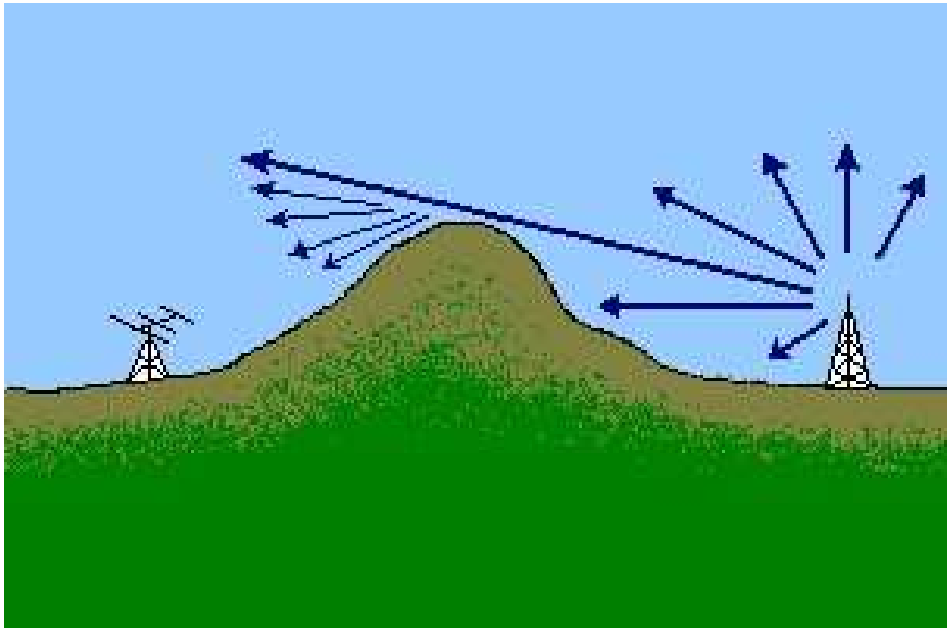
Good-useful



Bad-multipath

Microwave Propagation

- Diffraction
  - Bending of wavefronts around obstacles
  - Allows radio signals to propagate behind obstructions
  - Signals weak but often readable

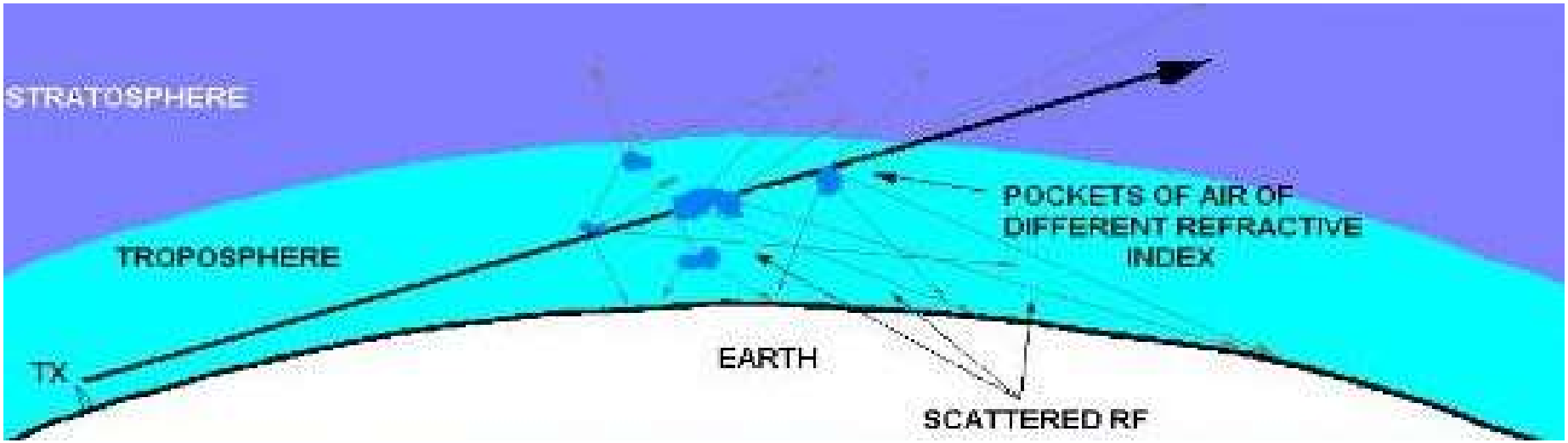


Microwave Propagation

- Scattering: Tropospheric Scattering
  - Troposhere: Lower 50,000 feet of the atmosphere
  - It's the region in which all weather phenomena occurs, airplanes fly, and is the region in which the "air" is found.
  - Although this region looks clear and uniform to the eye, it really contains a lot of turbulence and stratification.

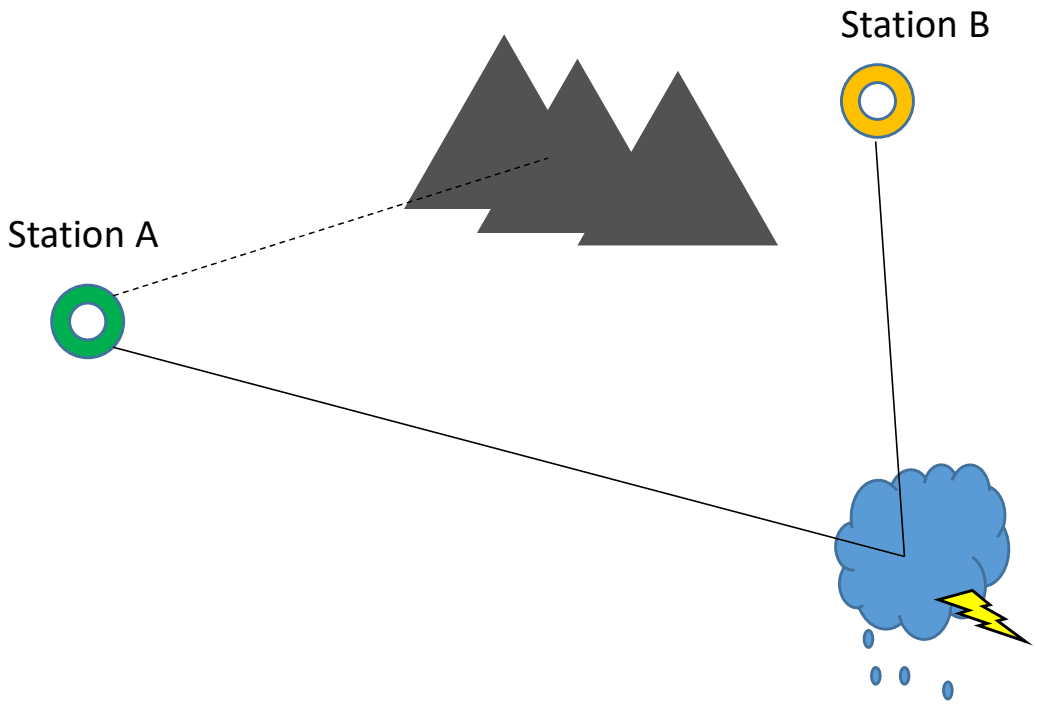
Microwave Propagation

- Scattering: Tropospheric Scattering
  - These variations alter the refractive index of the troposphere, which in turn affects how signals are bent (refracted) in passing from the transmitter to the receiver.



