# ANATOMY OF A REPEATER SITE

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LIMARC

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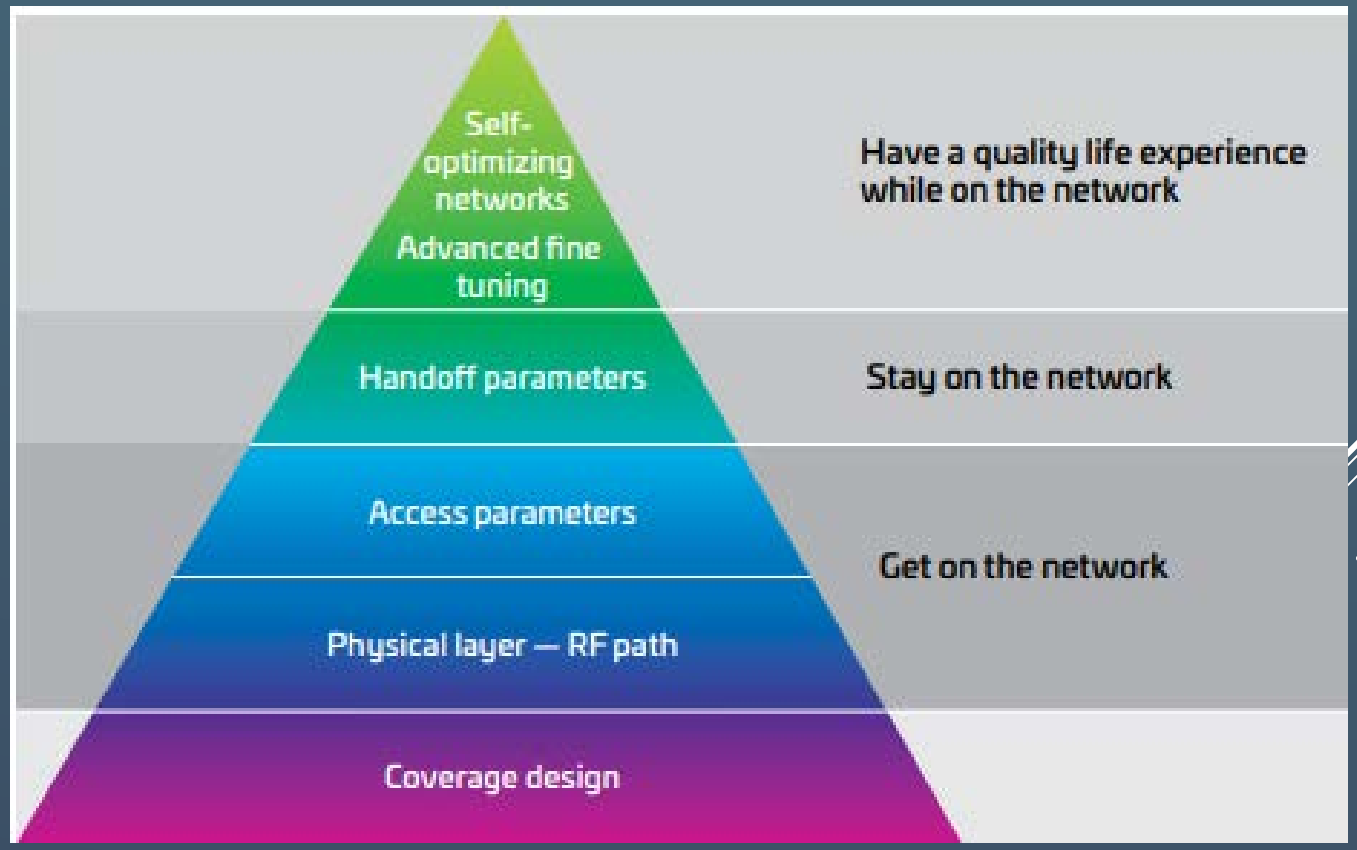
# AGENDA

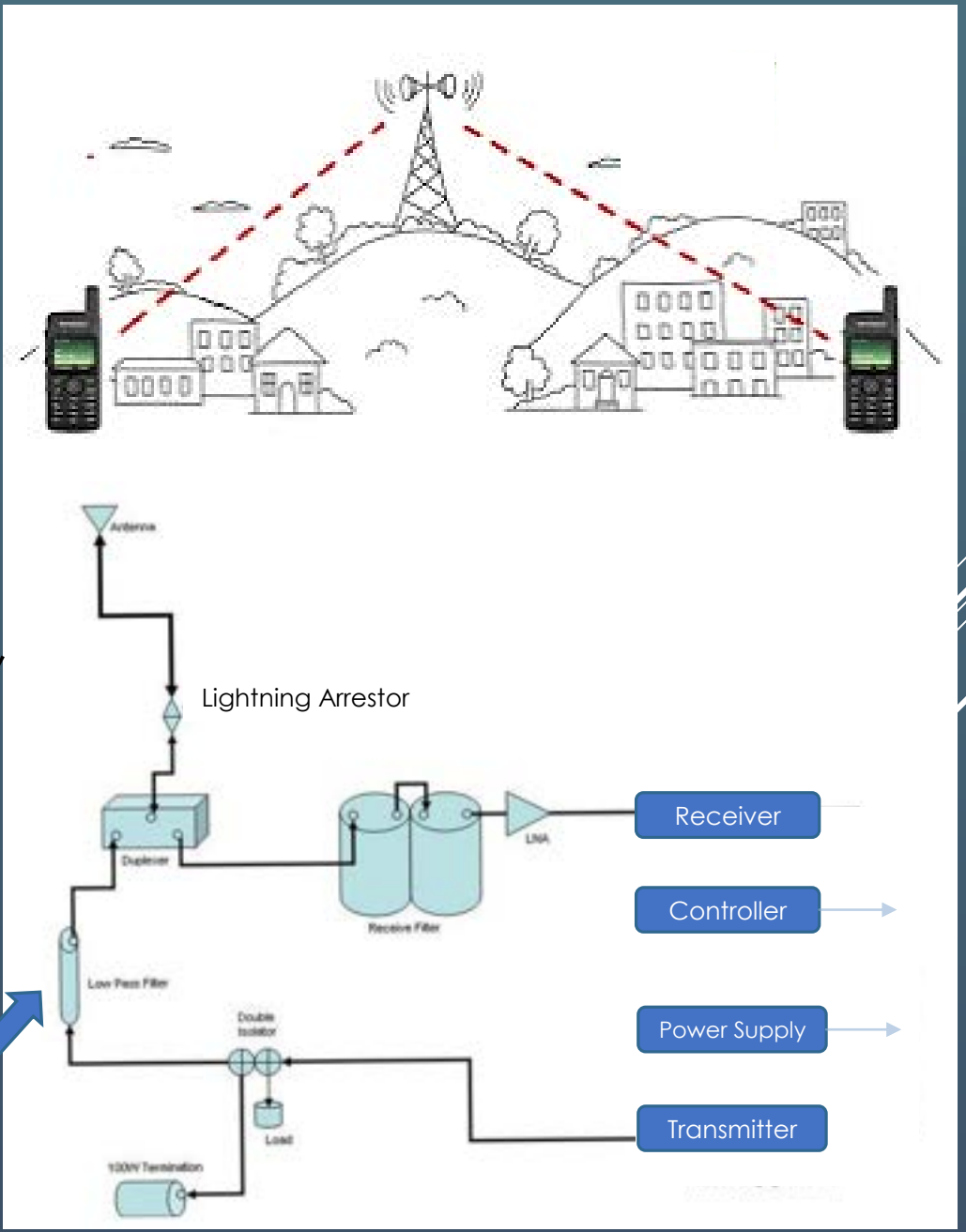
- What's Different about Repeaters vs. your Home Ham Radio Station
- What is a Repeater
- Coverage Area
- Site Environment
- Antenna System
- Power
- Receiver
- Transmitter
- Controllers
- Linking
- Security
- Laws & Regulations
- References



