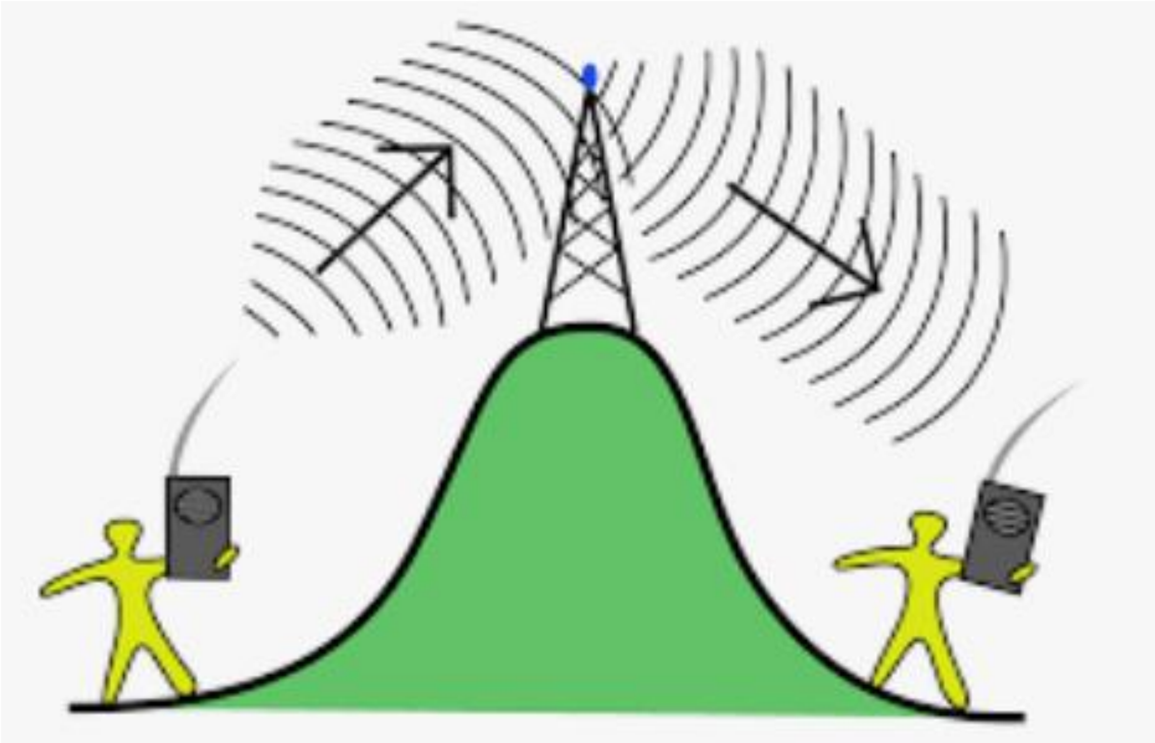
MARC Repeater Systems Explained

Dennis Silage K3DS



MARC Repeater Systems Explained

MARC began its repeater system with an initial installation on Toletine Hall at Villanova University on 147.06 MHz with the first callsign of *WR3ABZ* in 1973.




MARC Repeater Systems Explained

MARC itself was organized with the repeater as its core in December 1976.

WR3ABZ RADNOR REPEATER NEWS

DECEMBER 1976

Published by the Radnor Repeater Group, 9 Derwen Dr., Havertown, PA 19083

IN BRIEF

SERVING THE DELAWARE VALLEY

"WR3ABZ is and will continue to be an open repeater. Everyone, whether they join the club or not is welcomed to use the repeater." Bob Josuweit

NEW CLUB FORMED

Committees Begin to Organize

A new amateur radio club was formed last month by the users of the WR3ABZ, 66/06, repeater. The purpose of the club is to promote good operating skills and to bring together the many areas

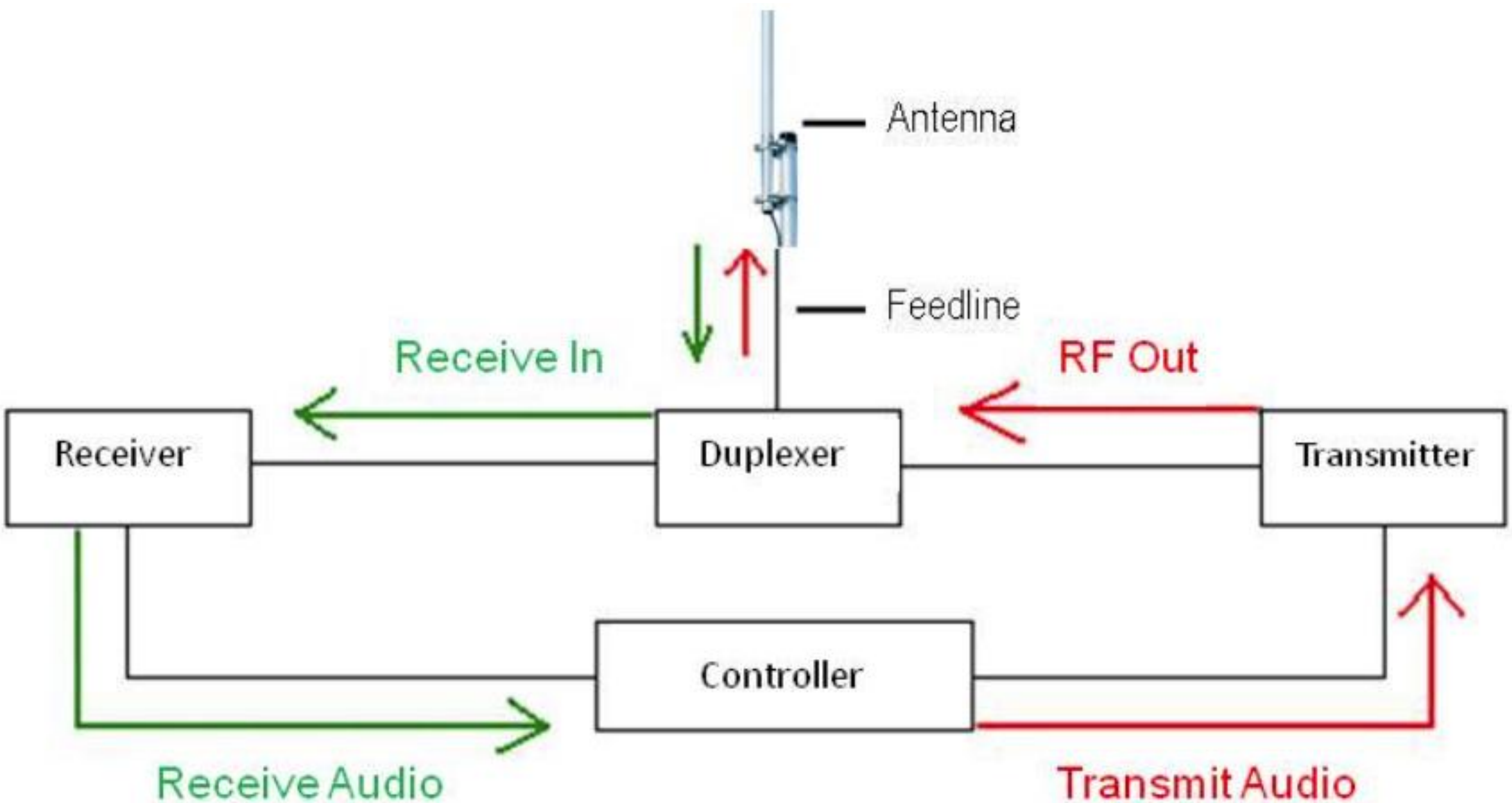
Following the organization of the club several committees were formed. These include bylaws, policy, public relations, public service, social and technical.

MARC Repeater Systems Explained

The repeater was somewhat of a *home brew* system with a power supply, receiver, transmitter, controller, duplexer and antenna.

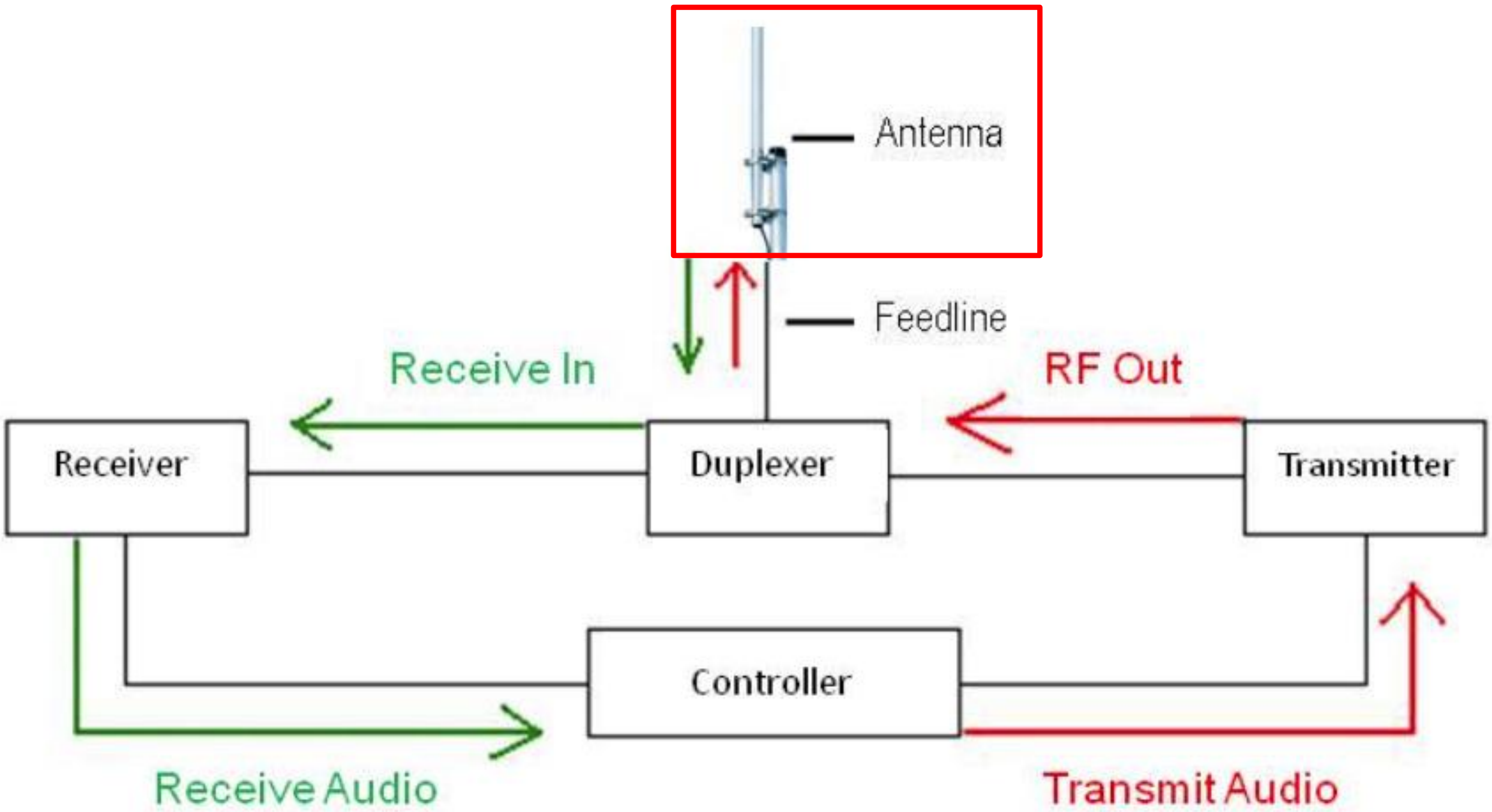
MARC Repeater Systems Explained

The basic configuration of a repeater has those same components arranged as a system. Each component contributes to the overall performance.



MARC Repeater Systems Explained

The repeater *antenna* is usually vertical, exhibits high gain and an *omnidirectional* response if mounted without a nearby obstruction.