Microwave Propagation

- Scattering: Rain scatter
  - Provides an opportunity to make a QSO where under different circumstances it would otherwise be impossible (e.g., intervening obstruction)
  - Can enhance communication for longer distances



Microwave Propagation

- Scattering: Rain Scattering
  - Water in the atmosphere clumps into a few ranges of particle sizes
  - Rain drops are exactly the right size range for scattering microwave signals (notably 10 GHz +)
  - Heavier rain storms (with their larger rain drops) give the best scattering returns

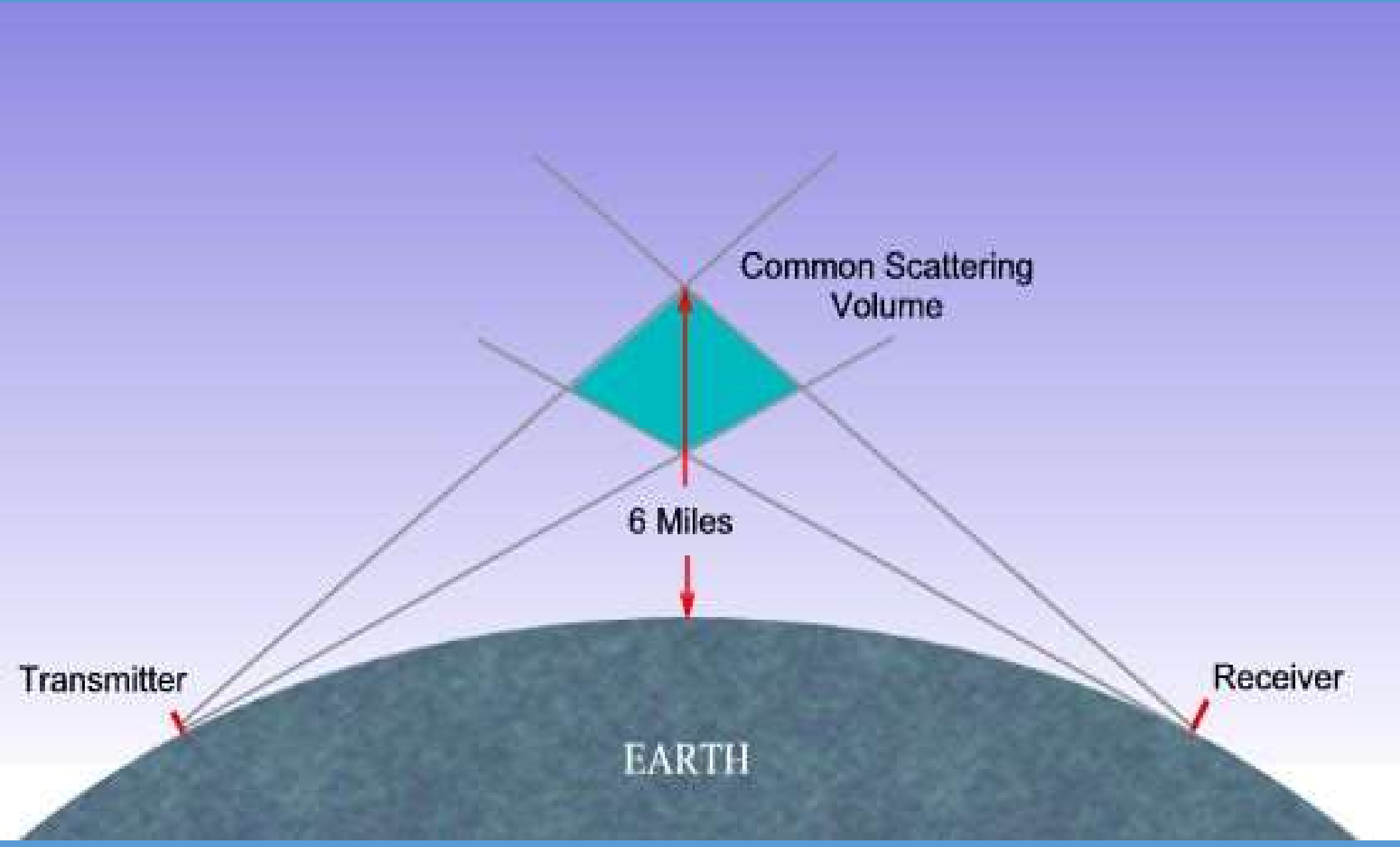
Microwave Propagation

- Rain scatter, continued
  - A characteristic of rain scatter is signal smearing
    - CW note becomes fuzzy because the individual raindrops are moving at slightly different speeds and directions
    - Sound is like aurora propagation on 2m
    - Voice is often unintelligible; CW or FM preferred

Microwave Propagation

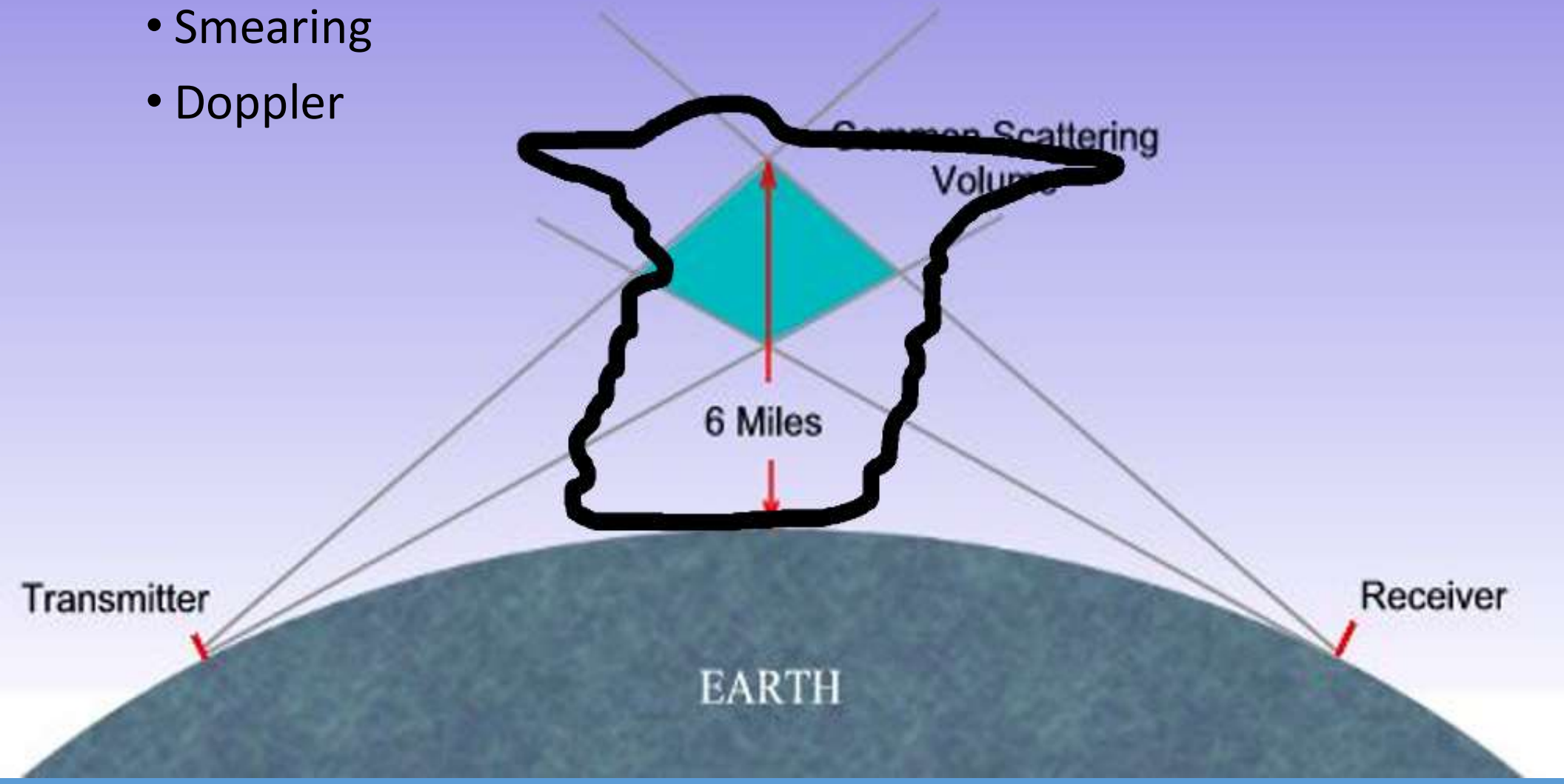
- Rain scatter, continued
  - Another characteristic of rain scatter is Doppler shift
    - Shift in frequency when the path between the transmitter and receiver is shortening or lengthening
    - Rain in storm is being blown by winds, the scatter is moving, the path length is changing, and the frequency shifts.