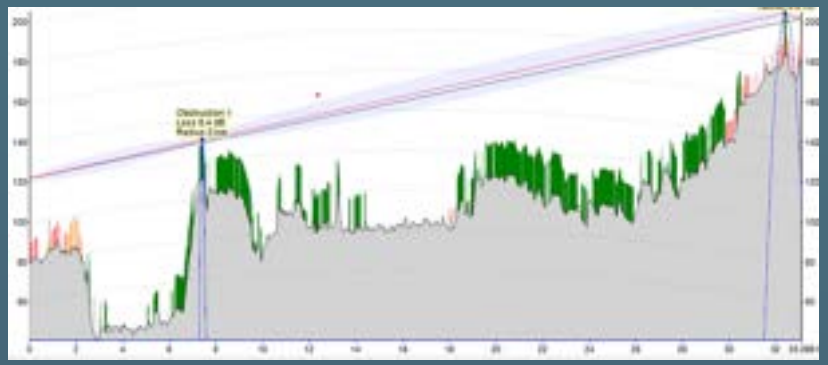
# WHAT IS A REPEATER

- A radio repeater is a receiver and a transmitter that receives a signal and retransmits it to cover longer distances. A repeater at a high elevation enables radios without line-of-sight to communicate.
- Most repeater systems use two different radio frequencies; the mobiles transmit on one frequency, and the repeater receives them and transmits on a second frequency.
- Since the repeater simultaneously transmits and receives, and may use the same antenna for both, very hi-Q RF filters prevent the receiver from being overloaded by the transmitted signal.