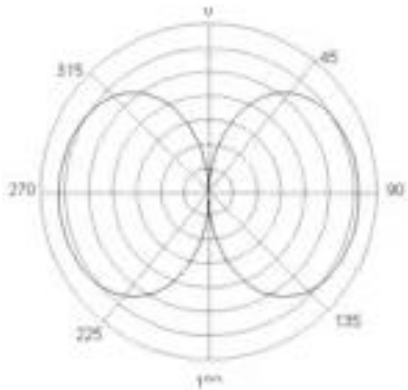


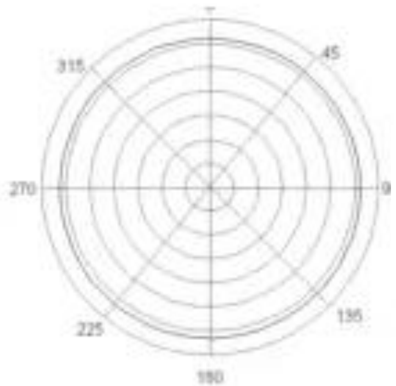
MARC Repeater Systems Explained

There are a variety of repeater antennas available. The 1/4 wave and 5/8 wave verticals and the four 1/2 wave dipole arrays are popular.

omnidirectional pattern

elevation azimuth





3D

MARC Repeater Systems Explained

Antenna gain is often measured in dBd or the logarithmic gain with respect to a dipole.

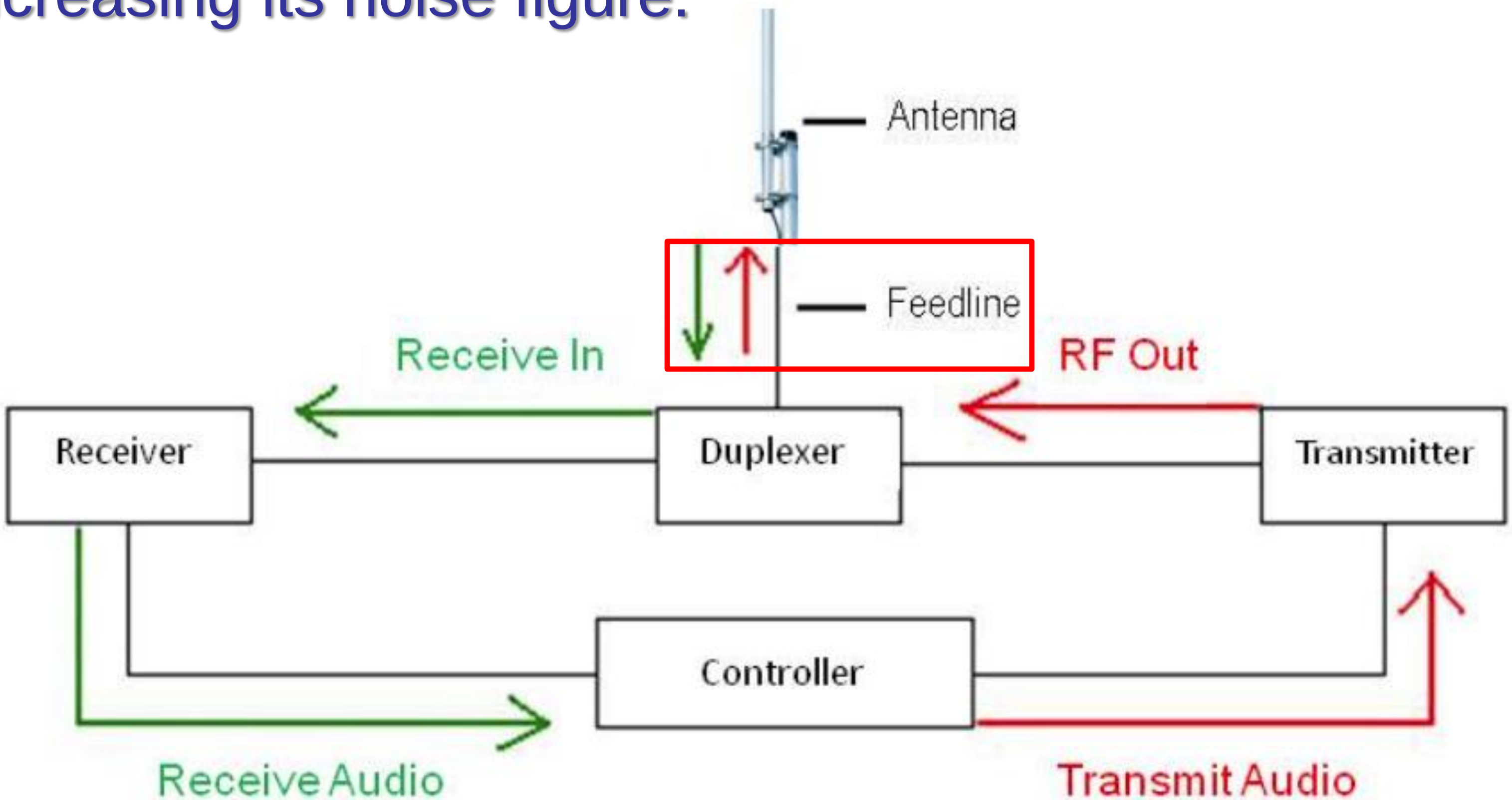
The 1/4 wave vertical antenna has 0 dBd gain.

The 5/8 wave vertical antenna has ~3 dBd gain..

The four 1/2 wave dipole array has ~6 dBd gain.

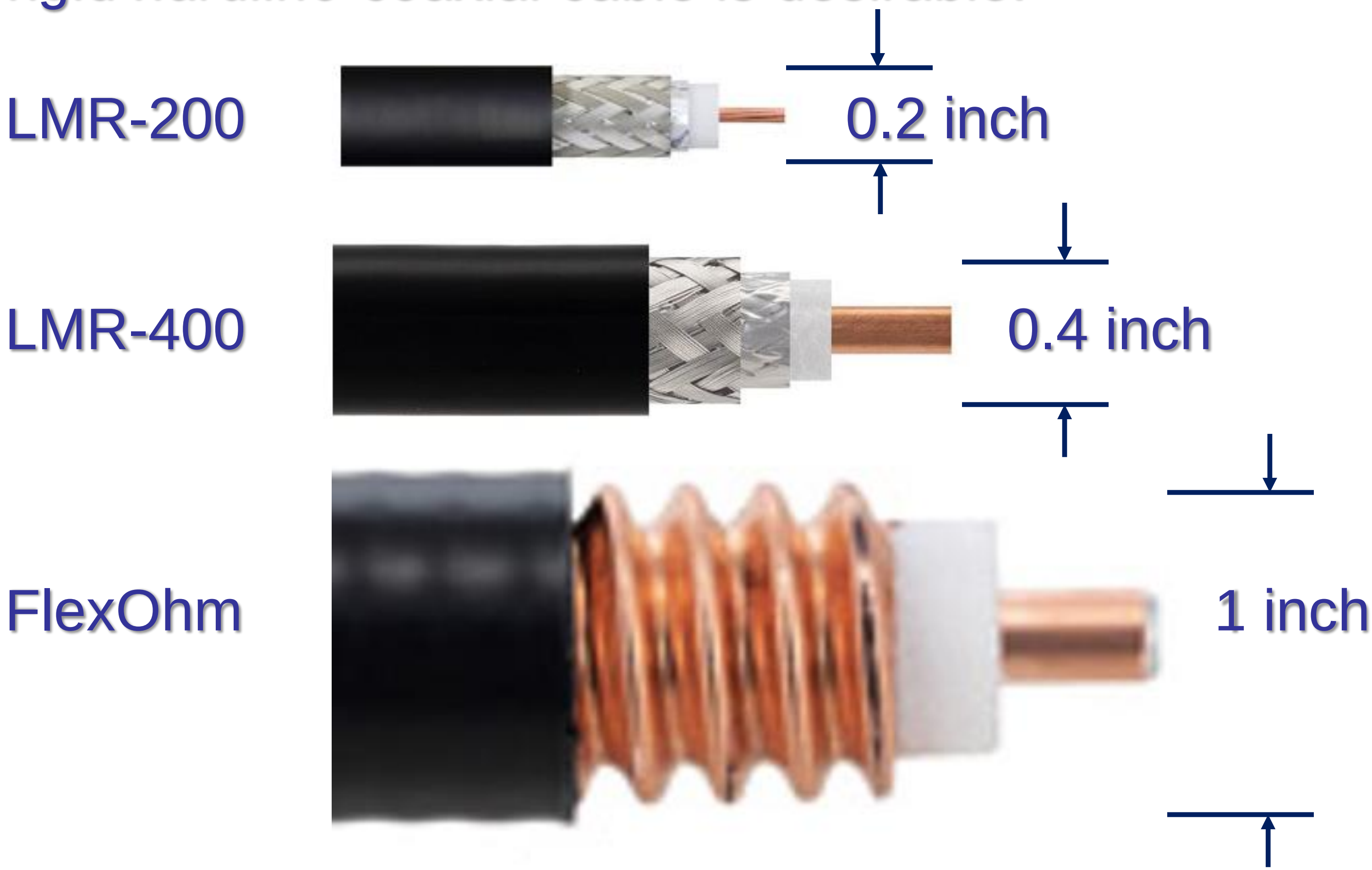
MARC Repeater Systems Explained

The coaxial cable *feedline* is also a crucial component. Lossy coaxial cable reduces the signal of the transmitter but even more so affects receiver performance by increasing its noise figure.



MARC Repeater Systems Explained

Although some repeater system use readily available LMR-200 and LMR-400 coaxial cables, larger diameter rigid *hardline* coaxial cable is desirable.



MARC Repeater Systems Explained

Hardline coaxial cable has significantly less loss, especially at UHF (440 MHz), although very expensive.