Microwave Propagation

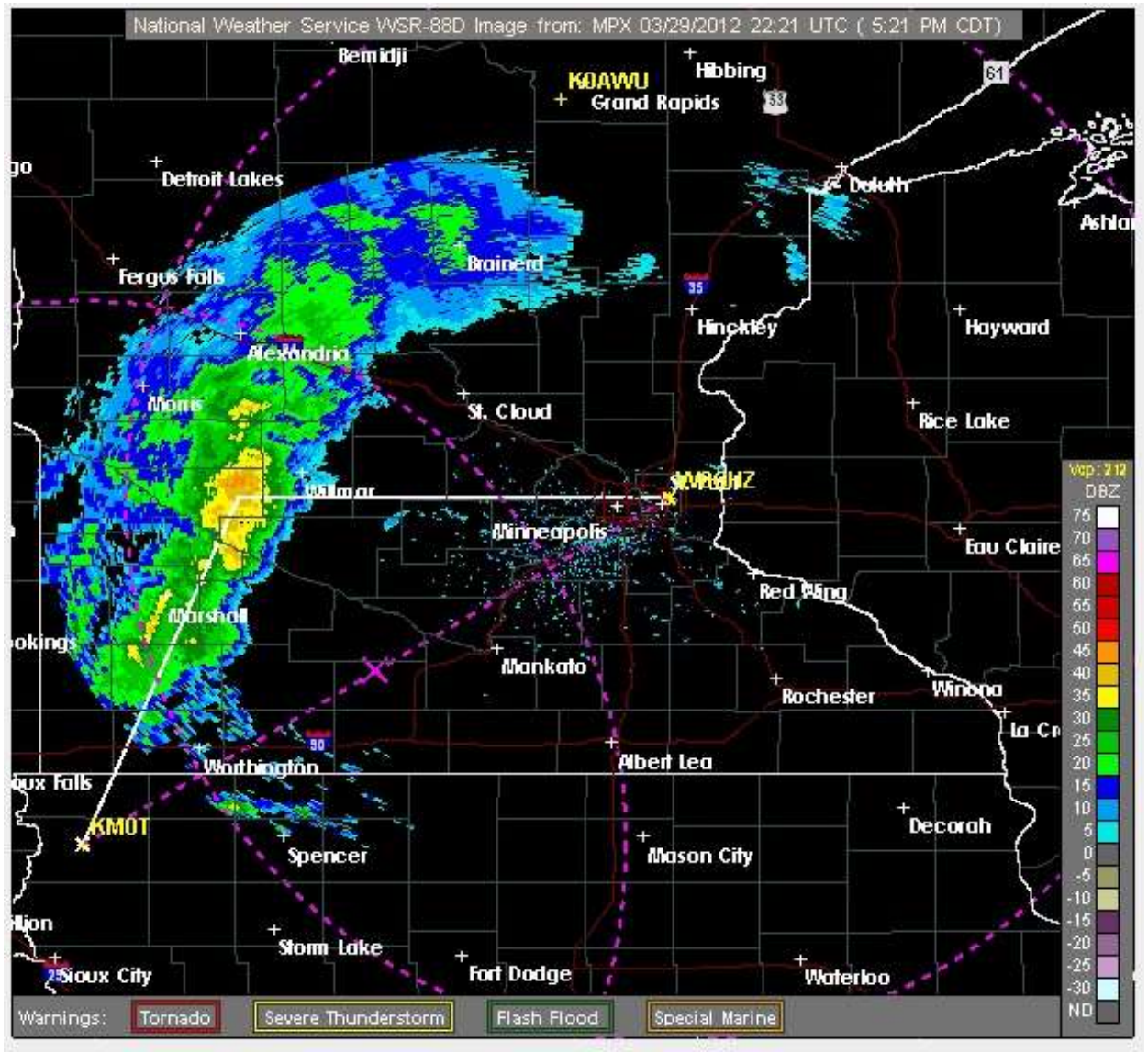


Microwave Propagation

- Rain Scatter
  - Smearing
  - Doppler

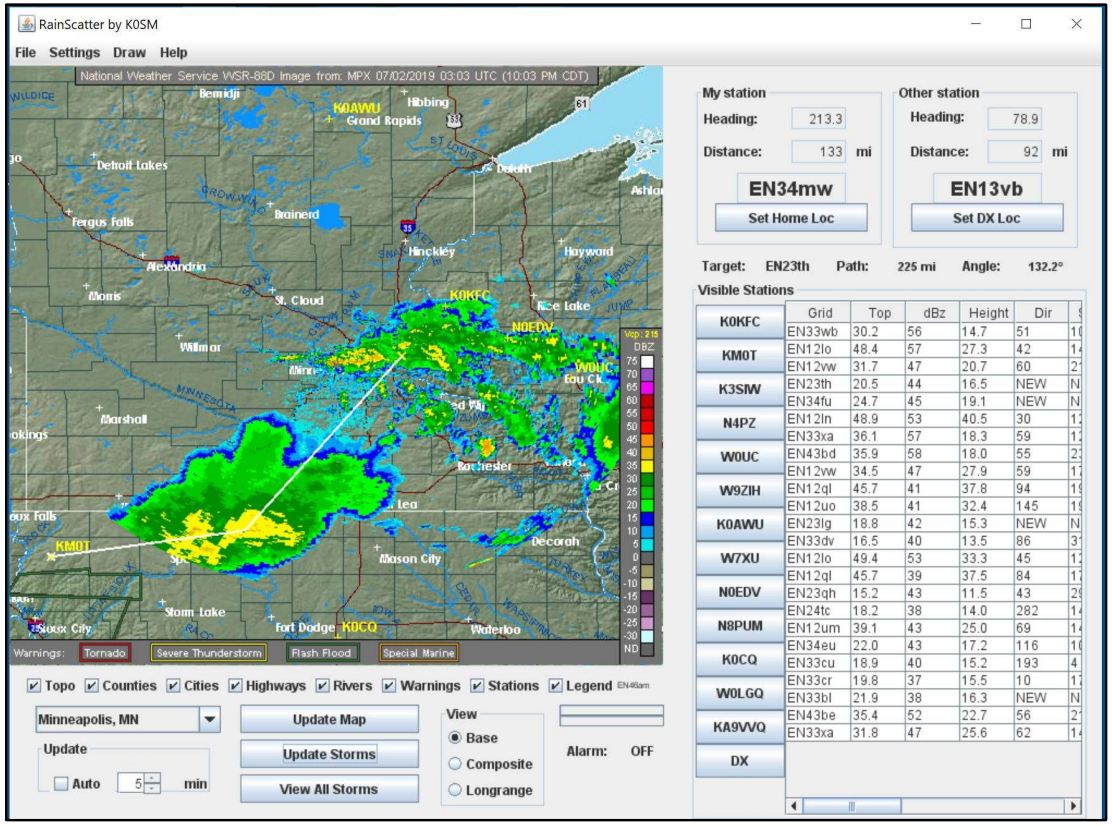


Microwave Propagation



Microwave Propagation

- Scattering: Rain Scattering
  - Useful (free) software: Rainscatter! by K0SM
  - http://www.frontiernet.net/~aflowers/rainscatter/