Low pass filter cleans off any harmonics that may be generated by the circulator



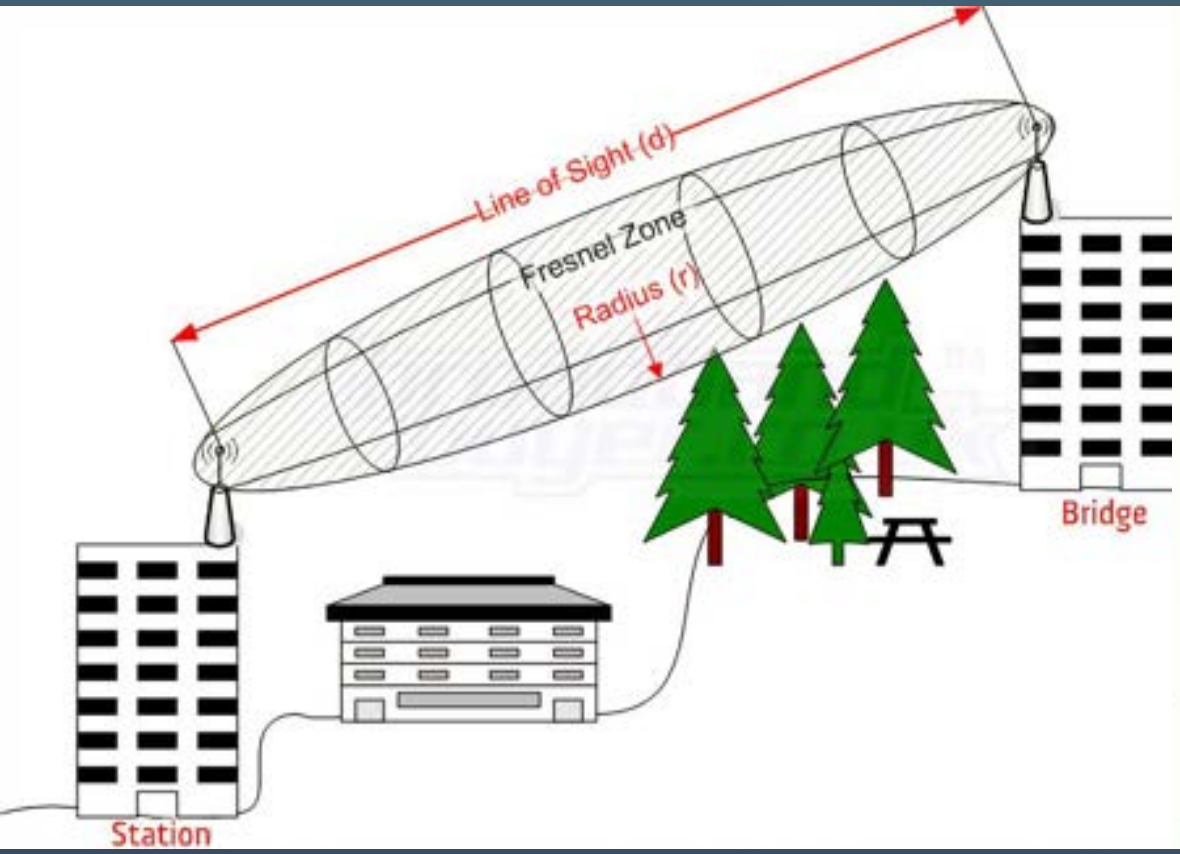
# COVERAGE AREA

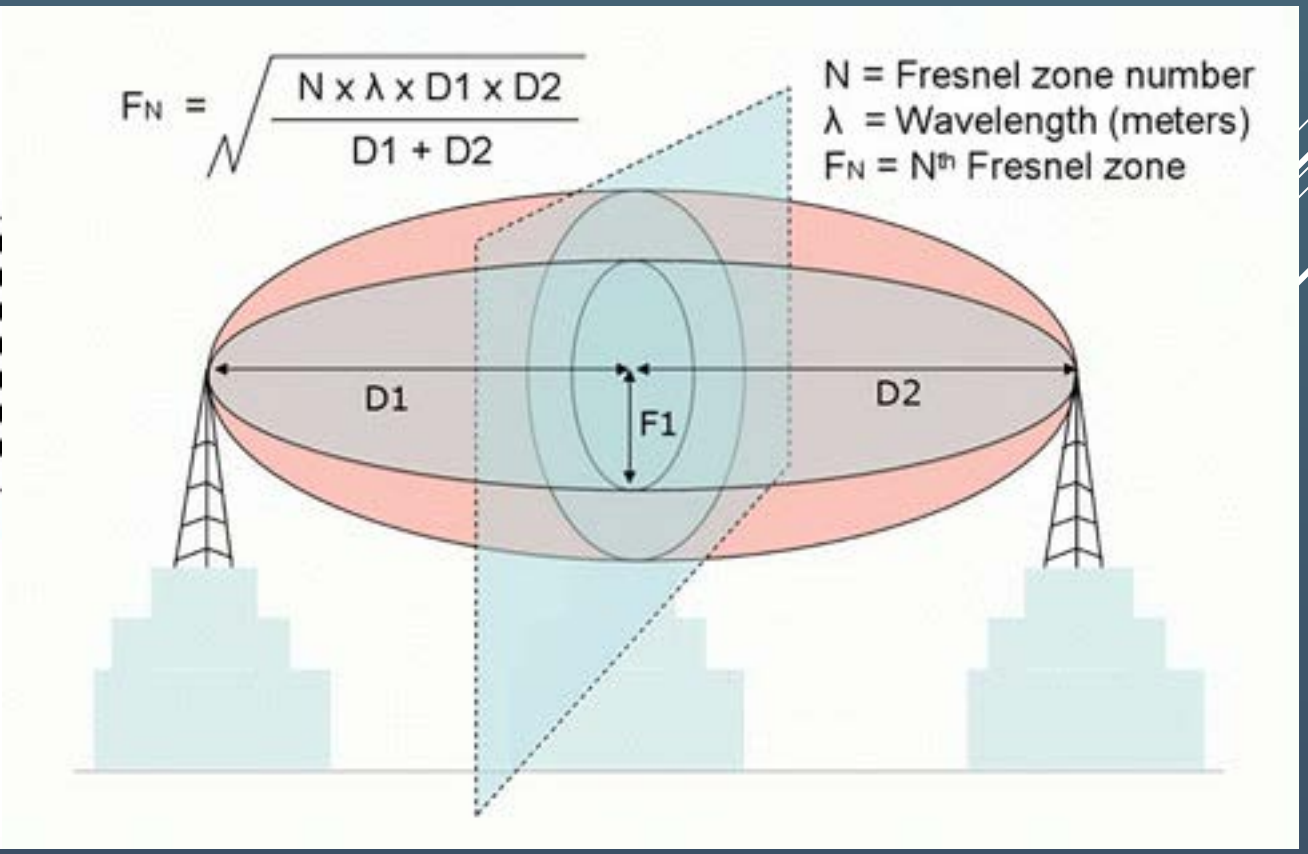


- 1st Step is to Determine Where Radio Coverage is Required
- Coverage is Based on Line-of-Site, Power Levels, and Channel Occupancy
- Strength of Mobile / Portable Stations Usually Limiting Factor
  - Assume handheld radio +30dBm (1 watt) transmit at a height of 1.5 meters (60")
  - Assume -6dB gain handheld antenna (typical rubber-duckie)
- Predict path loss and line-of-site
  - Path loss from Friis transmission equation : $$P_r^{[\mathrm{dB}]} = P_t^{[\mathrm{dB}]} + G_t^{[\mathrm{dBi}]} + G_r^{[\mathrm{dBi}]} + 20\log_{10}\left(\frac{\lambda}{4\pi d}\right)$$
  - Where λ is the wavelength, d is the distance between tx and rx antennas (λ and d must be in the same units, power is measured at the antenna feedpoint, power referred as dBm where 1 milliwatt = 0 dBm)
  - Line of site (distance to horizon) for h in meters and d in kilometers. $d = 3.57\sqrt{h}$
  - Don't forget about terrain obstacles along the path – use path mapping software
  - Calculate Fresnel Zone Clearance (mid-path usually worst case)
  - Perform at 3° Intervals for complete coverage picture (≥120 path radials from antenna site to LoS distance)
- Site Survey
  - Locate likely sites
  - Determine suitability

# FRESNEL ZONE CLEARANCE

Objects within the Fresnel zone can disturb line of sight propagation even if they don't block the geometric line between antennas.



# GLEN OAKS MOBILE COVERAGE
# 146.85 - 146.25

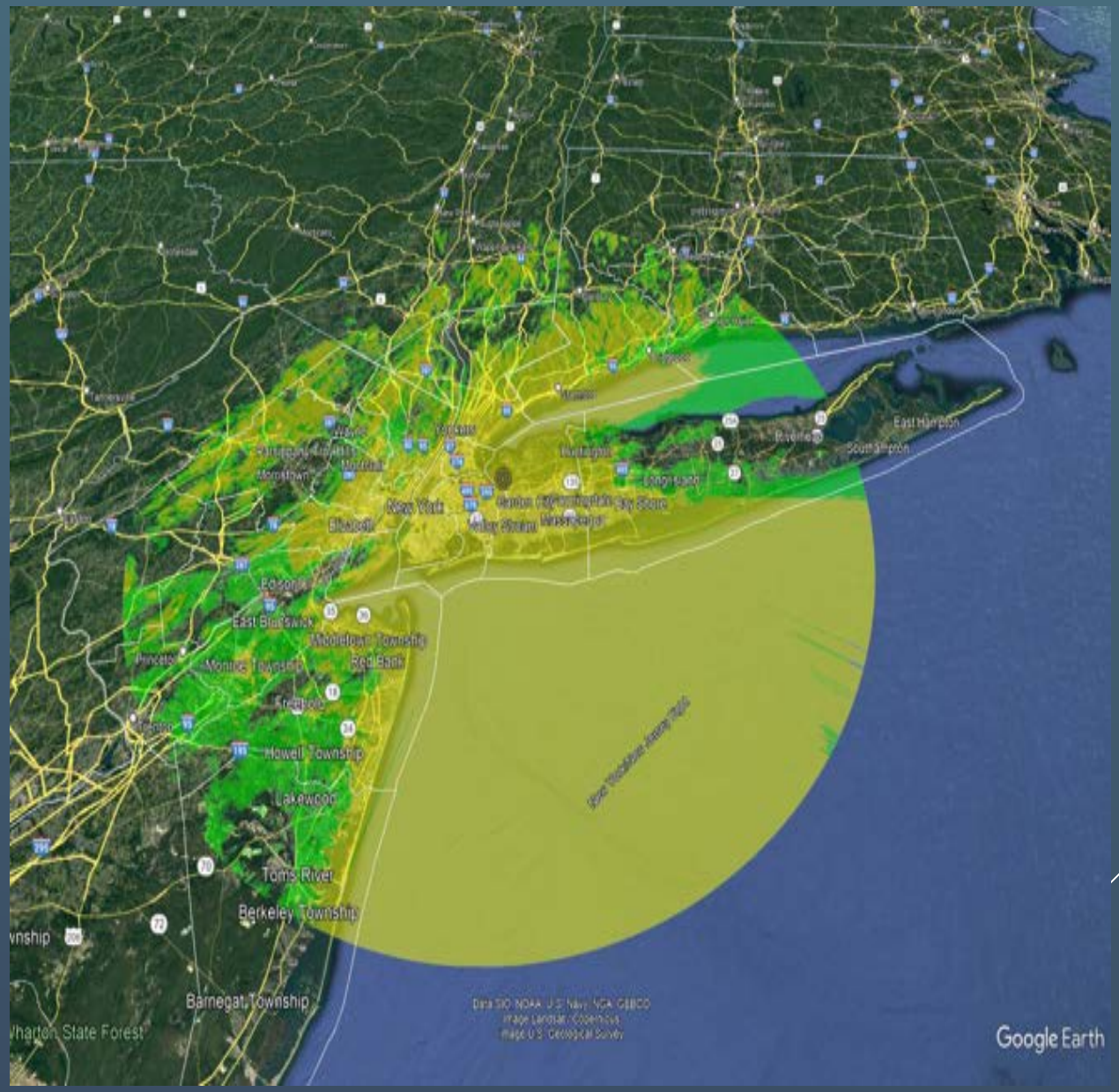
Repeater site is 78 Meters above sea level