LMR-200

8.3 dB/100 feet

LMR-400

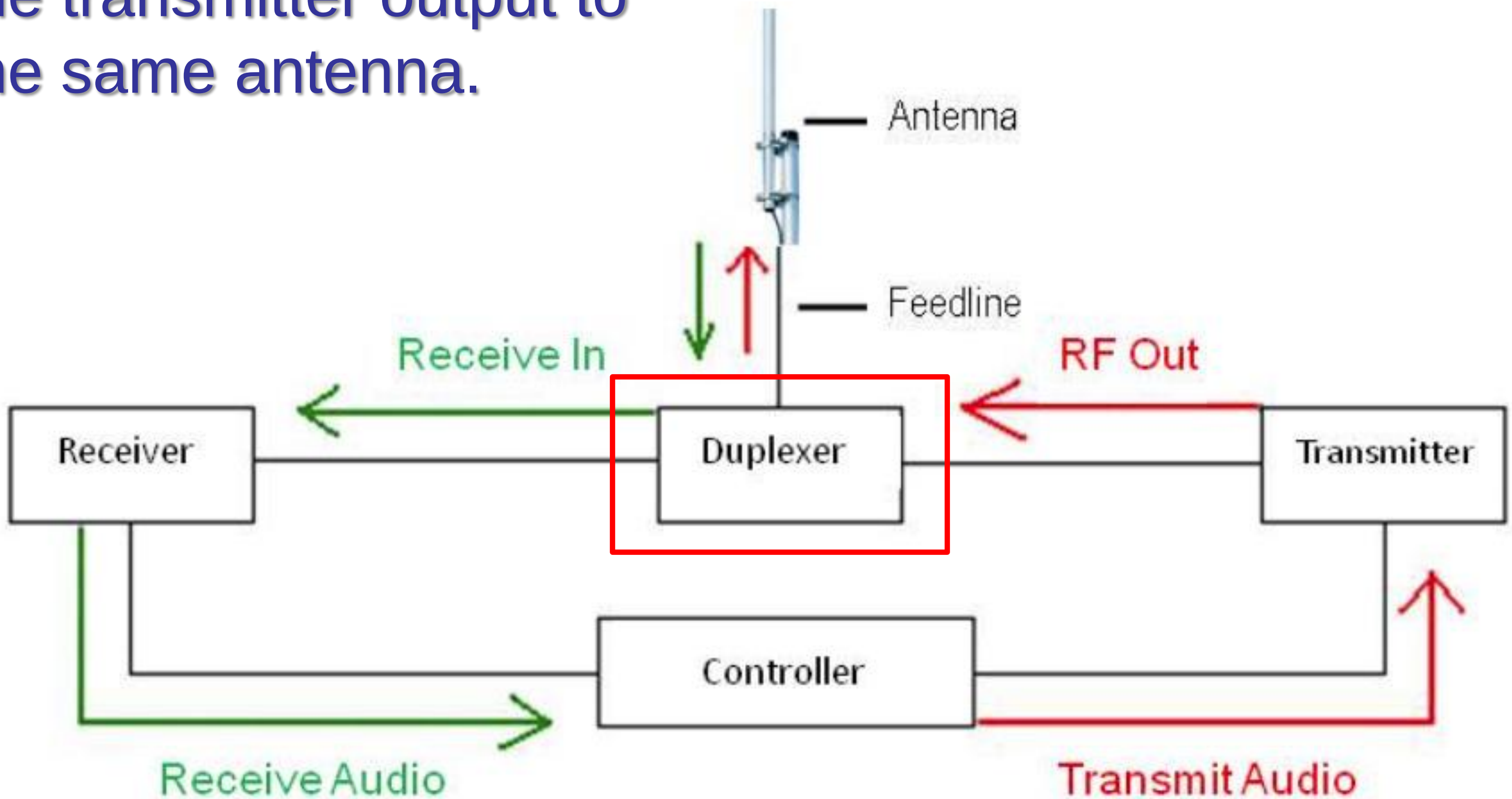
3.9 dB/100 feet

FlexOhm

0.6 dB/100 feet

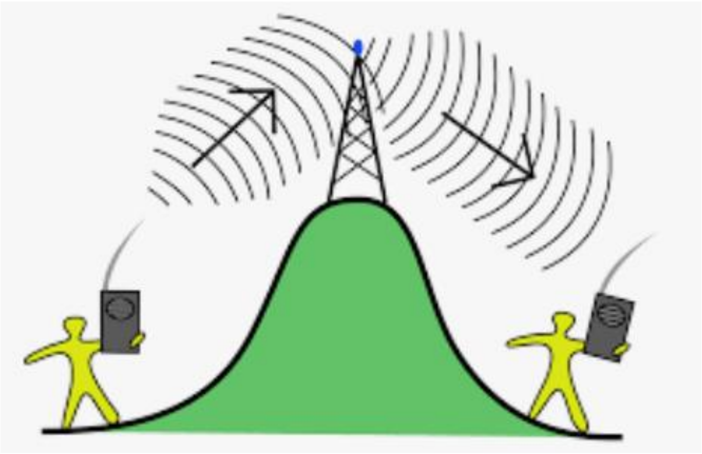
MARC Repeater Systems Explained

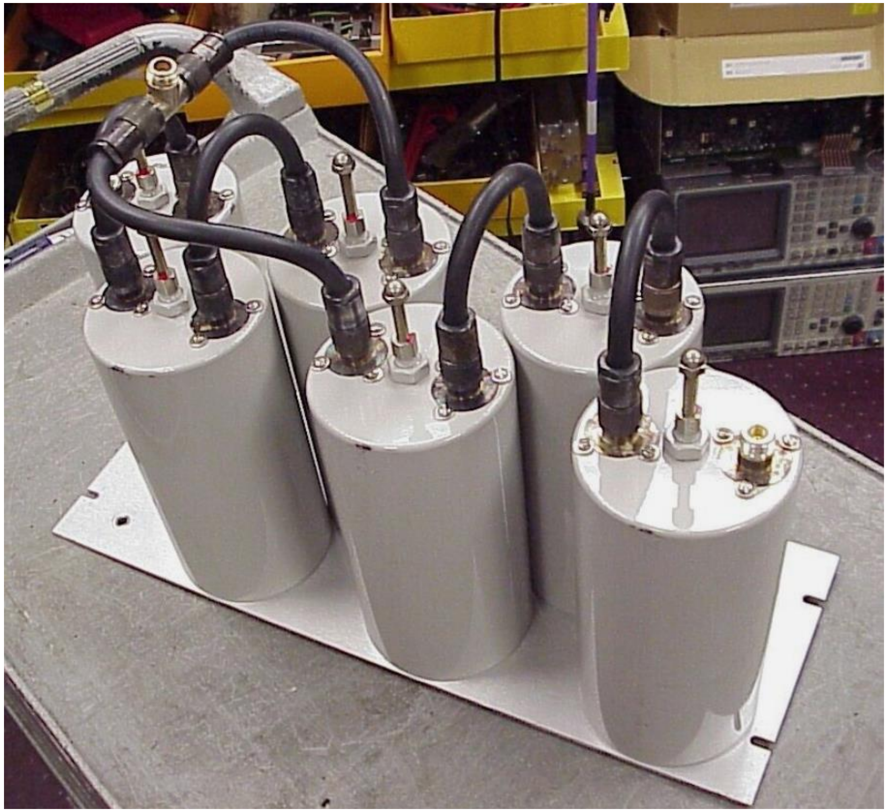
The *duplexer* is perhaps the most crucial component of the repeater systems. The duplexer isolates the microvolt sensitivity of the receiver input from the tens of volts of the transmitter output to the same antenna.



MARC Repeater Systems Explained

The duplexer works, for the first reason, because the receiver is on one frequency and the transmitter is offset on another. For a 2 m repeater, the offset is ± 0.6 MHz. For a 70 cm repeater, the offset is ± 5 MHz.

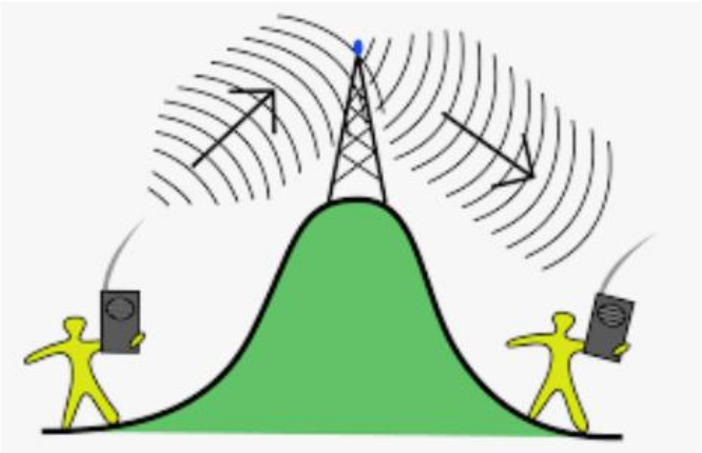




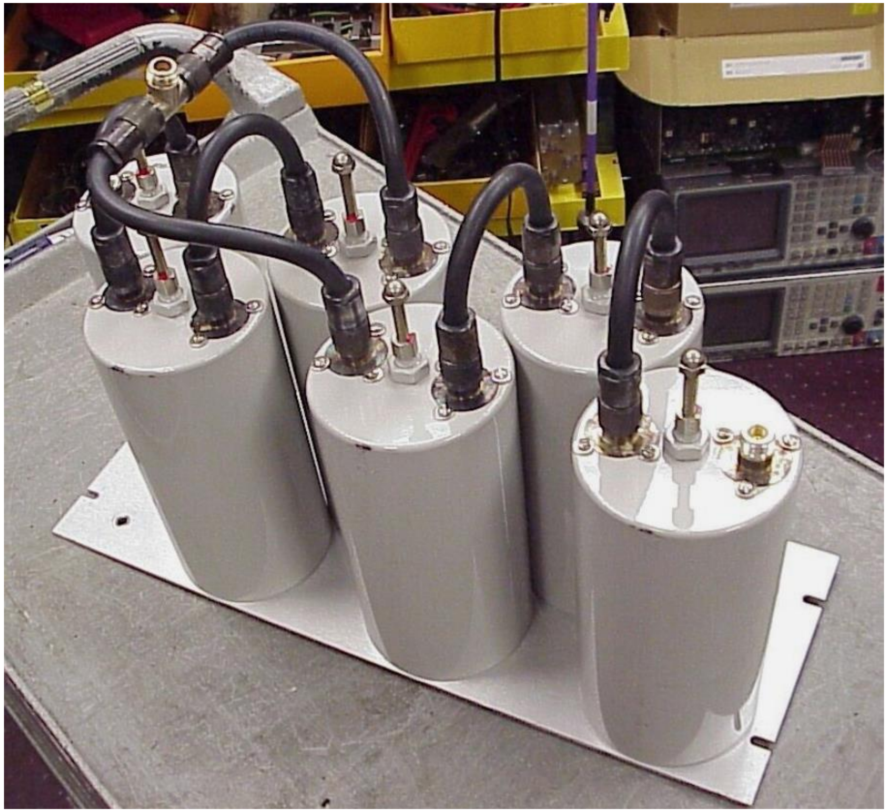
440 MHz duplexer

MARC Repeater Systems Explained

The duplexer consists of several interconnected *cavity resonators* with one side attached to the receiver, the other side to the transmitter.



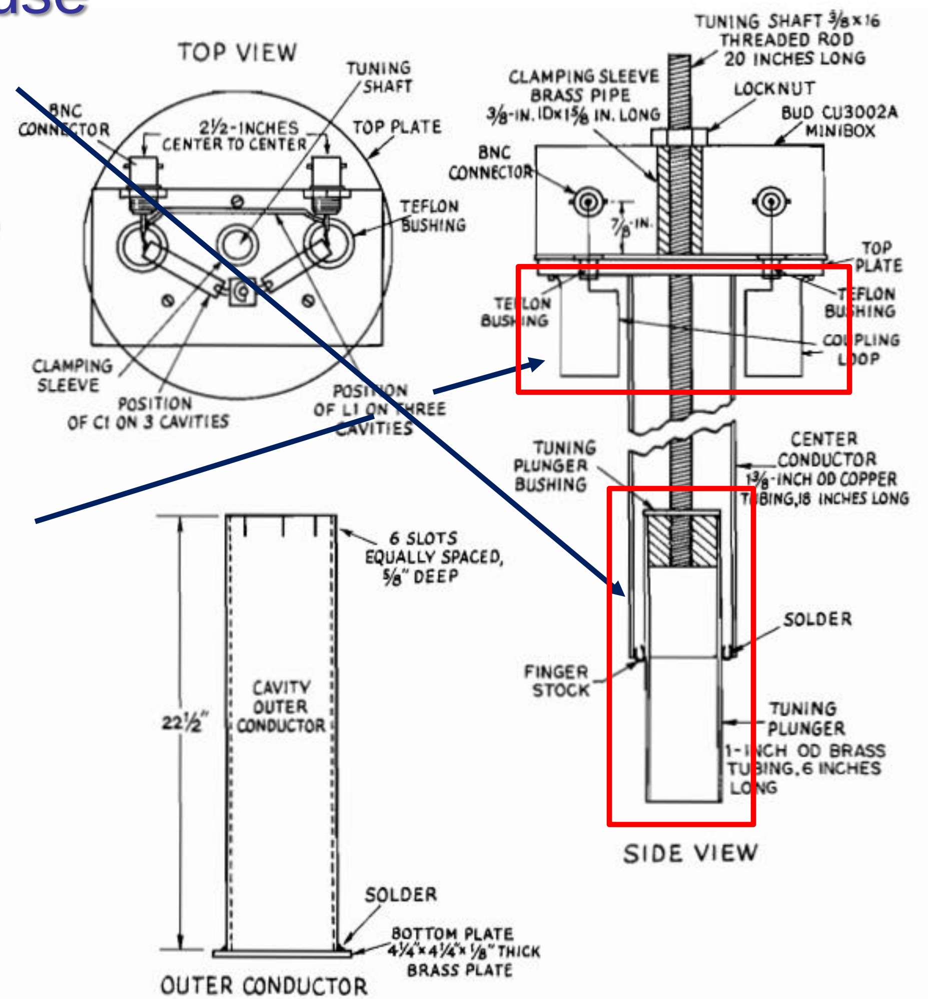
440 MHz duplexer



MARC Repeater Systems Explained

The duplexer cavity is usually cylindrical and works, for the second reason, because it has a movable *plunger* that tunes the device to *notch* (remove) either the receiver or transmitter signal.

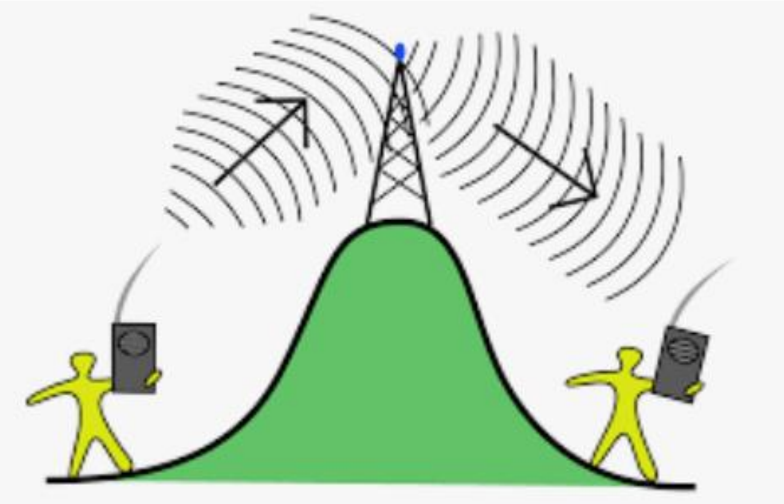
Coupling loops input and output the signal.