Microwave Propagation

Rain scatter QSOs (10 GHz):

FM of WB1FKF

SSB of WA1MBA

CW of WB1FKF

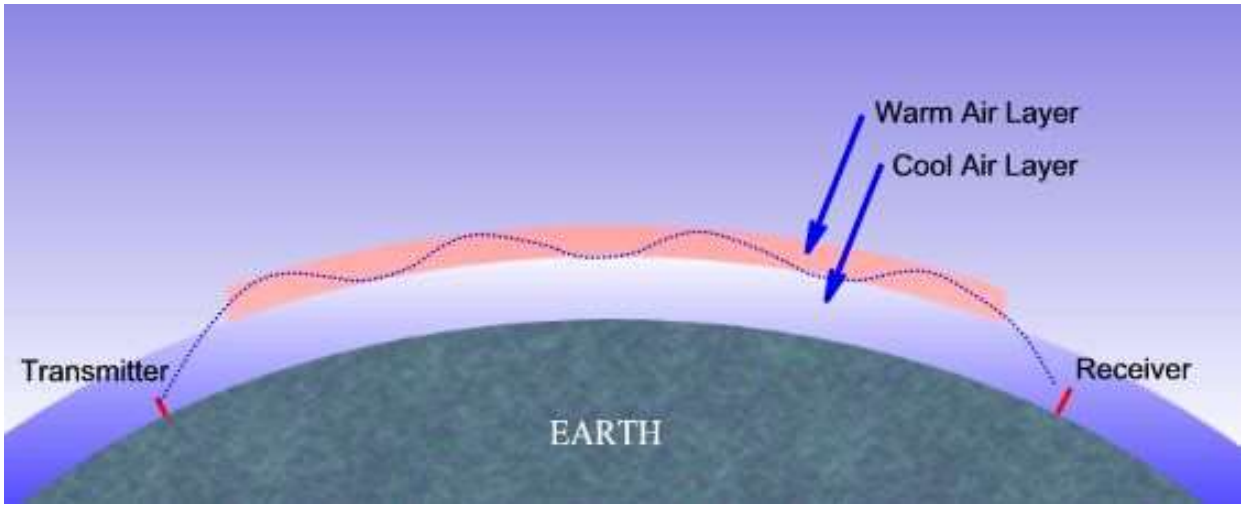
Audio rain scatter recordings courtesy W1GHZ
http://www.w1ghz.org/scatter/scatter.htm

Microwave Propagation

- Ducts
  - Occur when the atmospheric refractive index is modified by changes in temperature gradient, pressure, or water vapor content.
  - Under normal atmospheric conditions, the warmest air is found near the surface of the Earth. The air gradually becomes cooler as altitude increases.
  - At times, however, an unusual situation develops in which layers of warm air are formed above layers of cool air. This condition is known as temperature inversion.

Microwave Propagation

- Ducts:
  - These temperature inversions cause channels, or ducts, of cool air to be sandwiched between the surface of the Earth and a layer of warm air, or between two layers of warm air.