Antenna site is 105 Meters above ground

2M Line of Site path estimated to be 48.3 Km or ≈ 30 miles

1st 2M Fresnel zone at LoS range estimated to be 24 meters

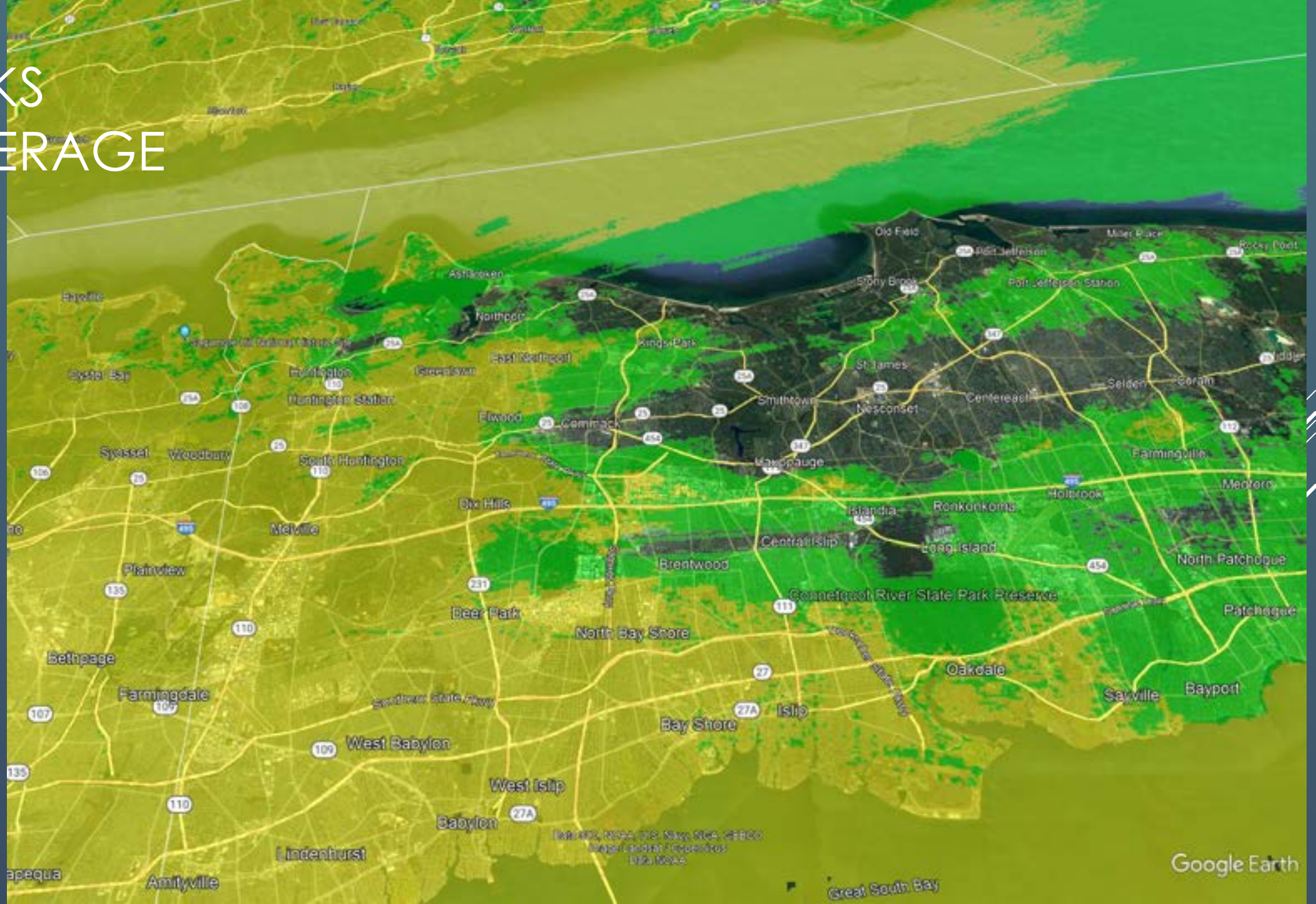
2M Receiver input power over a 42Km path estimated to be -78dBm from a 1watt hand-held radio with a rubber-duckie antenna



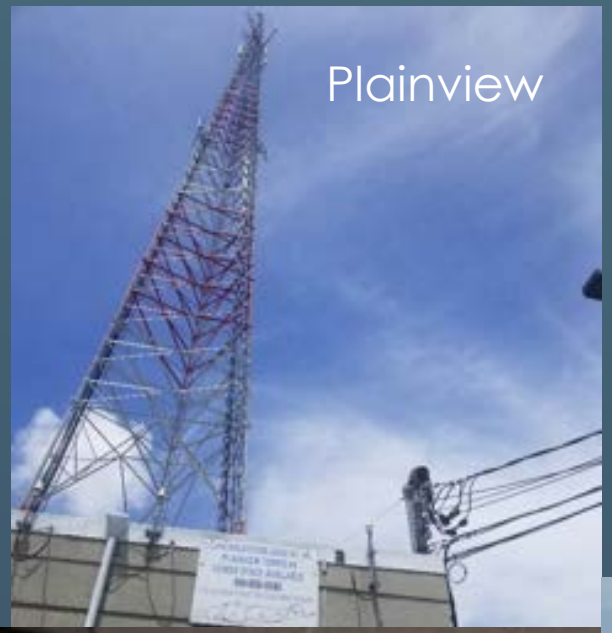

Legend
Yellow < 0 dBm
Green < -90 dBm

# GLEN OAKS VHF COVERAGE CLOSE-UP

Legend
Yellow < 0 dBm
Green < -90 dBm



# SITE ENVIRONMENT PICTURES








# ANTENNA SYSTEM

- Electrical – VSWR, Gain, Pattern, Beam Tilt
- Feedline – dB loss, power handling, connectors, pressurized vs dielectric
- Mechanical – Mount to prevent Aeolian flexure, ice build-up, shadowing
- Environmental:  lightning Arrester

Type N F/M Coaxial RF Surge Protector, 50MHz - 700MHz, DC Block, 200W, 313uJ, 50kA, Blocking Cap, Bracket Up, Hole Mount

IS-NEMP-C1-ME

**$150.99**

HELIAX® Coaxial Cable Selection Guide - 50-ohm, Foam Dielectric

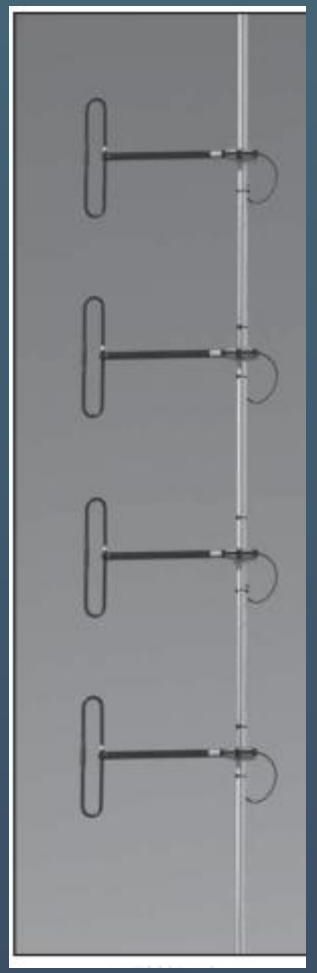
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Foam Dielectric, LDF Series | | | | |
| 1/4" 491 | 3/8" 493 | 1/2" 496 | 5/8" 500 | 7/8" 506 | 1-1/4" 513 | 1-5/8" 520 | 2-1/4" 524 |
| **Standard Cables** | | | | | | | |
| LDF1-50 | LDF2-50 | LDF4-50A | LDF4.5-50 | LDF5-50A | LDF6-50 | LDF7-50A | LDF12-50 |
| **Fire Retardant Cables** | | | | | | | |
| LDF1RN-50 | LDF2RN-50 | LDF4RN-50A | LDF4.5RN-50 | LDF5RN-50A | LDF6RN-50 | LDF7RN-50A | LDF12RN-50 |
| LDF1RN-50 | LDF2RN-50 | LDF4RN-50A | LDF4.5RN-50 | LDF5RN-50A | LDF6RN-50 | LDF7RN-50A | LDF12RN-50 |
| LDF1RN-50 | LDF2RN-50 | LDF4RN-50A | LDF4.5RN-50 | LDF5RN-50A | LDF6RN-50 | LDF7RN-50A | LDF12RN-50 |
| **Low VSWR Cables, Specially Tested** | | | | | | | |
| LDF1P-50-(**) | LDF2P-50-(**) | LDF4P-50A-(**) | LDF4.5P-50-(**) | LDF5P-50A-(**) | LDF6P-50-(**) | LDF7P-50A-(**) | LDF12P-50-(**) |
| **Special Application Cables** | | | | | | | |
| p. 590 | p. 590 | p. 590 | – | p. 590 | – | – | – |
| **Characteristics** | | | | | | | |
| 15800 | 13500 | 8800 | 6100 | 5000 | 3300 | 2500 | 2200 |
| 12.1 | 15.6 | 40 | 62 | 91 | 205 | 315 | 425 |
| 86 | 88 | 88 | 89 | 89 | 89 | 88 | 88 |
| 3 (76) | 3.75 (95) | 5 (125) | 8 (200) | 10 (250) | 15 (380) | 20 (510) | 24 (610) |
| **Attenuation, dB/100 ft (dB/100 m) Standard conditions: VSWR 1.0: ambient temperature 20°C (68°F).** | | | | | | | |
| 0.667 (2.19) | 0.563 (1.85) | 0.357 (1.17) | 0.254 (0.834) | 0.195 (0.641) | 0.135 (0.444) | 0.109 (0.356) | 0.091 (0.299) |
| 1.23 (4.05) | 1.04 (3.42) | 0.661 (2.17) | 0.473 (1.55) | 0.364 (1.19) | 0.254 (0.832) | 0.205 (0.671) | 0.173 (0.566) |
| 2.71 (8.88) | 2.29 (7.51) | 1.45 (4.75) | 1.05 (3.46) | 0.808 (2.65) | 0.571 (1.87) | 0.467 (1.53) | 0.400 (1.31) |
| 4.16 (13.6) | 3.52 (11.6) | 2.22 (7.28) | 1.64 (5.38) | 1.25 (4.12) | 0.897 (2.94) | 0.742 (2.43) | 0.644 (2.11) |
| 6.10 (20) | 5.17 (17) | 3.25 (10.7) | 2.44 (8.02) | 1.86 (6.11) | 1.35 (4.43) | 1.13 (3.71) | 0.994 (3.26) |
| 11.5 (37.7) | 9.79 (32.1) | 6.11 (20.1) | 4.76 (15.6) | – | – | – | – |
| 15.7 (51.5) | 13.4 (43.9) | – | – | – | – | – | – |
| **Average Power Rating, kW Standard conditions: VSWR 1.0: ambient temperature 40°C (104°F): inner conductor temperature 100°C (212°F): no solar loading.** | | | | | | | |
| 3.32 | 4.14 | 6.46 | 9.57 | 14.1 | 22.0 | 30.9 | 39.8 |
| 1.79 | 2.24 | 3.49 | 5.14 | 7.56 | 11.7 | 16.4 | 21.0 |
| 0.818 | 1.02 | 1.59 | 2.31 | 3.41 | 5.22 | 7.18 | 9.06 |
| 0.533 | 0.663 | 1.04 | 1.48 | 2.19 | 3.32 | 4.52 | 5.64 |
| 0.363 | 0.451 | 0.710 | 0.996 | 1.48 | 2.21 | 2.96 | 3.65 |
| 0.193 | 0.239 | 0.378 | 0.511 | – | – | – | – |
| 0.141 | 0.175 | – | – | – | – | – | – |