MARC Repeater Systems Explained

As an example, for the MARC Darby 444.050 repeater, the user would transmit on the input of 449.050 MHz and receive the output on 444.050 MHz.

Of course, the repeater would simultaneously transmit the user input on the output, which is why a duplexer is required.



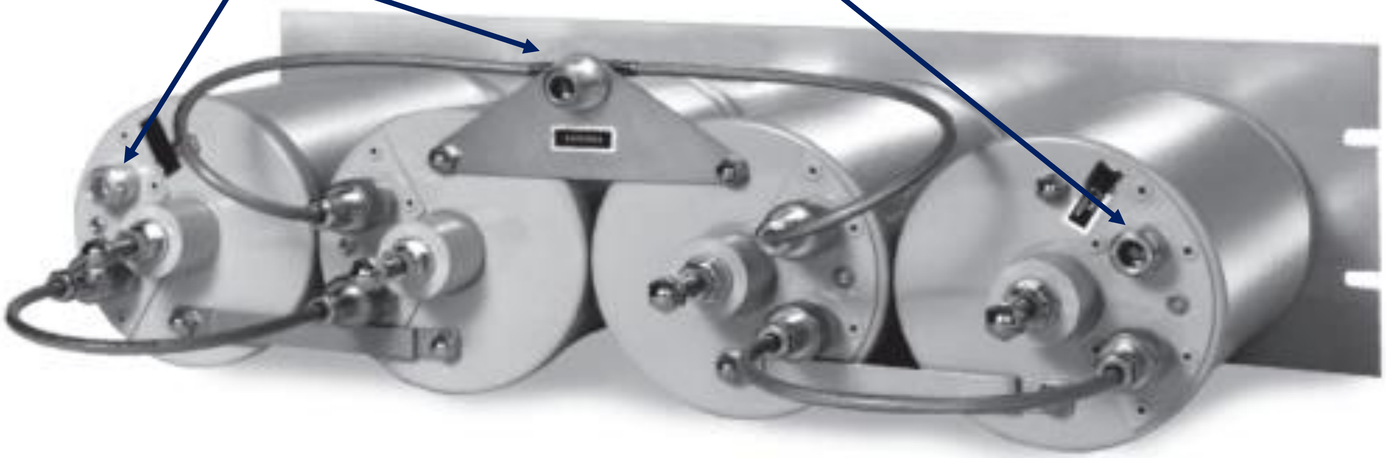
MARC Repeater Systems Explained

A 0.22 µV sensitive repeater receiver and even a 10 W repeater transmitter that outputs 22 V requires at least 80 decibels (dB) of *isolation*. A cavity resonator duplexer is required to do at least that or even more.

80 dB is a difference of 10^8 or what 1 cent is to a million dollars!

MARC Repeater Systems Explained

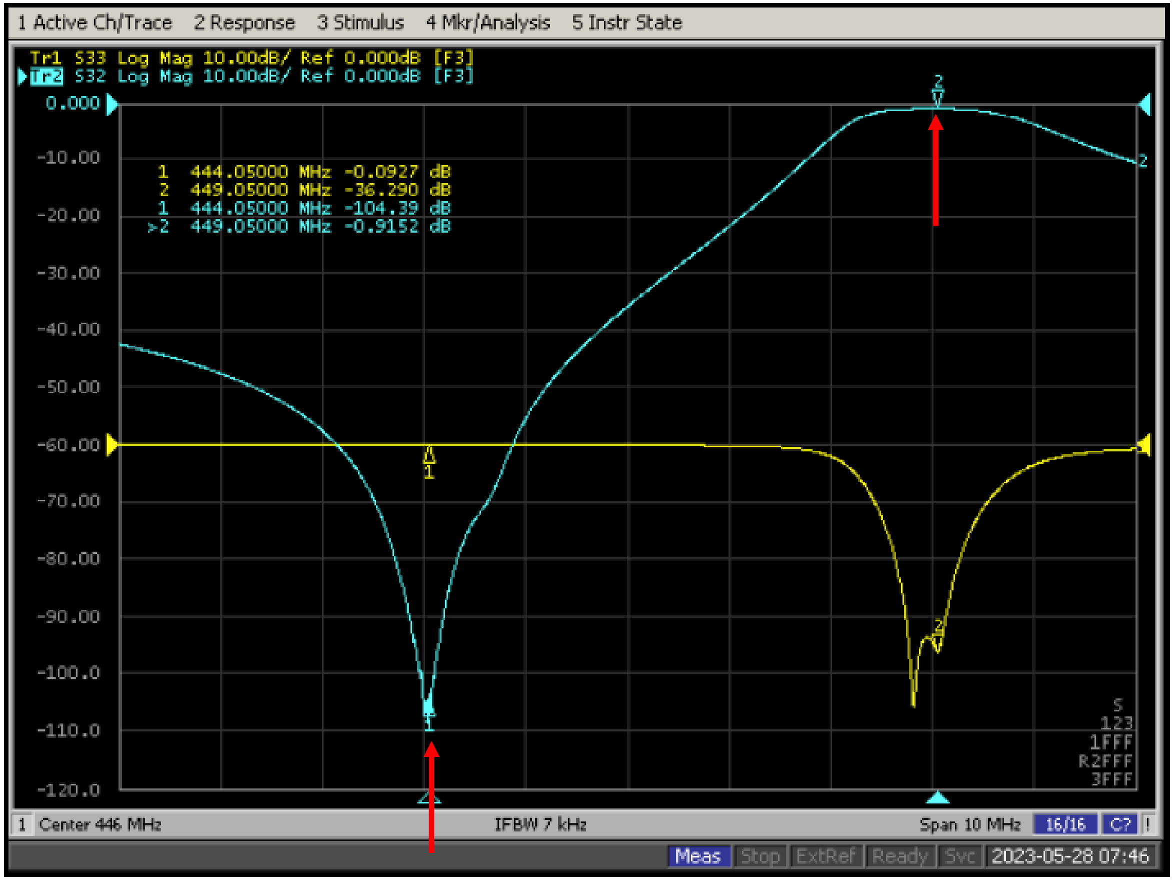
The MARC Darby UHF repeater has four resonant cavities, two on the receive and two on the transmit side with separate input and output and joined together in parallel.



Tuning a duplexer requires a *spectrum analyzer*.

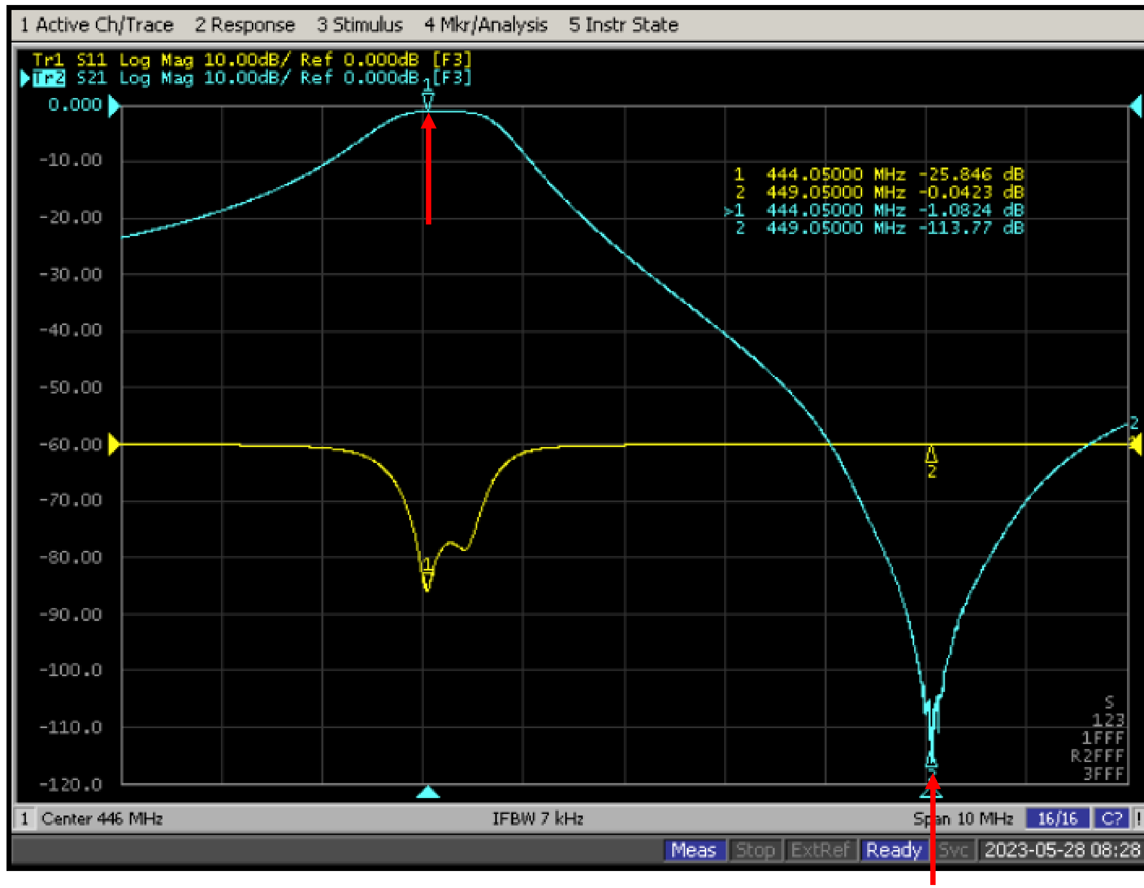
MARC Repeater Systems Explained

Here is the duplexer frequency response (in blue) for the MARC Darby UHF repeater receiver notching 444.050 MHz at −104 dB (the transmit signal) and passing (actually attenuating) 449.050 MHz at −0.9 dB (the receive signal).



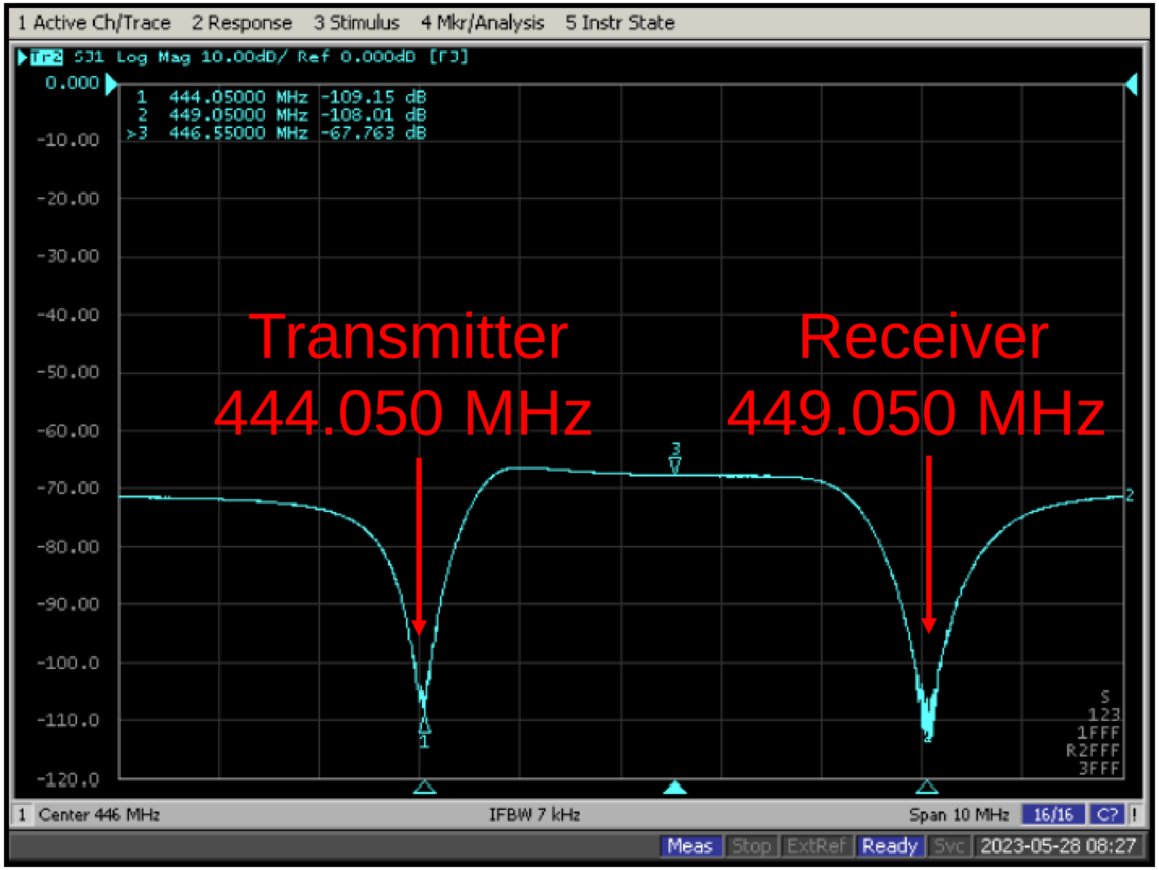
MARC Repeater Systems Explained

Here is the duplexer frequency response (in blue) for the MARC Darby 444.050 repeater transmitter notching 449.050 MHz at −114 dB (the receive signal) and passing (actually attenuating) 444.050 MHz at −1.1 dB (the transmit signal).