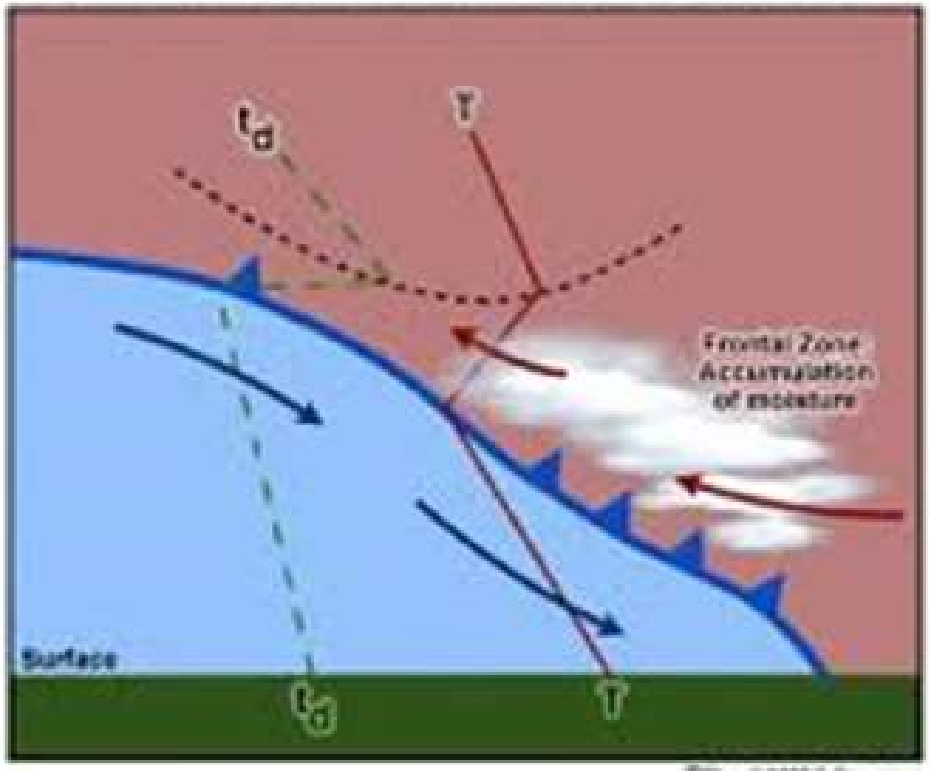


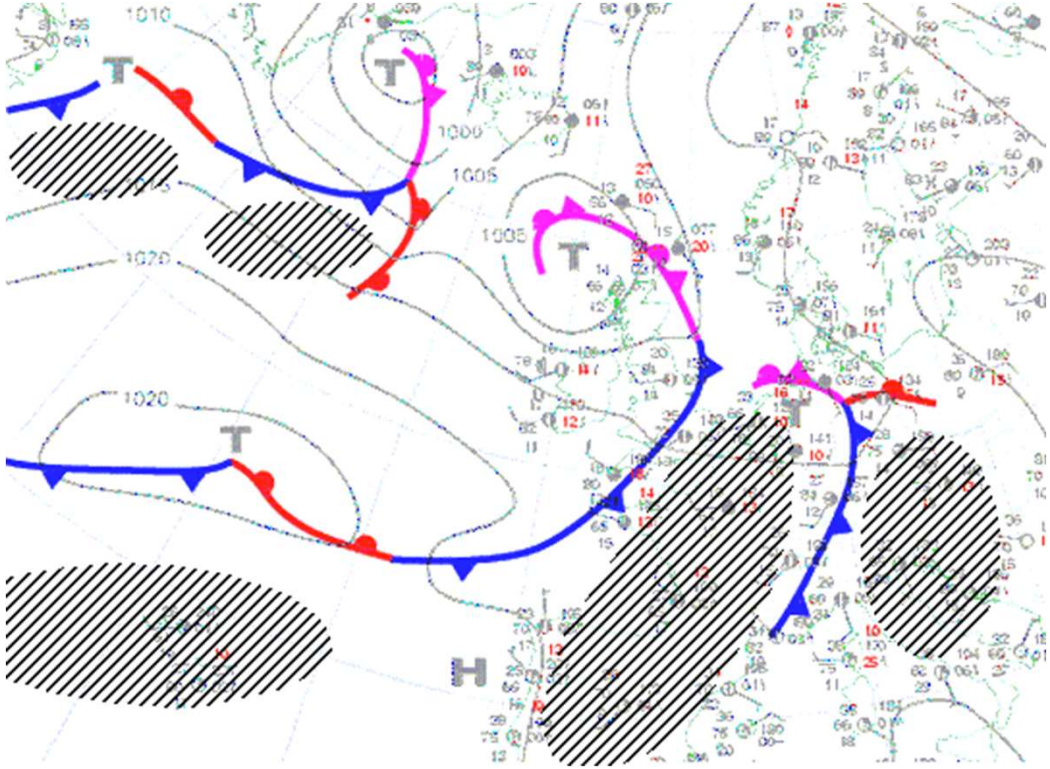
Microwave Propagation

- Ducts
  - Many types
    - Subsidence ducts – form from sinking air that becomes compressed and heated as it descends. This process often causes strong temperature inversions to form at altitudes ranging from 1,000 to 10,000 feet.
    - Sea breeze ducts – form where cooler sea breeze meets a warmer of land breeze.
    - Surface ducts – form where the ground cools by radiation forming a cool layer close to the ground with warmer air above it.
    - **Frontal ducts** – form where a wedge of cold air pushes under warm air to form a duct.
    - **Evaporative ducts** – form over water where the cooling near the surface from evaporation results in cool air below warm air and a temperature inversion.

Making a Microwave QSO

- Propagation: Frontal Duct





Making a Microwave QSO

- Propagation: Evaporative Duct

Evaporative duct over water where the distant shore line appears to be extended vertically.
From: Andrew Martin, VK3KAQ, VHF and Microwave Propagation Characteristics of Ducts, 2007.

Microwave Operating

- Fixed station or rover
- Location
- Which bands, where to start?

Making a Microwave QSO

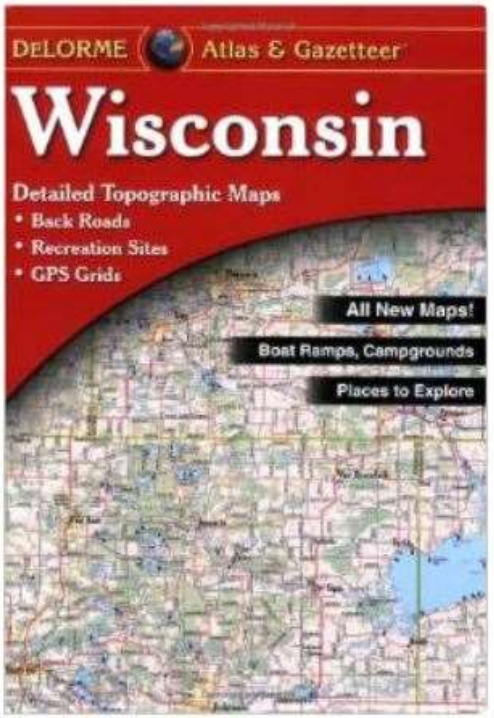
Making a Microwave QSO

Making a Microwave QSO

- **Location, location, location!**
  - Clear horizons
  - Watch out for obstructions that absorb microwaves
    - **Trees! Corn!**

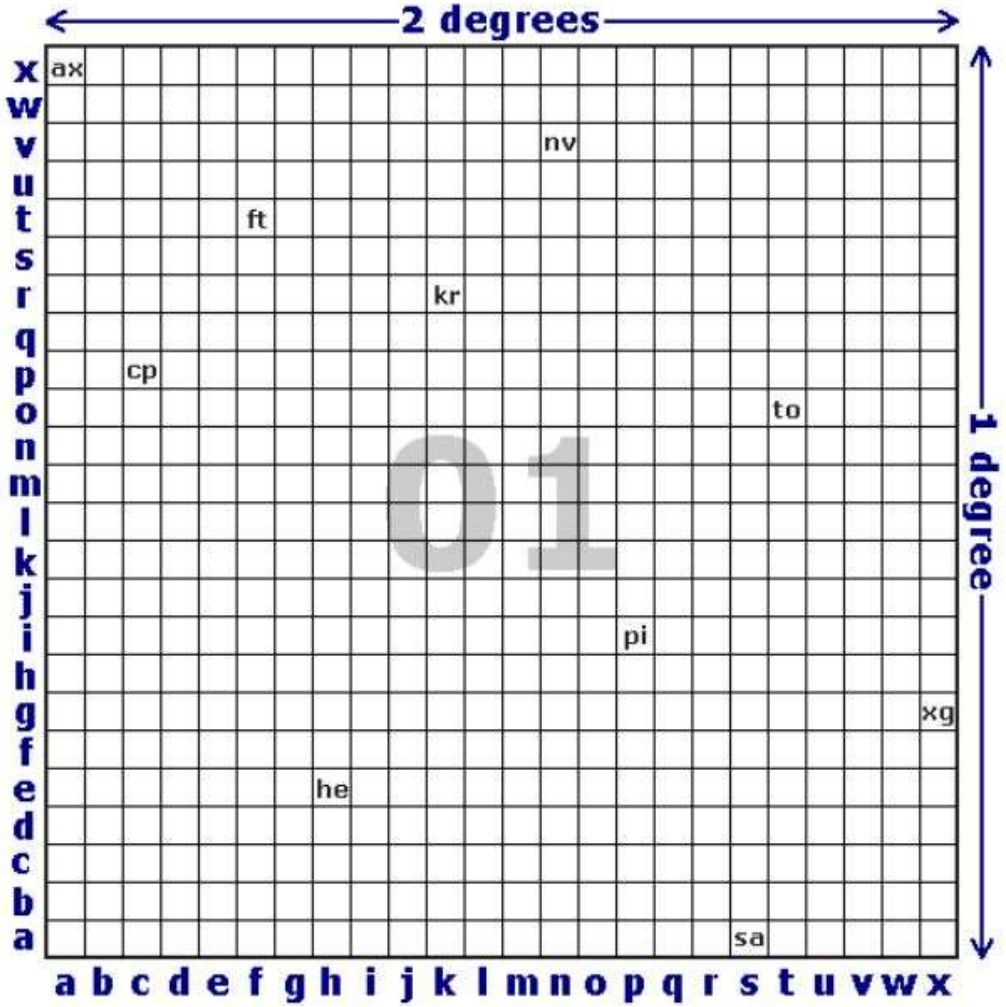
Making a Microwave QSO

- Roving: Choosing an operating site
  - Topographic road maps
    - Delorme state atlases especially useful
      - Elevation contours
      - Back roads, dirt roads, trails
  - HeyWhatsThat.com
    - Web-based terrain profile analysis



Making a Microwave QSO

- Know your 6-digit grid square!