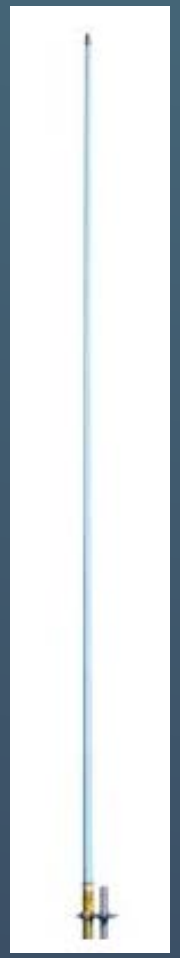
***Passive intermodulation (PIM)***

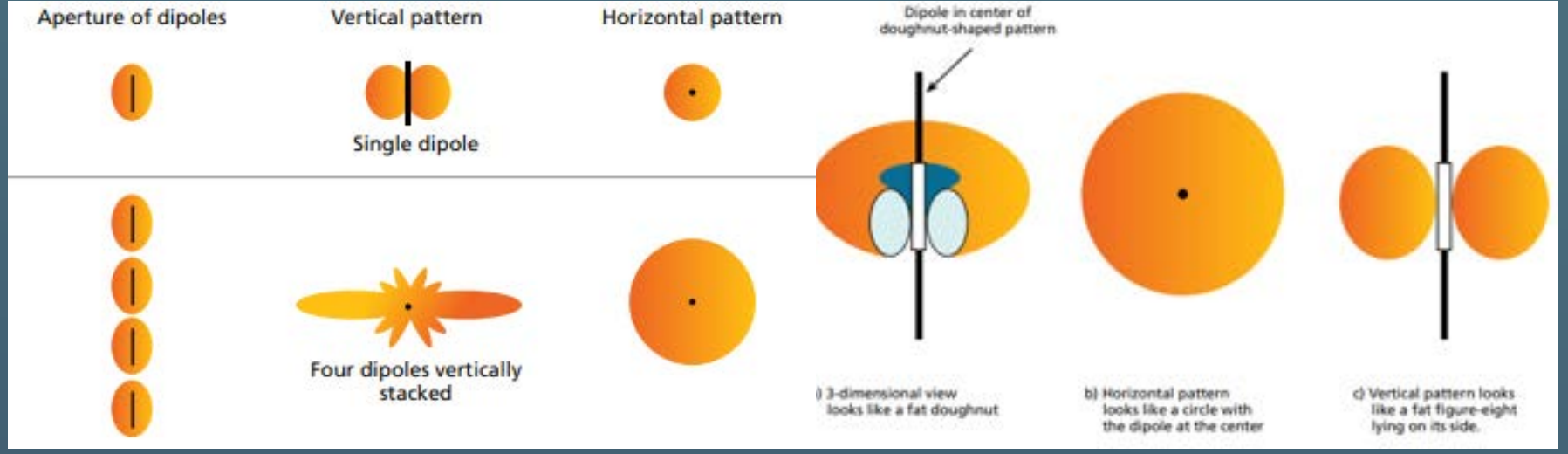
A potential side effect of having more than one high-powered signal operating on a passive device such as a cable or antenna.

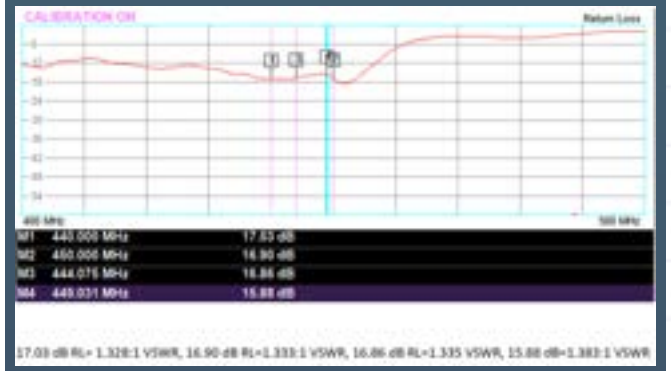
PIM occurs at non-linear points in a system, such as junctions, connections or interfaces between dissimilar metal conductors—creating interfering frequencies that can decrease efficiency. The higher the signal amplitude, or power, the greater the effect.