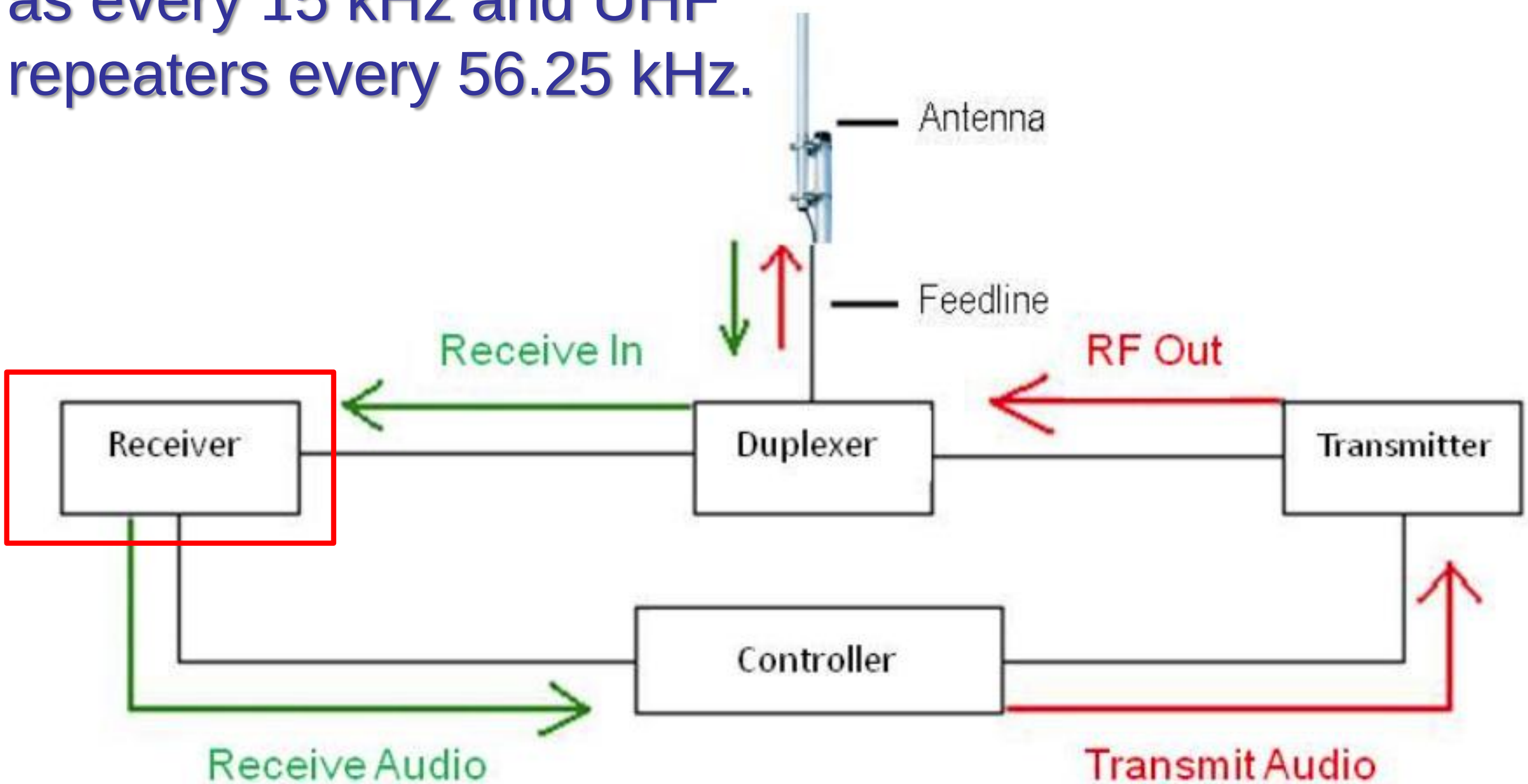
MARC Repeater Systems Explained

The duplexer cavity resonators work in concert as shown in this combined spectrum analysis. The receiver cavities notch the transmitter signal at 444.050 MHz. The transmitter cavities notch any noise on the receiver input at 449.050 MHz that is generated by the transmitter.



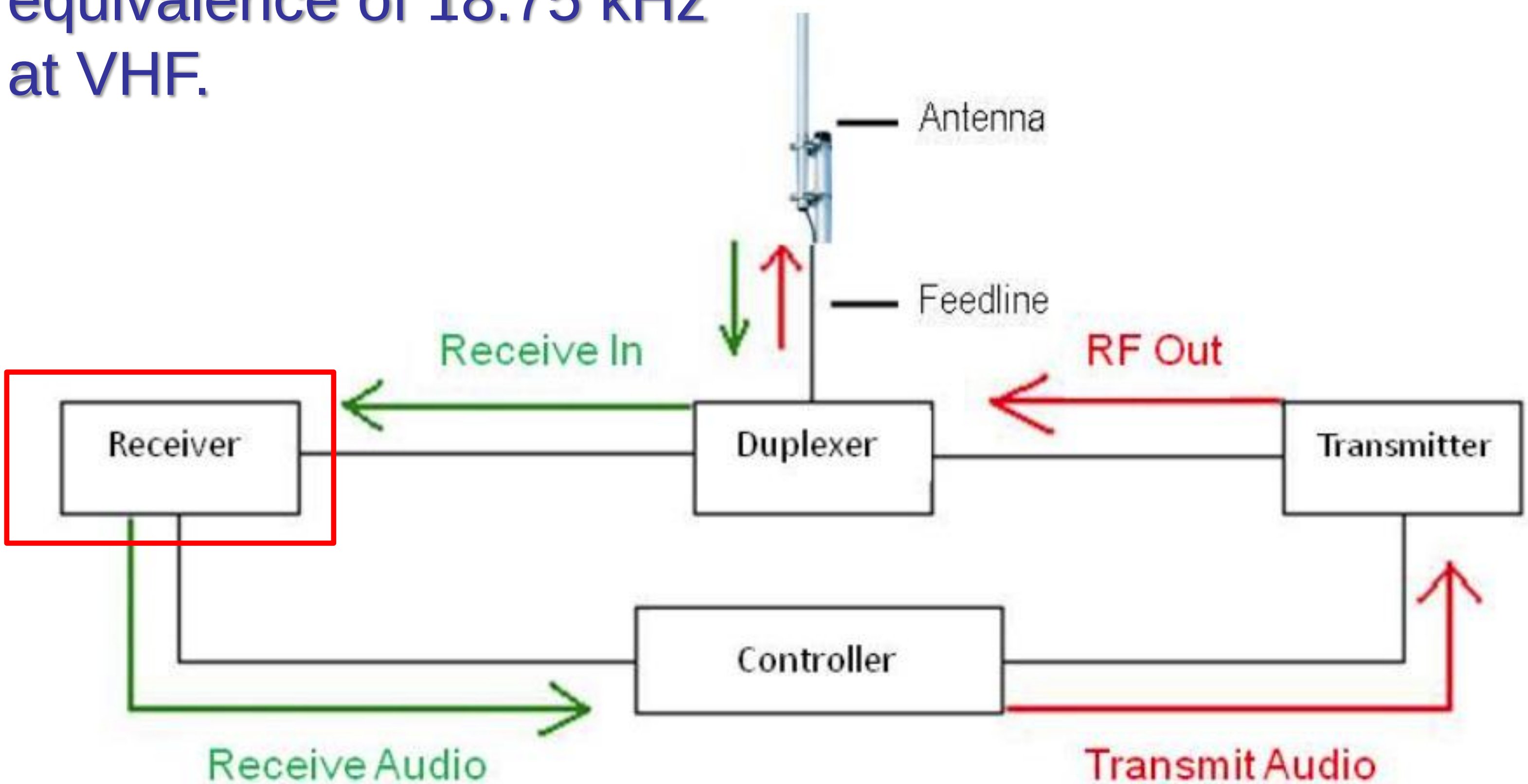
MARC Repeater Systems Explained

The *receiver* in a repeater system needs to be sensitive to the input signal but also immune to adjacent signals. VHF repeaters can be coordinated to be spaced as close as every 15 kHz and UHF repeaters every 56.25 kHz.



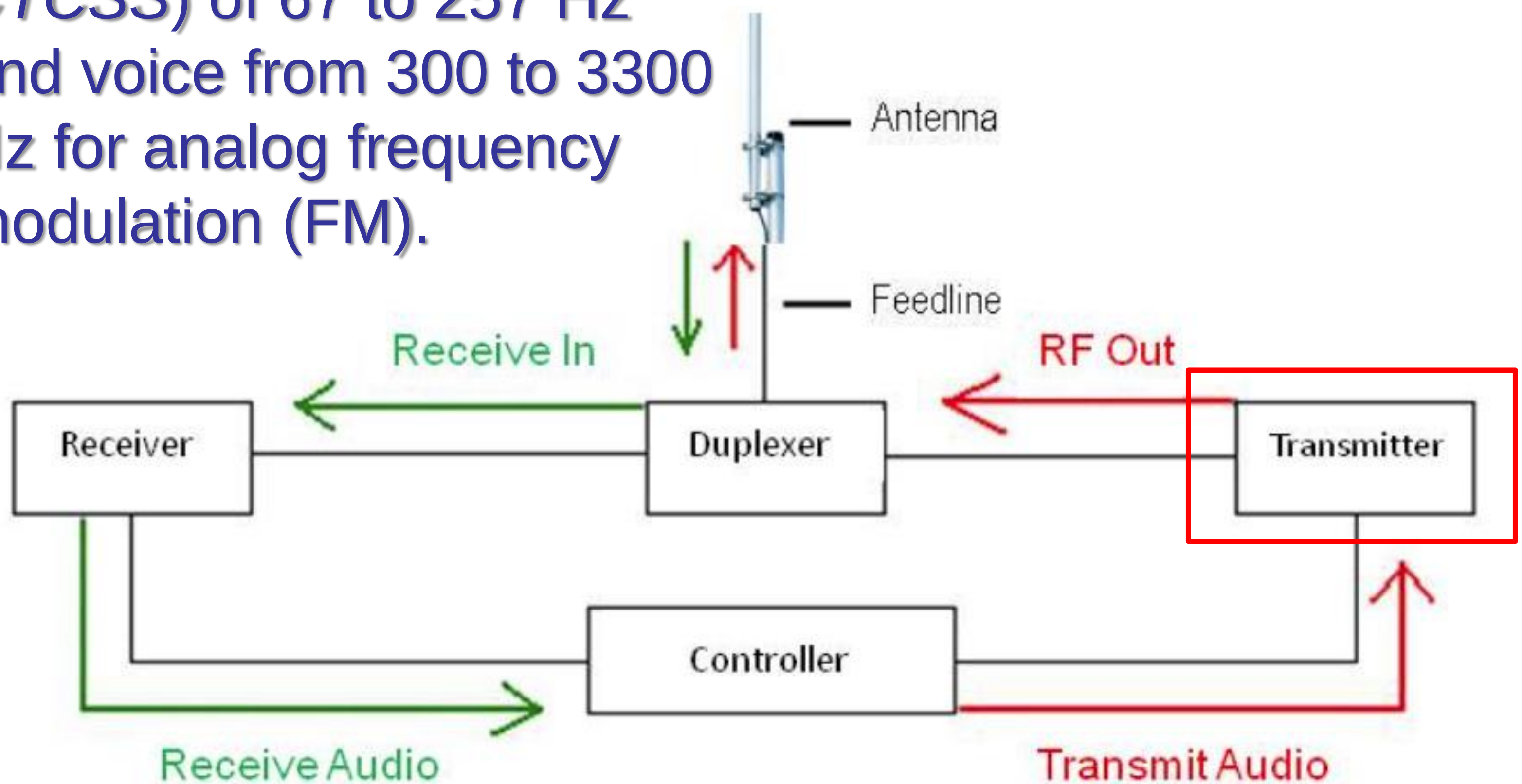
MARC Repeater Systems Explained

Although 56.25 kHz spacing sounds expansive for UHF, you must divide that by 3 (440/144 ≈ 3) for their actual bandwidth to center frequency relationship resulting in an equivalence of 18.75 kHz
at VHF.