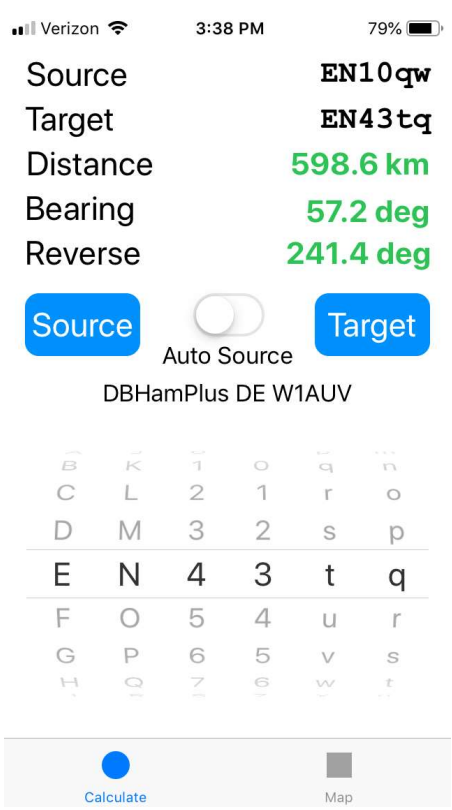


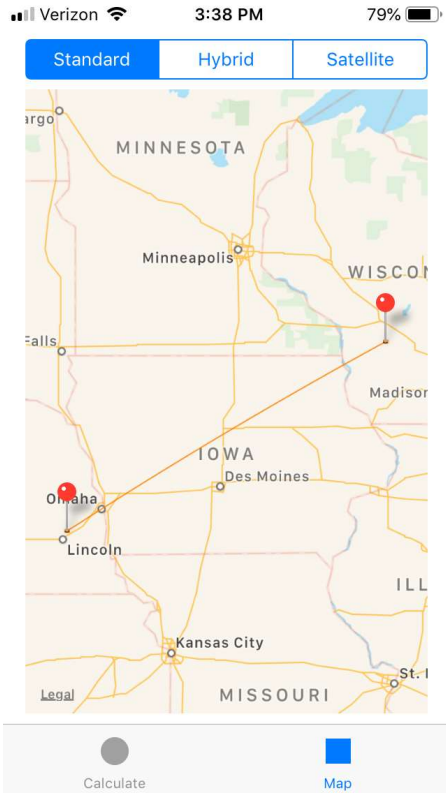
Making a Microwave QSO

- Getting pointed at each other
  - High gain microwave antennas are very sharp
    - DSS dish beamwidth at 10 GHz ~ 4 degrees!
    - Can't just point dish in a random direction and call CQ!
  - Coordination is therefore essential
  - Set up a "sked"
    - 2m SSB liaison (144.260 MHz)
    - Cell phone now more common

Making a Microwave QSO

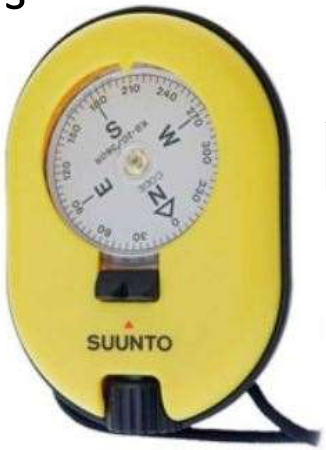
- Getting pointed at each other, continued
  - Know your grid square
    - Many Garmin GPS can provide your 6-character grid square
    - Smart phone apps & software available too
  - Compass and grid distance and bearing calculators
    - Smart phone apps available
    - iphone: DBHamPlus
    - Android: HamGPS





DBHamPlus

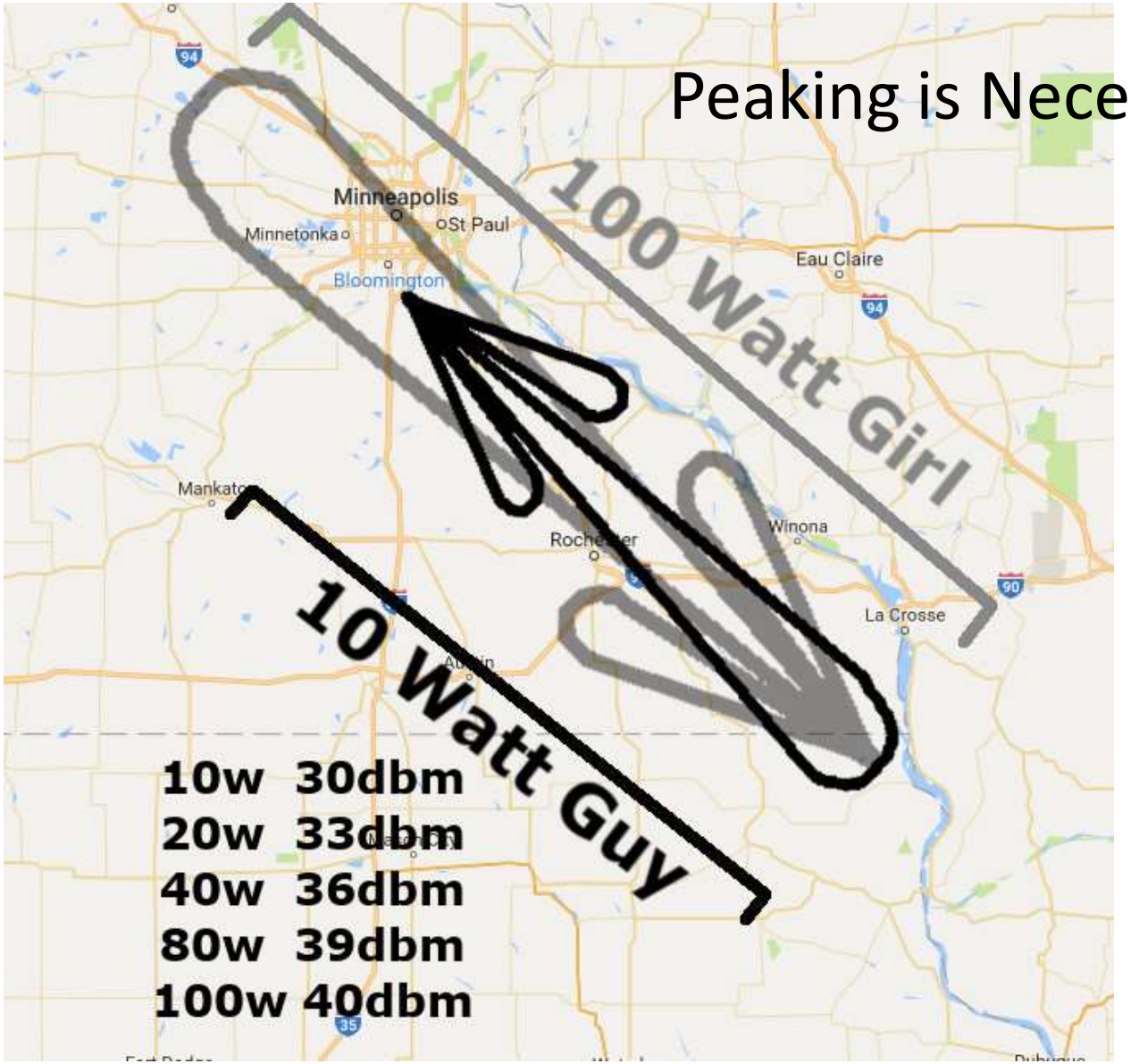
Suunto KB-20 Compass
- Highly recommended
- ~$50