# ANTENNA





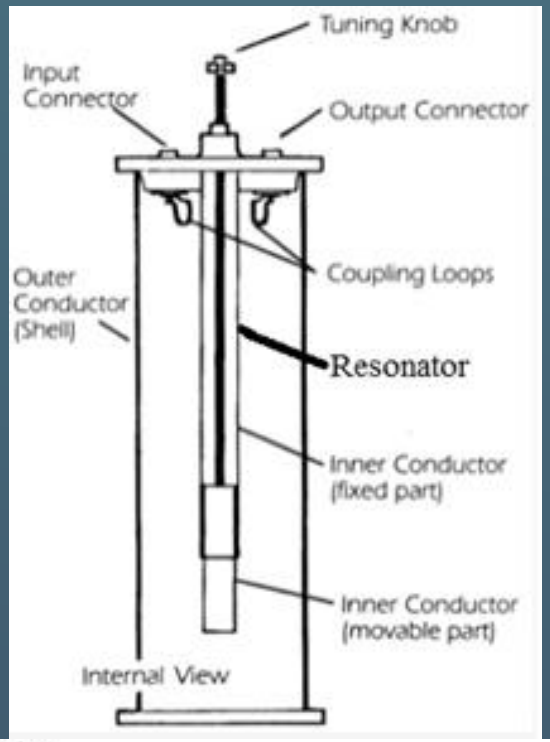


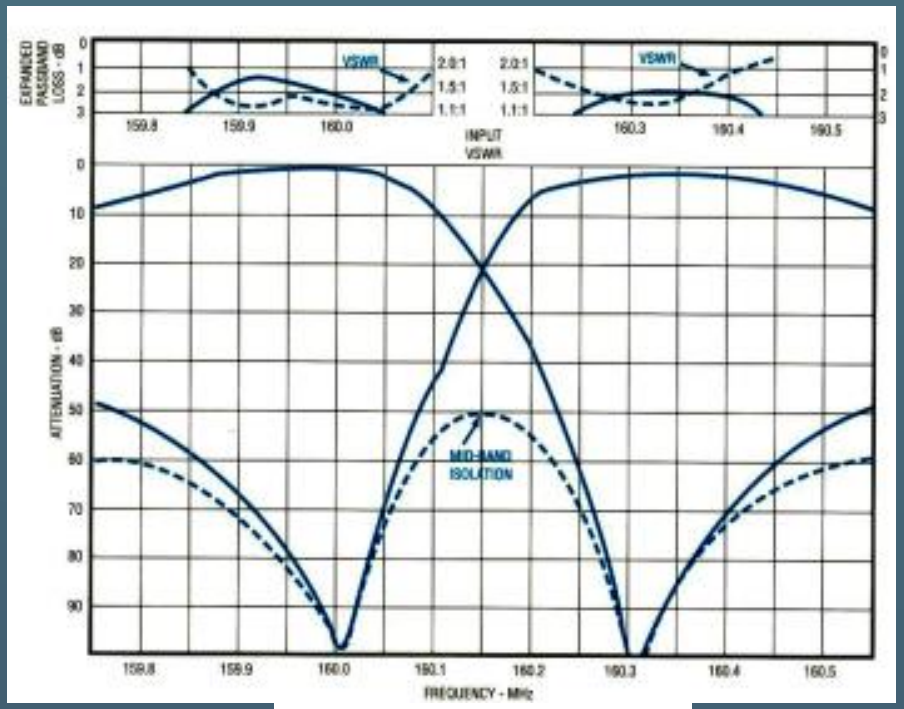
| | | | |
|---|---|---|---|
| Item Weight | 32 lb | Vertical Beamwidth | 20 deg |
| Item Height | 256 in | Maximum VSWR | 1.5:1 |
| Item Width | 2.75 in | Maximum Rated Wind Velocity | 150 mile/h |
| Item Length | 2.75 in | Tuned Frequency (MHz) | 144-151 |
| Gain dBd | 6 dBd | Lightning Protection | DC Ground |
| Gain dBi | 8.15 dBi | Lateral Thrust @ RWV (lb) | 162 Lbs. @ 100 MPH |
| Jumper Included | Yes | Support Pipe Dia. | 2.75" |
| RF Connectors | N Female | Support Pipe Length | 26" |
| Polarization | Vertical | Frequency Band | VHF |
| Specific Frequency | 144-151 MHz | | |

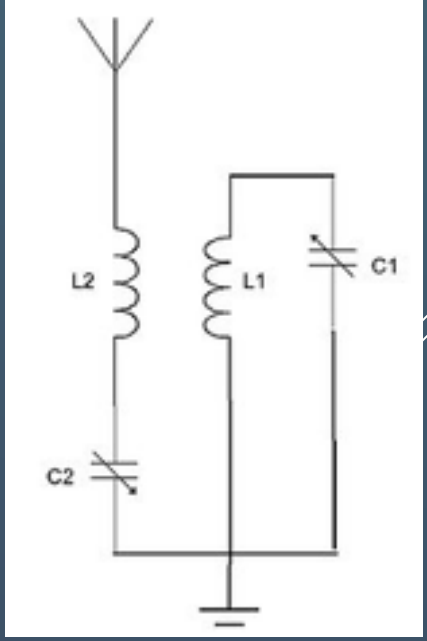
# RF CAVITY FILTERS

The Q201 series duplexers utilizes Sinclair's Q-circuit design in a 6-cavity configuration to provide very high attenuation at extremely close frequency separation in the 132-148 MHz band. This design provides a quasi-bandpass response, resulting in suppression of spurious and sideband transmitter noise between, and adjacent to, the duplex frequencies. The typical isolation attained between duplex frequencies is greater than 50 dB.




| Electrical Specifications | | |
|---|---|---|
| Frequency Range | MHz | 132 to 148 |
| Input VSWR (max) | | 1.5:1 |
| Impedance | Ω | 50 |
| Average Power Input (max) | W | 350 |
| Connectors | | N-Female |
| Frequency separation (min) | MHz | 0.3 |
| Insertion Loss (max) Tx to Ant | dB | 2.2 |
| Isolation (min) | dB | 95 |
| **Mechanical Specifications** | | |
| Width | in (mm) | 19 (483) |
| Depth | in (mm) | 15 (381) |
| Length/ Height | in (mm) | 61 (1549) |
| Weight | lbs (kg) | 95 (43.13) |
| Shipping weight (package 1) | lbs (kg) | 60 (27.24) |
| Shipping weight (package 2) | lbs (kg) | 60 (27.24) |
| Shipping dimensions (package 1) | in (mm) | 22x18x38 (559x457x965) |
| Shipping dimensions (package 2) | in (mm) | 22x18x38 (559x457x965) |
| Mounting configurations | | 19 inch rack |
| **Environmental Specifications** | | |
| Temperature range | °F (°C) | -40 to +140 (-40 to +60) |



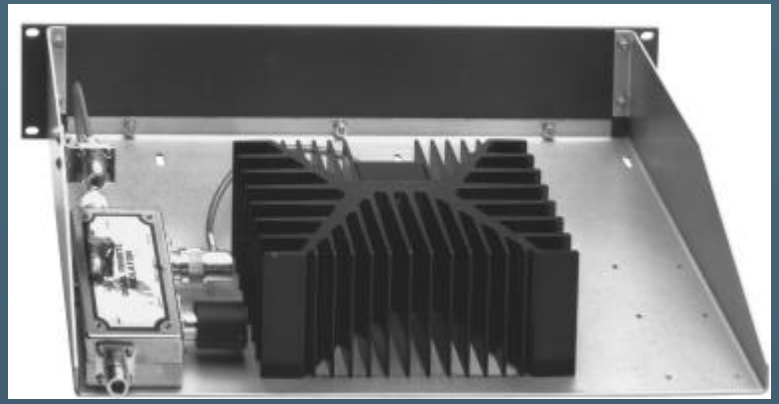



Dual stage isolator with 30+125 Watt load provides 75 dB (typ) isolation
Can be tuned over the 132-174 MHz band and comes with built-in harmonic filters

# CIRCULATOR / ISOLATOR

| Mechanical Specifications | | |
|---|---|---|
| Width | in (mm) | 19 (483) |
| Depth | in (mm) | 9.13 (232) |
| Length/ Height | in (mm) | 3.5 (89) |
| Actual shipping weight | lbs (kg) | 20 (9.08) |