MARC Repeater Systems Explained

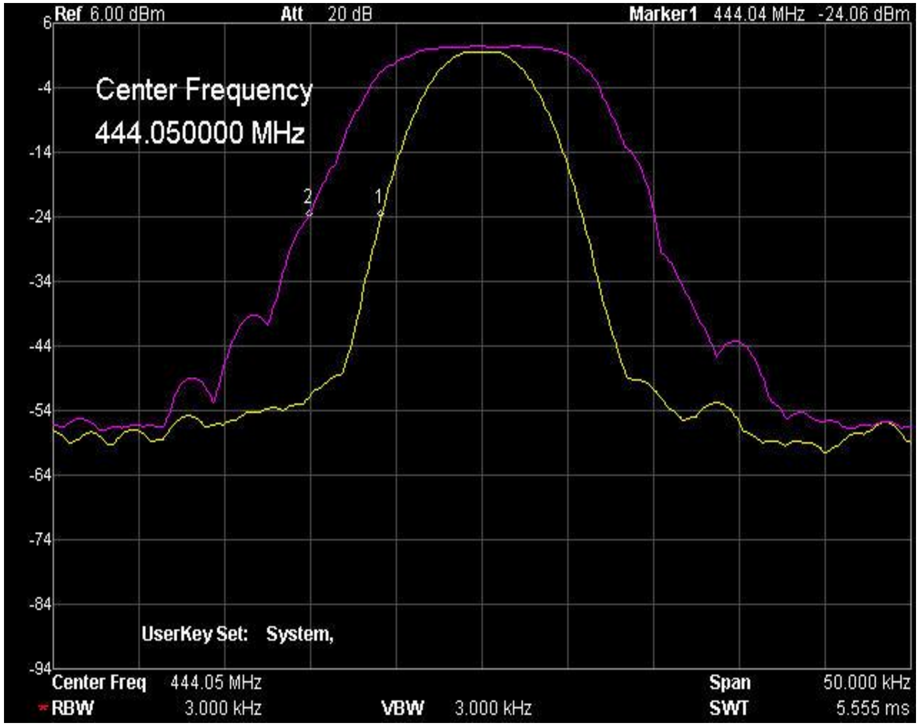
The *transmitter* in a repeater system should produce a spectrally pure output signal with a bandwidth wide enough to accommodate the tone access signal (*PL* or *CTCSS*) of 67 to 257 Hz and voice from 300 to 3300 Hz for analog frequency modulation (FM).



MARC Repeater Systems Explained

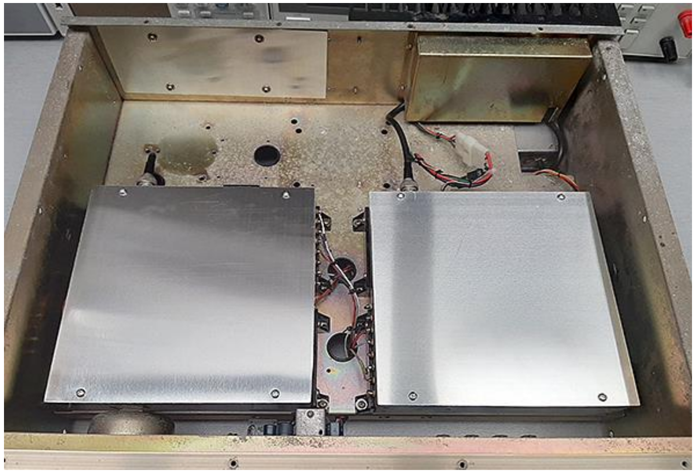
Here is the unmodulated carrier (yellow) and modulated (purple) frequency spectrum of the MARC Darby 444.050 MHz repeater in analog FM.

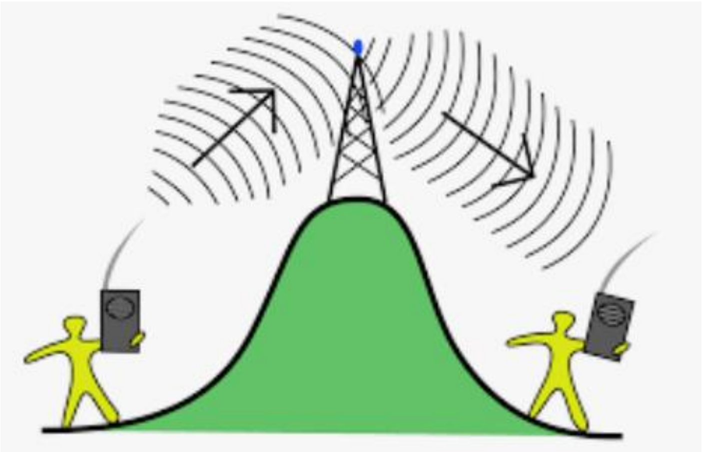
The frequency deviation at −23 dB down from the peak of the unmodulated carrier is approximately the recommended +−4.2 kHz (5 kHz per horizontal division).

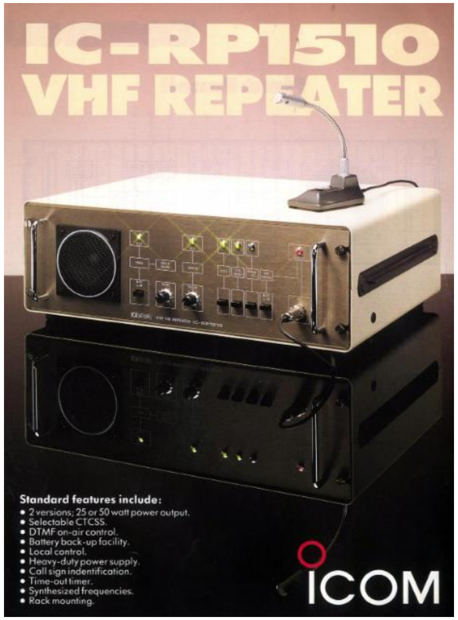


MARC Repeater Systems Explained

Early repeaters from the 1970s through the 2010s consisted of receivers and transmitters that were specifically designed for that type of use.



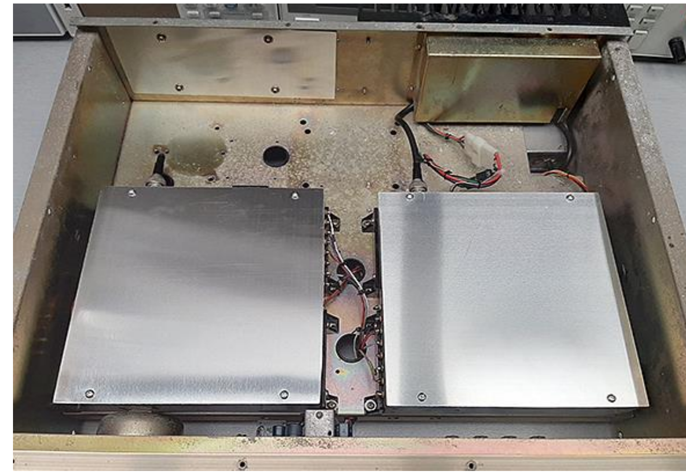


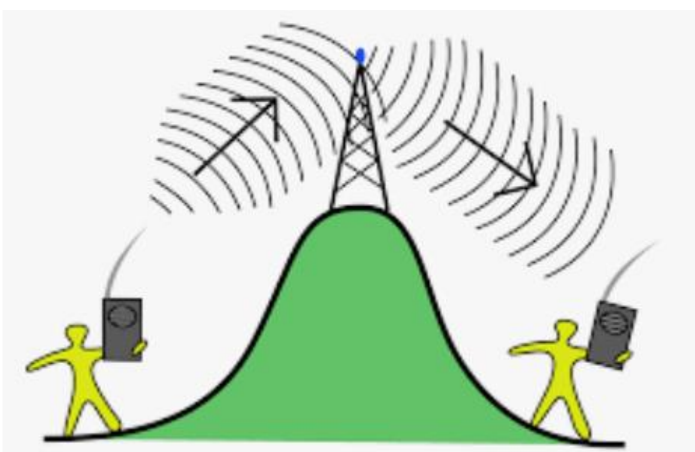


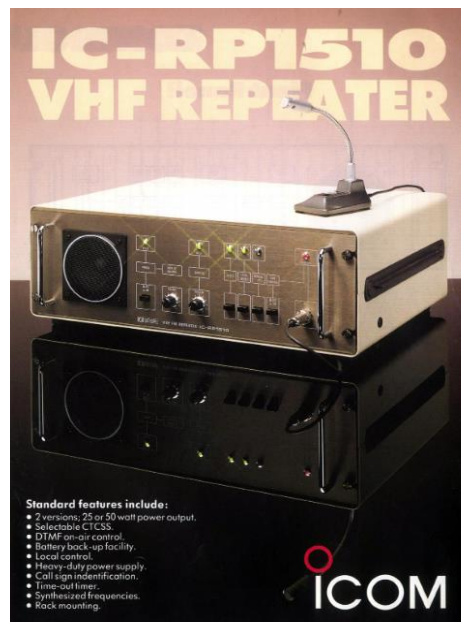
MARC Repeater Systems Explained

The receivers were often *triple conversion superheterodynes*.

The transmitters were either crystal controlled or used spectrally pure *frequency synthesizers*.







MARC Repeater Systems Explaine

However, recent repeaters, including those from Yaesu and BridgeCom, utilize two available but modified transceivers as the repeater receiver and transmitter.

MARC Repeater Systems Explained

Before 2012 the MARC VHF repeaters in Newtown Square (147.06 MHz) and Paoli (145.13 MHz) utilized early 1970 era Motorola Micor systems. Although somewhat serviceable, they were prone to failure after 40 years of service.

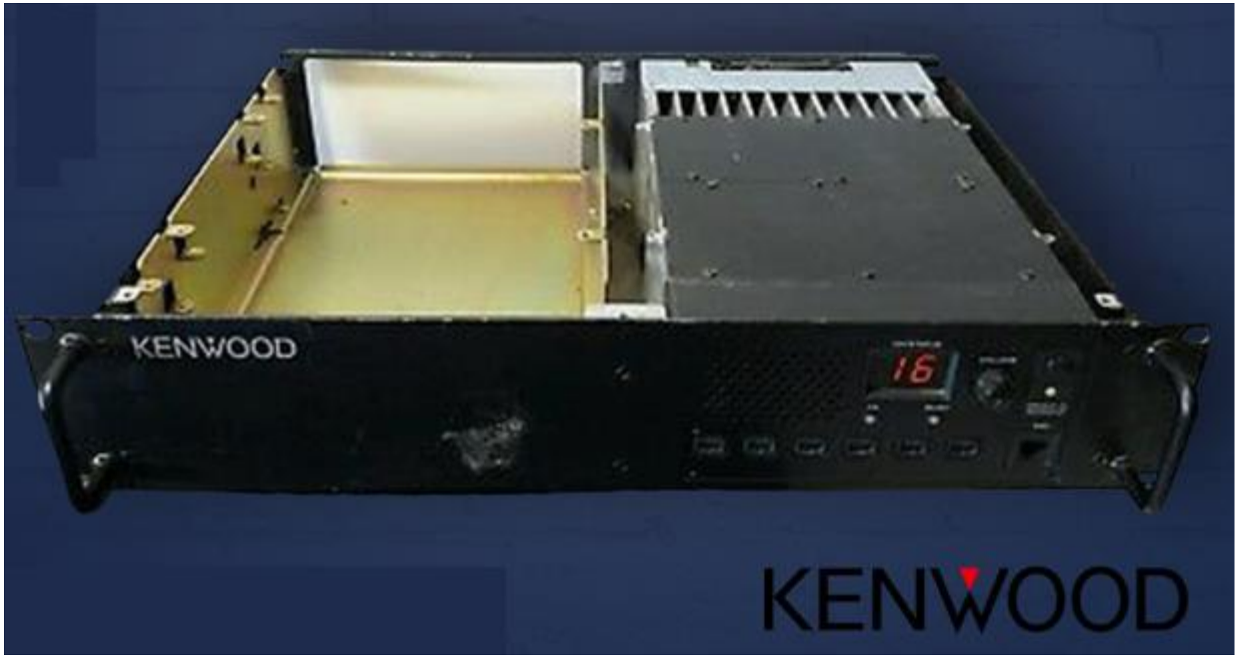
Here was the MARC VHF Micor repeater installed at Newtown Square.