Making a Microwave QSO

- Aiming the antenna
  - Horizontal (azimuth) and vertical (elevation) are equally important
  - Antennas are “pointy”
  - Who’s going to start transmitting 1st….beaconing
  - Peaking up
  - Once peaked, it’s your turn to beacon the other station so he can peak his dish on your signal

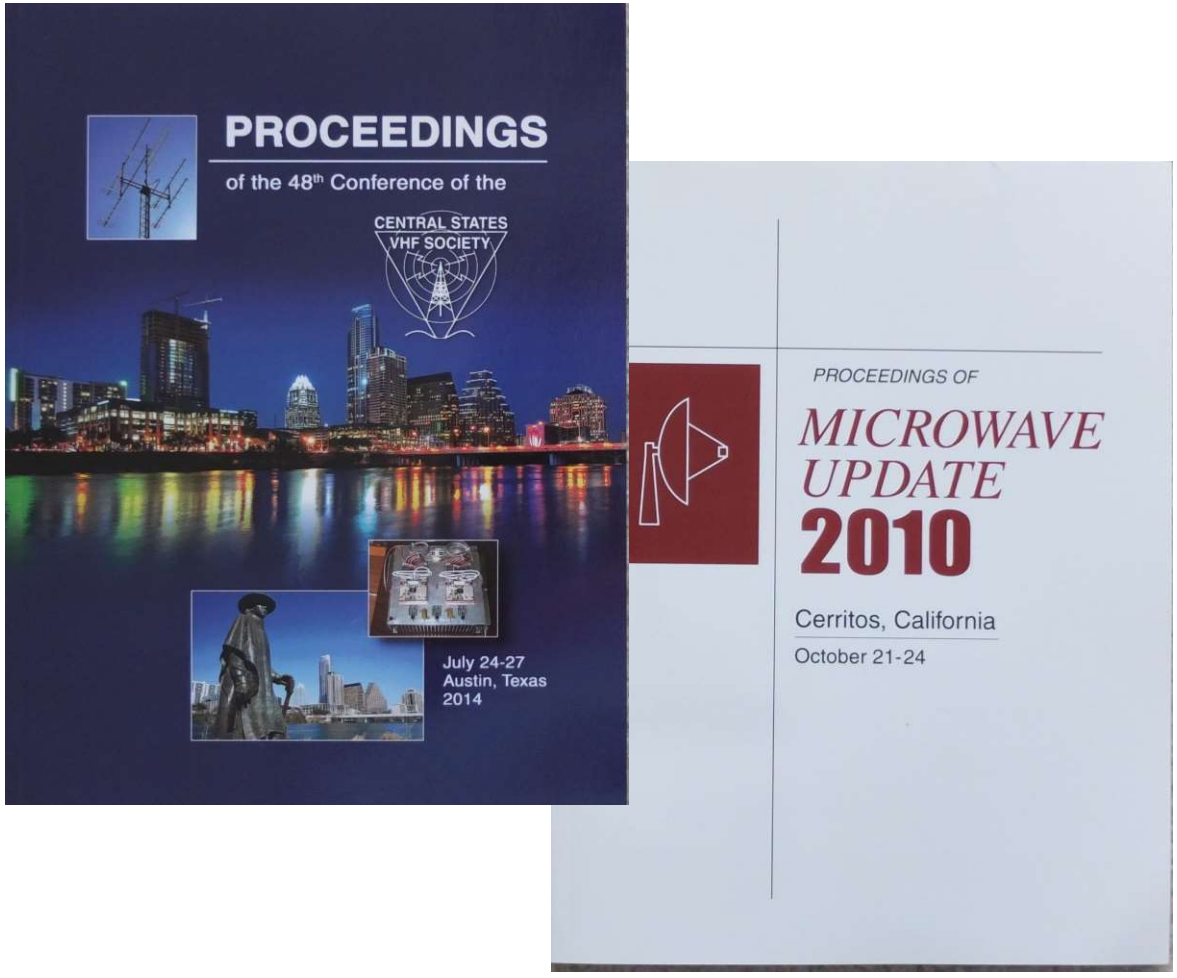
Making a Microwave QSO



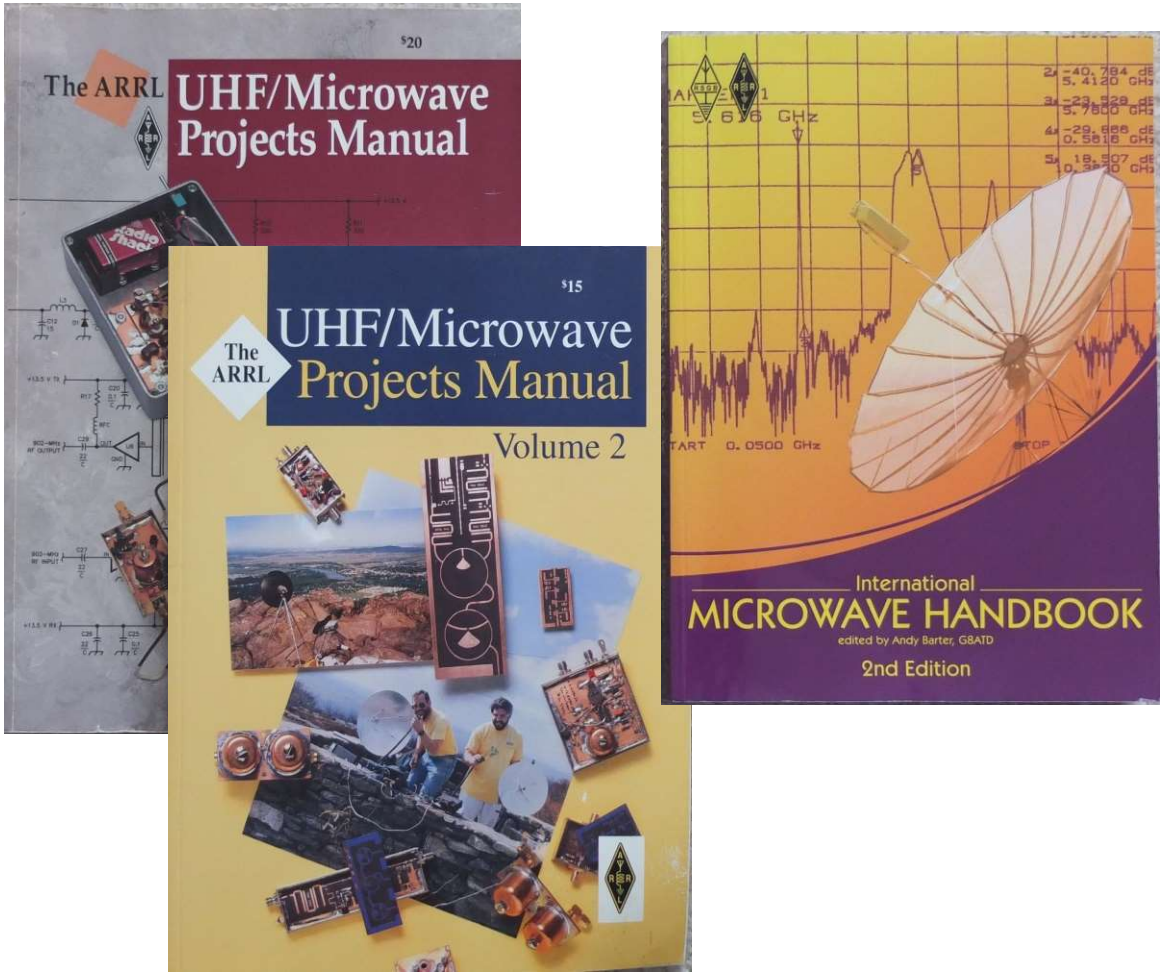
Making a Microwave QSO

Side lobes and nulls must be considered

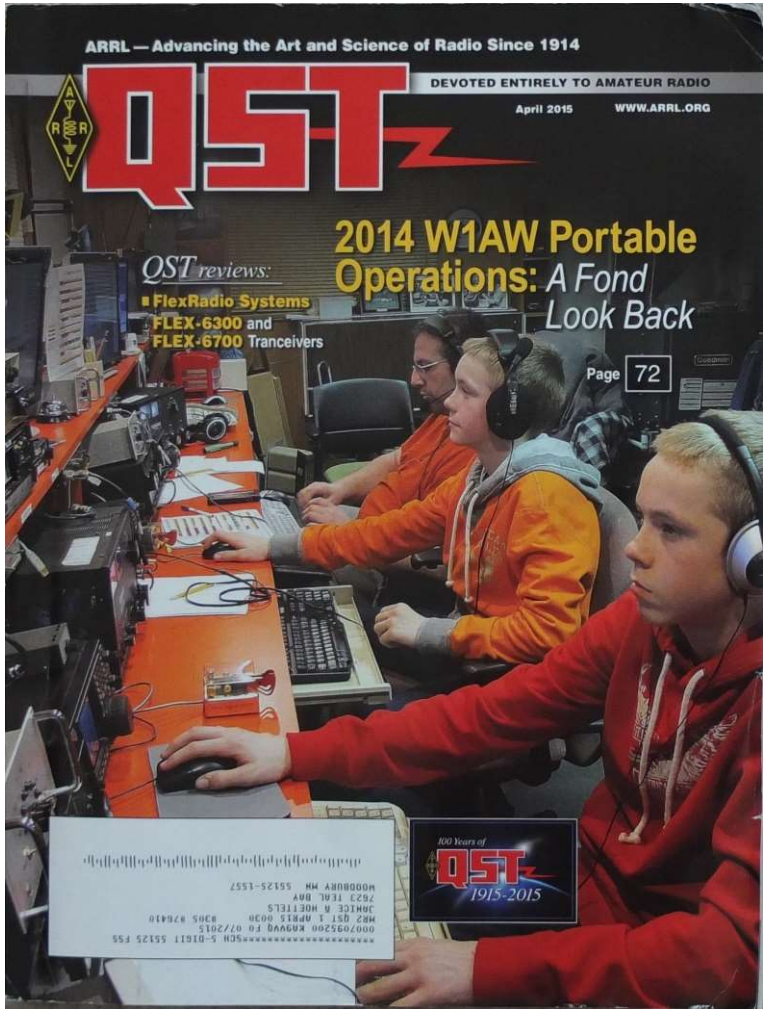
Resources


PROCEEDINGS
of the 48th Conference of the
CENTRAL STATES
VHF SOCIETY
July 24-27
Austin, Texas
2014
PROCEEDINGS OF
MICROWAVE
UPDATE
2010
Cerritos, California
October 21-24

Resources

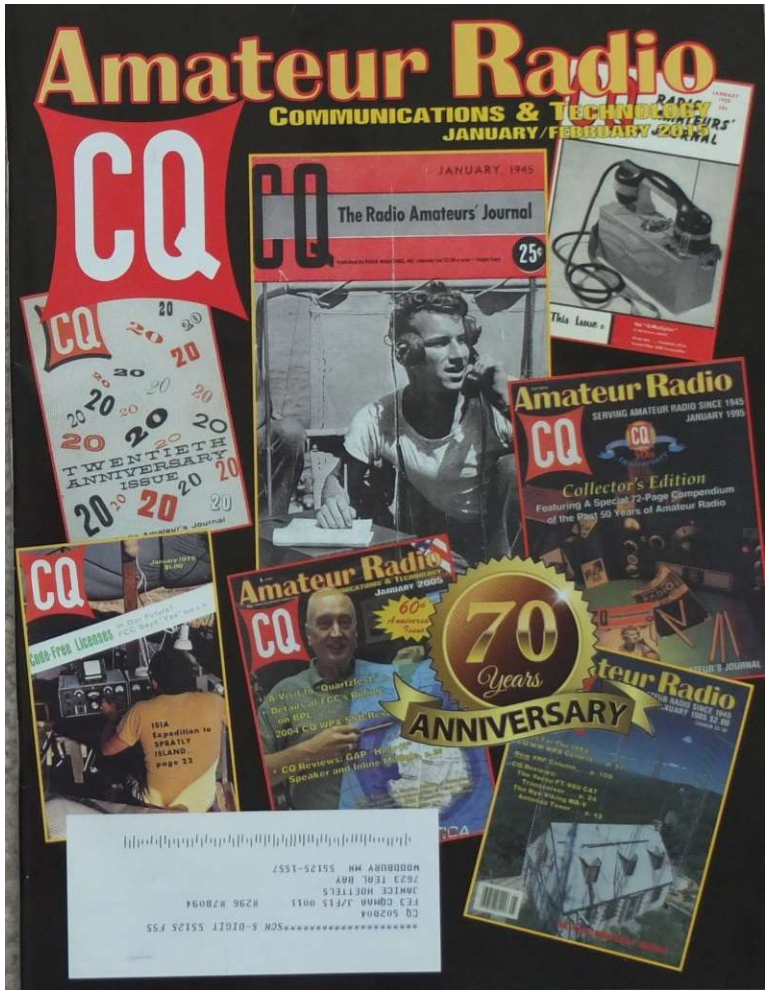

$20
The ARRL
UHF/Microwave
Projects Manual
$15
The
ARRL
UHF/Microwave
Projects Manual
Volume 2
International
MICROWAVE HANDBOOK
edited by Andy Barter, G8ATD
2nd Edition

Resources



- Microwavelengths
  - Paul Wade, W1GHZ
- World Above 50 MHz
  - Jon Jones, N0JK

Resources



- VHF Plus
  - Trent Fleming, N4DTF

Resources

- Microwave Groups:
  - Northern Lights Radio Society www.nlrs.org
  - Central States VHF Society www.csvhfs.org
  - Microwave Update (MUD) www.microwaveupdate.org
  - North East Weak Signal Group www.newsvhf.com
  - North Texas Microwave Society www.ntms.org
  - Roadrunners Microwave Group (South Texas) www.k5rmg.com
  - San Bernardino Microwave Society www.ham-radio.com/sbms
  - Pacific Northwest VHF Society www.pnwvhfs.org
  - Midwest VHF-UHF Society www.mvus.org
  - Southeastern VHF Society www.svhfs.org
  - Mt. Airy VHF Radio Club (Pennsylvania) www.packratvhf.com
  - Rochester (NY) VHF Group www.rvhfg.org
  - UK Microwave Group www.microwavers.org

Resources

- Microwave Reflector
  - https://www.mailmanlists.us/mailman/listinfo/microwave
- The W1GHZ Online Microwave Antenna Book
  - http://w1ghz.org/antbook/contents.htm

Questions?