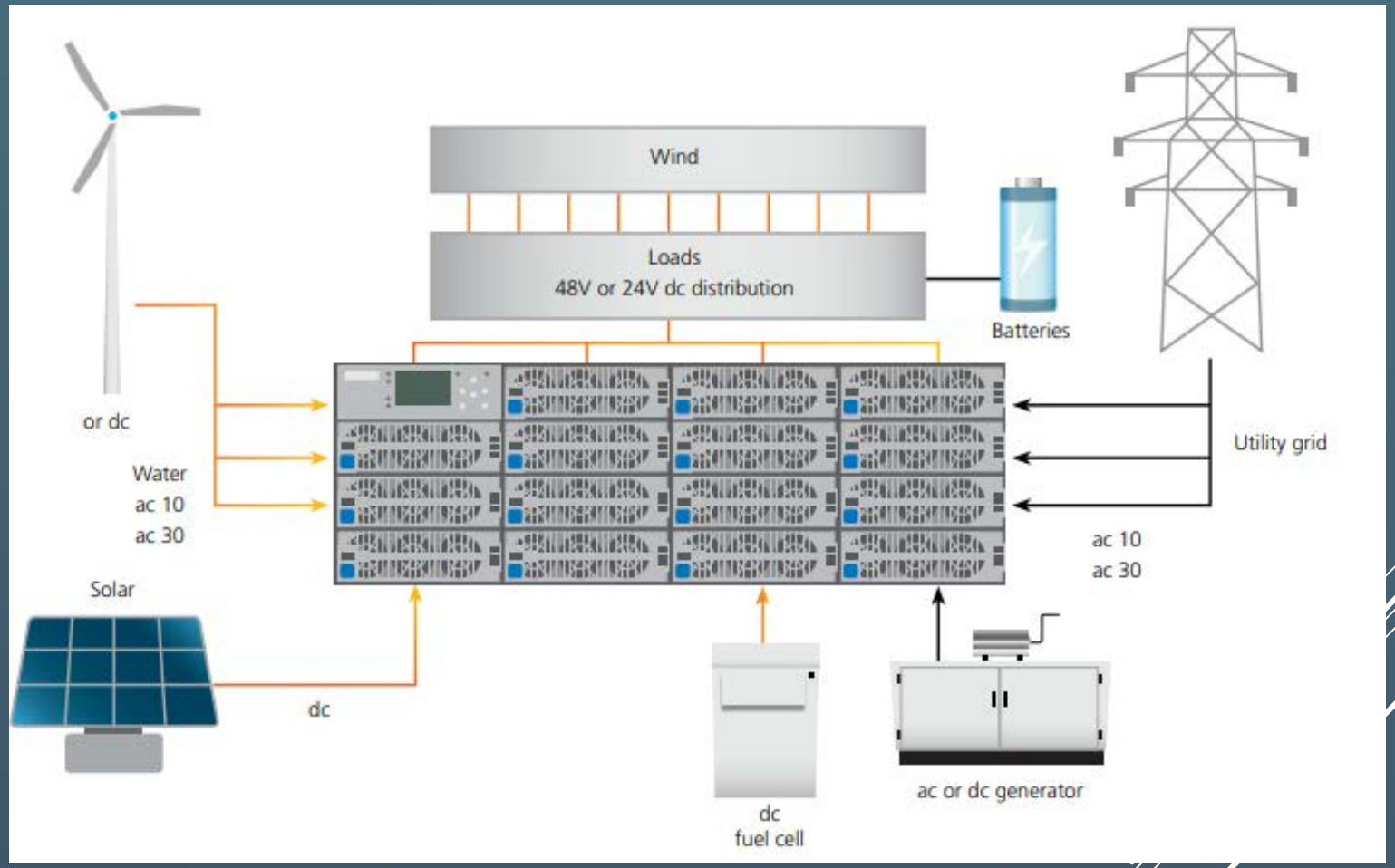
| Electrical Specifications | | |
|---|---|---|
| Frequency Range | MHz | 132 to 174 |
| Bandwidth | MHz | 5 |
| VSWR (max) | | 1.25:1 |
| Isolation (typ) | dB | 75 |
| Average Power Input (max) | W | 125 |
| Connectors | | N-Female |
| Insertion Loss (typ) Tx to Ant | dB | 0.7 |
| Insertion Loss (max) Tx to Ant | dB | 1 |
| Isolation (min) | dB | 50 |



Ferrite isolators and circulators generate harmonics
An isolator / circulator should usually be followed by a bandpass or low pass filter

# POWER

- Commercial 60Hz
  - 120 v / 240 v / 440v
  - Access to Breaker Box
  - Arc Fault / Ground Fault
  - Surge Protection
  - Locking Connectors (Twist-Lok)
- UPS
  - Battery Backup / Inverter
  - Generator / Auto Start
  - Fossil Fuel Source  (runtime)
  - Transfer Switch
  - Renewable  (solar / wind)
- Keep record of Power Availability with time stamp logs of all outages
- Document all sharing arrangements (keys, fuses, breaker box access, etc.) with other site users / site management



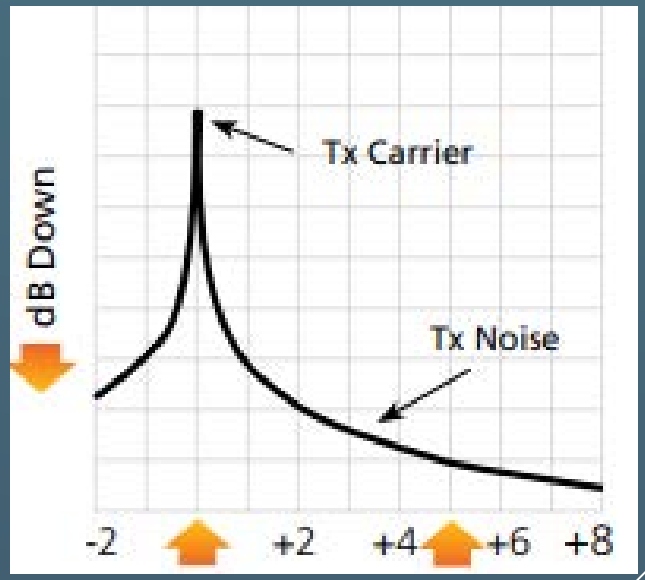
# RECEIVER


- RF Input  (µV or dBm for full quieting)
- Desensitization - Rx picks up noise energy from Tx thus lowering S/N ratio
- IF Output (Translator)
- Audio Output to Mixer Bus, Local Site Speaker
- Valid Carrier Detect
  - Nice to have RSSI in dBm sysd logged and time stamped
- PL Present /PL Output – reverse burst results in no burst of squelch noise being heard.
- Discriminator Output
- Status Outputs (test points)
- Power Supply Input

| Code | Tone Freq. | Code | Tone Freq. | Code | Tone Freq. |
|---|---|---|---|---|---|
| XZ | 67.0 | 1B | 107.2 | 6A | 173.8 |
| WZ | 69.3 | 2Z | 110.9 | 6B | 179.9 |
| XA | 71.9 | 2A | 114.8 | 7Z | 186.2 |
| WA | 74.4 | 2B | 118.8 | 7A | 192.8 |
| XB | 77.0 | 3Z | 123.0 | M1 | 203.5 |
| WB | 79.7 | 3A | 127.3 | 8Z | 206.5 |
| YZ | 82.5 | 3B | 131.8 | M2 | 210.7 |
| YA | 85.4 | 4Z | 136.5 | M3 | 218.1 |
| YB | 88.5 | 4A | 141.3 | M4 | 225.7 |
| ZZ | 91.5 | 4B | 146.2 | 9Z | 229.1 |
| ZA | 94.8 | 5Z | 151.4 | M5 | 233.6 |
| ZB | 97.4 | 5A | 156.7 | M6 | 241.8 |
| 1Z | 100.0 | 5B | 162.2 | M7 | 250.3 |
| 1A | 103.5 | 6Z | 167.9 | 0Z | 254.1 |