MOTOROLA

MARC Repeater Systems Explained

In 2012 MARC acquired two Kenwood TKR-750 VHF repeaters for the sites in Newtown Square and Paoli. This 25 W repeater occupies only one-half a standard rack but still maintains the high-performance receiver and transmitter of earlier designs.

Kenwood
TKR-750



MARC Repeater Systems Explained

Here is the before and after configuration of the MARC VHF repeater in Newtown Square. A new power supply, RF power amplifier, controller and UHF link transceiver were also installed in 2012.

MARC Repeater Systems Explained

Here is the before and after configuration of the MARC VHF repeater in Paoli. A new power supply, RF power amplifier, controller and UHF link transceiver were also installed in 2012.

MARC Repeater Systems Explained

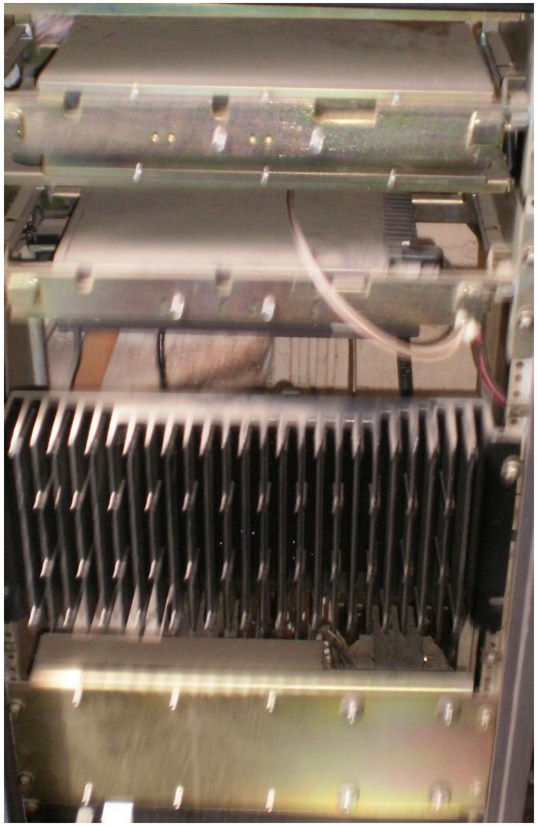
A Yaesu Fusion DR-2X UHF repeater and new duplexer for 445.6750 MHz replaced the defunct ICOM RP-4120 UHF FM analog repeater in Paoli.

YAESU
System Fusion

MARC Repeater Systems Explained

Before 2022 the MARC VHF repeater in Darby (147.36 MHz) utilized an EF Johnson Model 100 system obtained in 1985. The repeater operated without a significant failure for over 38 years until the receiver lost its sensitivity.

Here was the MARC VHF EF Johnson repeater installed at Darby.



EFJohnson TECHNOLOGIES

MARC Repeater Systems Explained

In 2022 MARC acquired a BridgeCom BCR-50V 50 W repeater for 147.36 MHz and a BCR-220 30 W repeater for 224.5 MHz at the site in Darby. The BridgeCom repeaters provide their own power supply.

BCR-50V

BCR-220

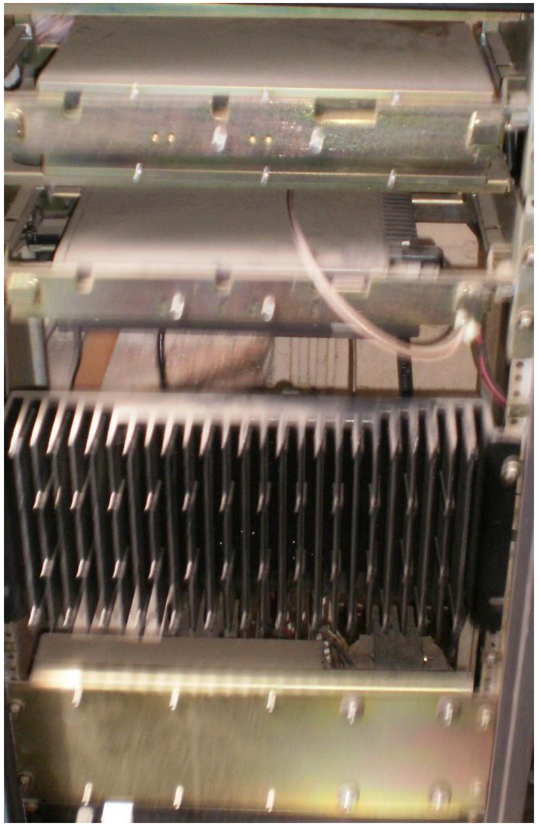
BridgeCom
SYSTEMS

MARC Repeater Systems Explained

Here is the before and after configuration of the MARC repeater in Darby. The BridgeCom 147.36 MHz and 224.5 MHz repeaters are shown on the bottom.

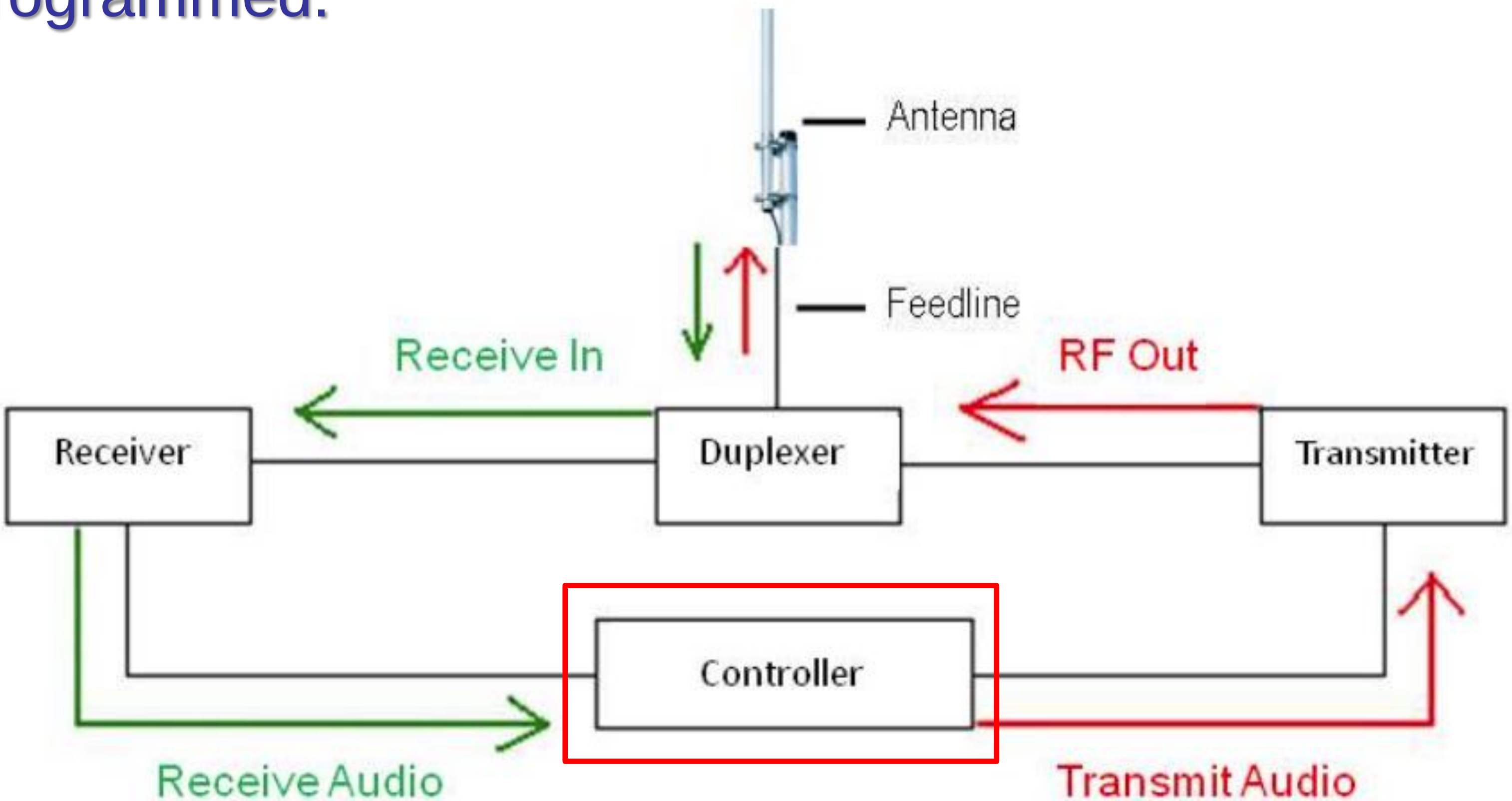
A Yaesu Fusion DR-2X UHF repeater and duplexer for 444.050 MHz is at the top.

YAESU System Fusion



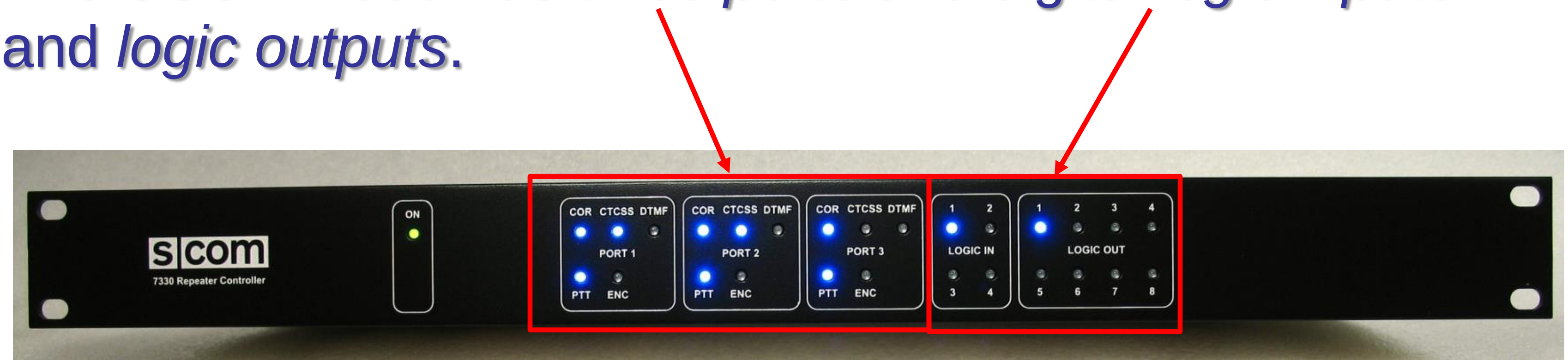
MARC Repeater Systems Explained

A *controller* coordinates the operation of the repeater and adds other functionality such as linking and announcements. The controller is an embedded microcomputer that can be programmed.



MARC Repeater Systems Explained

All of the MARC repeaters use the SCOM 7330 controller. The SCOM 7330 has three *ports* and digital *logic inputs* and *logic outputs*.



The repeater receiver provides a carrier operated signal (COS) to the controller port when a signal exceeds the squelch level and has the correct PL (or CTCSS) signal.

An older name for COS is carrier operated relay (COR).

MARC Repeater Systems Explained

The COR and CTCSS signals are indicated on the LEDs of the controller for the port in use.