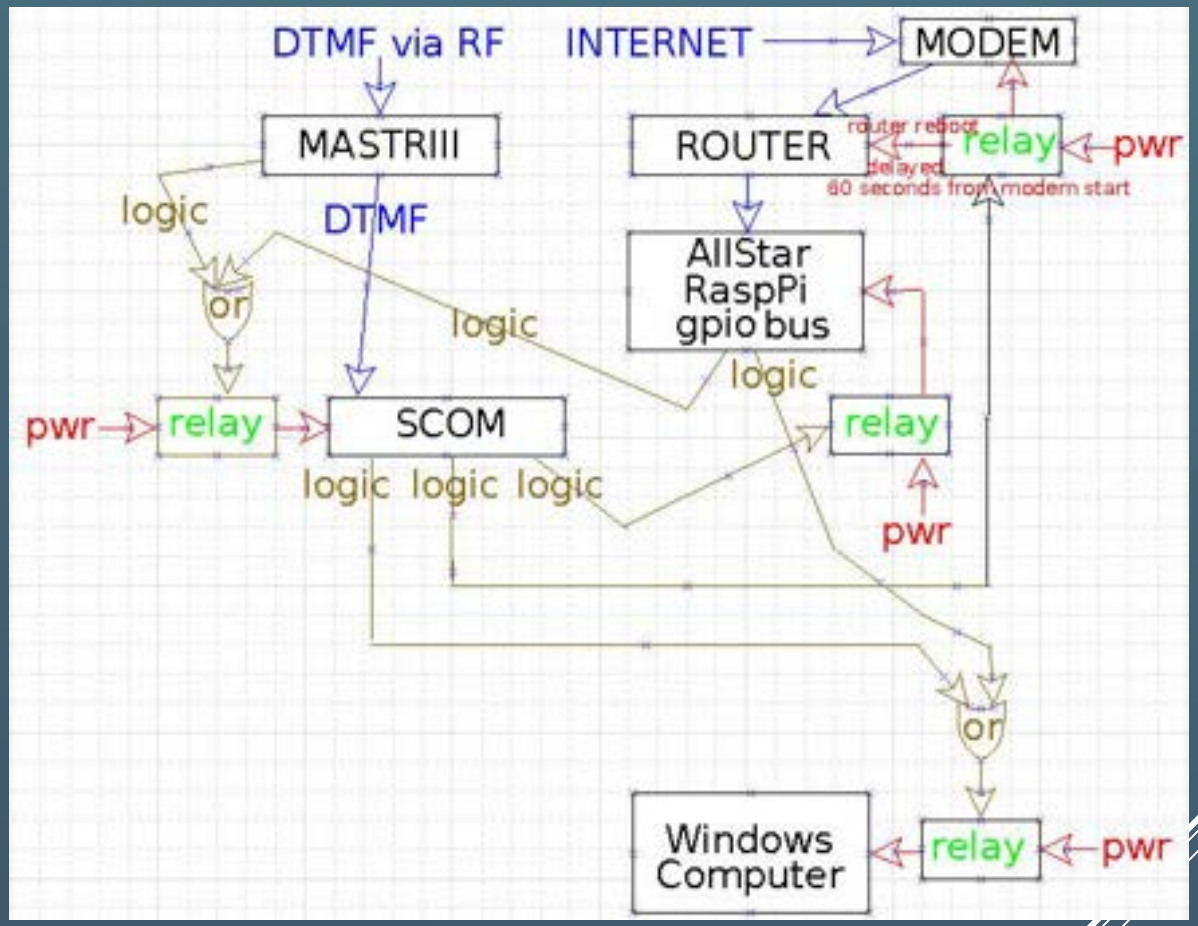
# TRANSMITTER

- RF Output  (1 to 250 watts, 30 dBm to 54dBm)
- Power Supply Input  (monitor Tx current drain)
- Audio Input (output of audio mixing bus)
- PL Handling
- IF Input (Translator)
- Carrier Enable (PTT) – audio delay from PTT to full output
- VSWR Detection and Alarm notification
- Transmitter AM and Phase Noise
- Status Outputs



# CONTROLLERS

- Local Control Panel
- Control via Landline / Internet
- Control via Radio Link
- Audio Mixing Buss
- Syslog Daemon
- Time Synchronization (NTP)
- Message Record / Store / Playback  (news line & announcement  function)
- Security Precautions




# BACKHAUL & LINKING

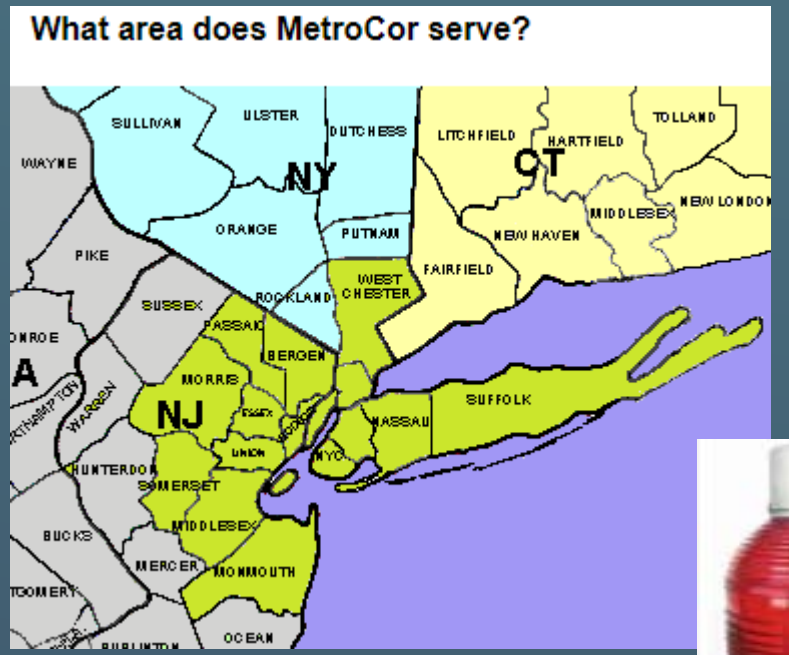

- Land Line
- Internet Interface
- **AllStarLink** is a world wide network of repeaters, remote base stations, and hot spots accessible to each other via the Internet and/or private IP networks. AllStar software runs on a dedicated Linux computer (including the Raspberry Pi). AllStar is based on the open source Asterisk PBX and is released under the GNU GPL. The core of AllStar and AllStarLink is the powerful app_rpt application and associated modules that load into the Asterisk PBX system.
- IRLP / Internet VoIP
- RF Link

# SECURITY

- Availability  - improving MTBF
- Cyber Security
- AntiJam
- Site Physical Security
  - Fence, Locks
  - Surveillance Cameras
  - Small Arms Target –Practice and Vandal Proof
- Signal Recognition
- Cooperative Direction Finding

# LAWS & REGULATIONS

- FCC 97.205 Repeater station.
- FCC Part 15 (electronic good neighbor)
- FCC Part 17 (tower lights and obstruction markings)
- Radio Amateur Frequency Coordination (MetroCor)
- Site Specific Rules
- Site Management
- Trade Unions
  - Equipment installation
  - Elevator operation




Tower structures over 200 feet (less in some circumstances) require FAA notification and a determination of "no hazard" before FCC antenna structure registration (ASR).

Antenna structure owners are required to maintain records of tower lighting problems. The rules "require antenna structure owners to maintain a record of observed or otherwise known extinguishments or improper functioning of structure lights for two years, and to provide such records to the Commission upon request."

# FUTURE DIRECTIONS FOR REPEATERS (TAPR)

It's insane that Amateur Radio VHF / UHF spectrum is technologically divided by incompatible modes. A radio built for Digital Mobile Radio (DMR) cannot operate using digital voice on a repeater built for D-Star. And only D-Star (partially) makes an accommodation for data over D-Star repeaters. Some features of a "Century 21" (C21) repeater:

- **Based on Open Source and SDR technology** - the operational parameters of the repeater can be updated with software. While the reality of repeater operations in high-density sites probably preclude easily changing transmit frequencies, an SDR receiver(s) are a normal part of a C21 repeater. Thus repeaters can be linked, perhaps even dynamically, by listening to another repeater's transmissions.

- **Single-frequency repeaters** - now feasible using Time Division Duplex (TDD) protocols. This has been demonstrated by modifying DMR's two time slots (normally used for two independent channels) for simultaneous Rx and Tx on a single channel.

- **C21 repeaters can be aggregated**. (channel bonding) For example, digital video requires a minimum bandwidth which isn't available on a single repeater (using conventional 25 kHz channels). C21 repeaters can, on demand, aggregate together to provide a minimum bandwidth such as 4 repeaters at a single site aggregating into a 100 kHz channel.

- **C21 repeaters can transfer data as easily as voice** - "bits are bits" - voice is just a bitstream with a "voice" tag. C21 repeaters are also considered to be usable not just for human use, but for Amateur Radio computers to "file sync". In the wee hours when there is little human usage, C21 user radios use otherwise wasted airtime to transmit Amateur Radio call sign database updates, bulletins, low-priority email messages, satellite predictions, tutorials, etc. The airtime has no extra cost, and demonstrates a unique Amateur Radio capability.

- **User radios for C21 repeaters** can be less expensive because they're based on open source designs that are largely software - basically fast Digital to Analog (D/A) and Analog to Digital (A/D) converters, a Field Programmable Gate Array (FPGA), a processor, and a power amplifier… all of which are getting cheaper and cheaper. The rest is software.

- **Experimentation** is encouraged. C21 repeaters, and user radios, are software defined, and based on Open Source, thus the barrier to changing something about the operation of a repeater or a radio is low; if something doesn't work, the base level of software can easily be reloaded.

# REFERENCES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