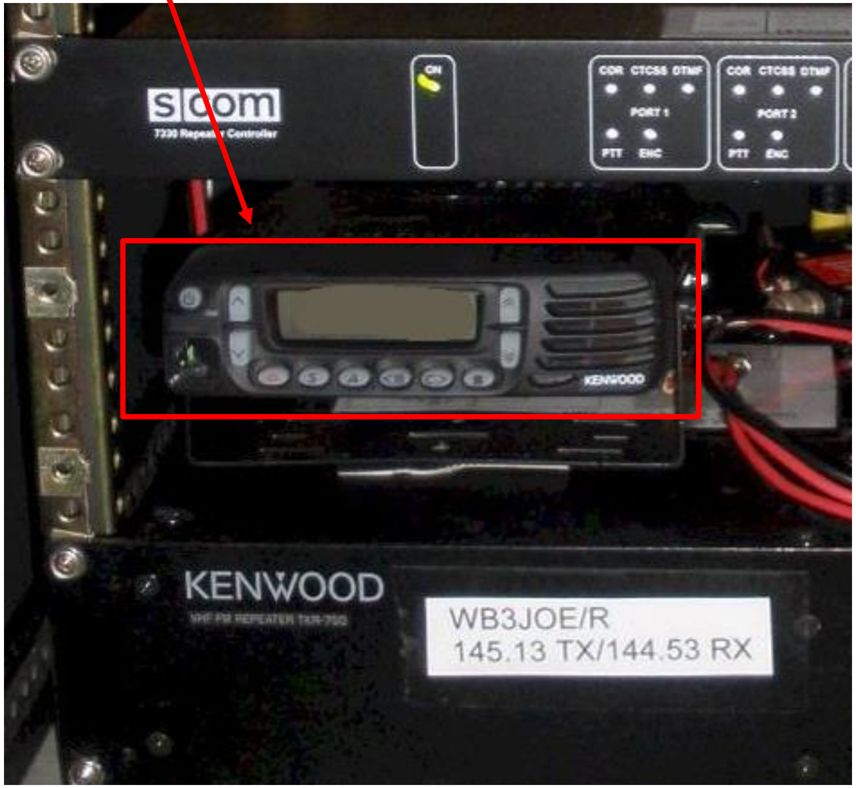
The controller then outputs a push-to-talk (PTT) signal to the repeater transmitter.

If there are *linked* repeaters, then the received audio signal and PTT are also outputted to those transmitters.

MARC Repeater Systems Explained

The MARC VHF repeaters at Newtown Square (147.06 MHz) and Paoli (145.13 MHz) are *linked* by Kenwood UHF transceivers on a dedicated simplex frequency.

The link can be disabled by the controller for *stand-alone* repeater use.



Paoli repeater

MARC Repeater Systems Explained

The SCOM 7330 controllers are programmed from a text file via serial communication to non-volatile memory that encodes the operation to be performed. For example, the voice announcement:

This-is the MARC WB3JOE link repeater PL 131.8

is programmed with these code words terminated with *:

*31 0109 9960 0359 0357 1054 0067 0046 0005 **

MARC Repeater Systems Explained

The SCOM 7330 controller has several interesting features. *Macro messages* can be created and then scheduled to execute. For example, the hourly time macro message 5:

Good M/A/E the time is $12HOUR $AMPM this-is the MARC WB3JOE link repeater

is programmed with these code words terminated with *:

*20 0005 15 9991 9960 0860 9831 0357 0091 0287 9820 9821 0359 0357 1054 0067 0046 0005 0054 0059 0049 0294 0342 **

MARC Repeater Systems Explained

The hourly time macro message 5 then can be scheduled to execute as a voice message every hour of every day (99 is a wild card):

*28 01 0005 99 99 99 00 **

The MARC Hamfest periodic announcement macro message 9:

MARC Hamfest Sunday August thirteenth

MARC Repeater Systems Explained

is programmed with these code words terminated with *:

20 0009 15 9991 9993 10 9960 1054 0273 0083 0078 0025 *

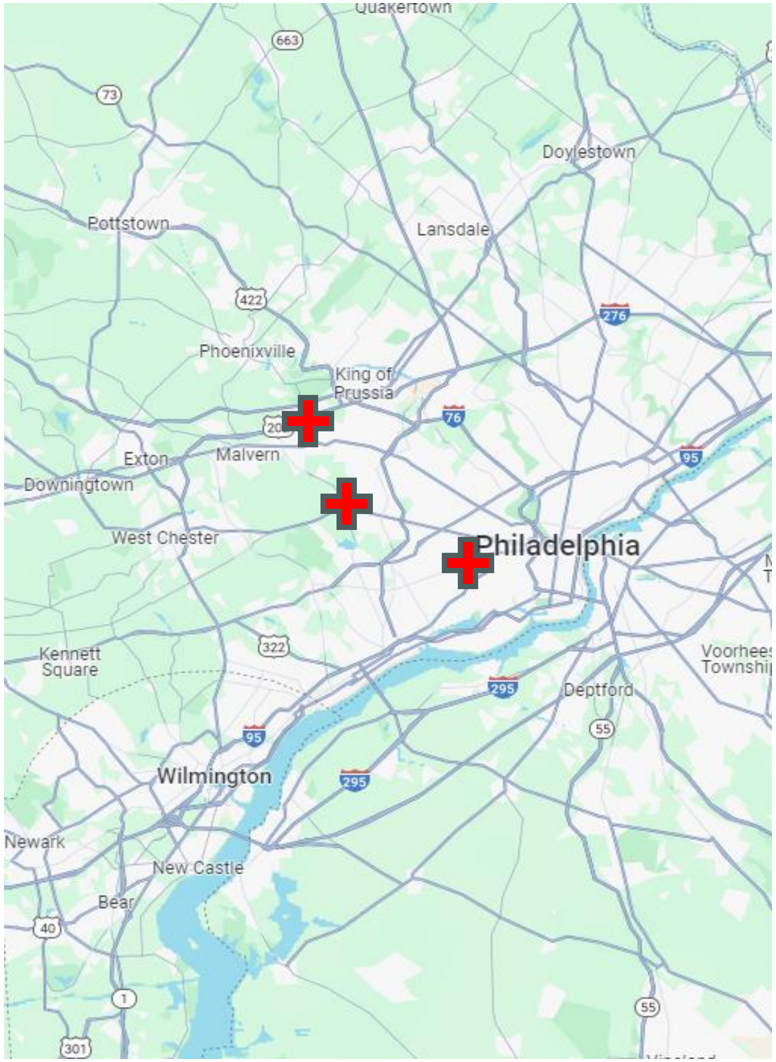
The SCOM controller performs various tasks such as connecting the link transceiver to the appropriate repeater, monitoring repeater *time out* and generating the *courtesy beep* at the end of reception with a distinctive two-tone response if the link is active.

MARC Repeater Systems Explained

Repeater Locations

MARC has three repeater sites

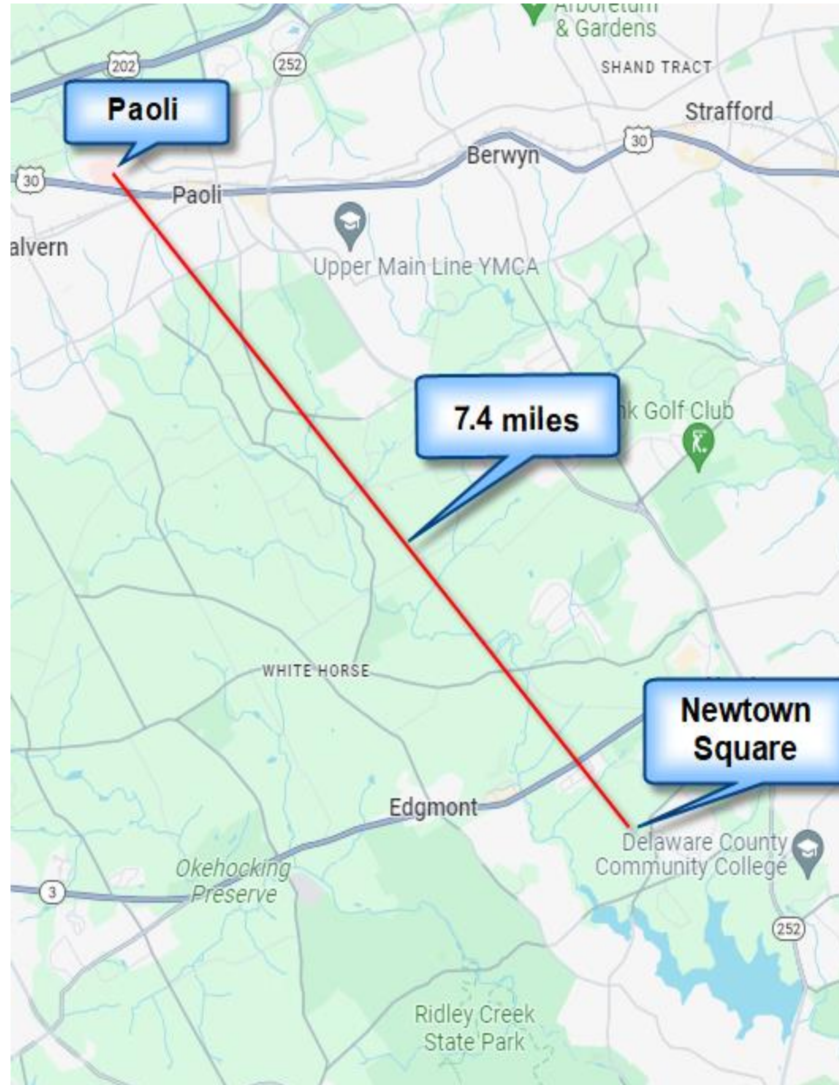
- Paoli Hospital
  VHF 145.13 MHz
  UHF 445.675 MHz
- Broadcast Entity
  Newtown Square
  VHF 147.06 MHz
- Mercy Fitzgerald Hospital
  Darby
  VHF 147.36 and 224.5 MHz
  UHF 444.050 MHz



MARC Repeater Systems Explained

The MARC VHF Newtown Square and Paoli repeaters are only 7.4 miles apart.

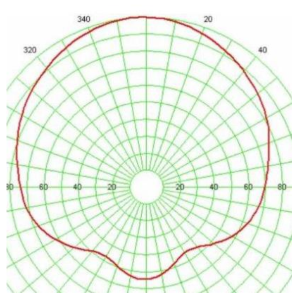
However, the path between is clear and small Yagi antennas and low power provides a good signal for the RF link.

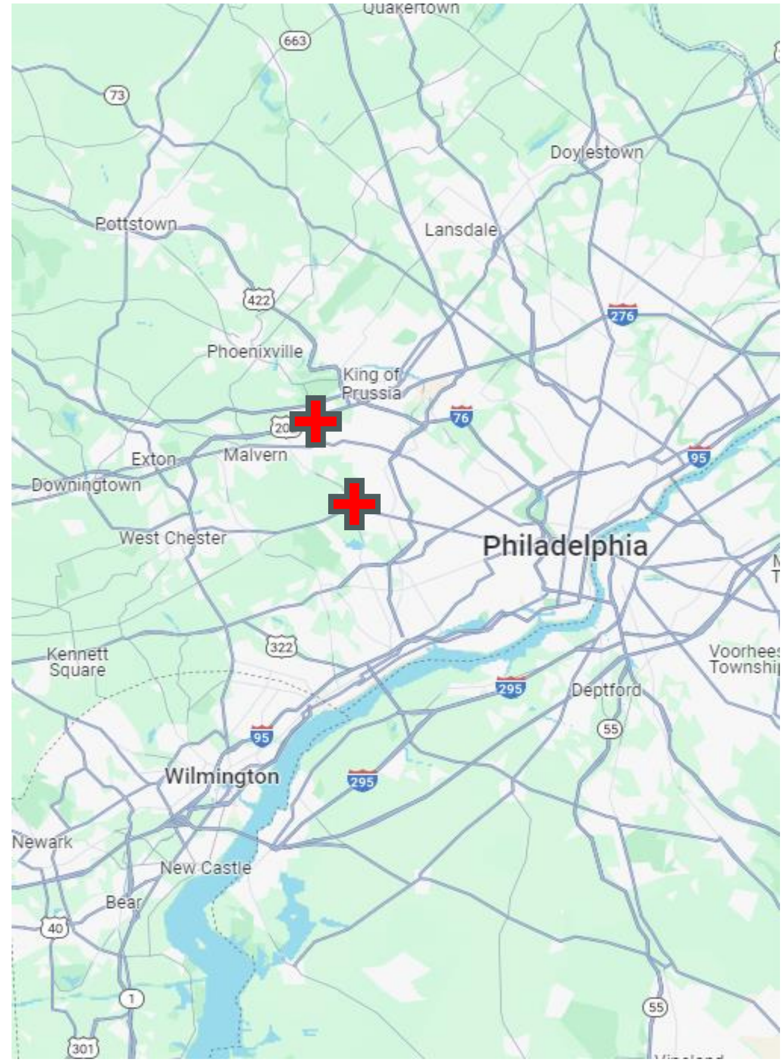


MARC Repeater Systems Explained

With omnidirectional antennas at these two nearby sites the repeater coverage would overlap considerably.

However, the four 1/2 wave dipoles of the antenna at Paoli are mounted on the same side, resulting in a *cardioid* pattern.

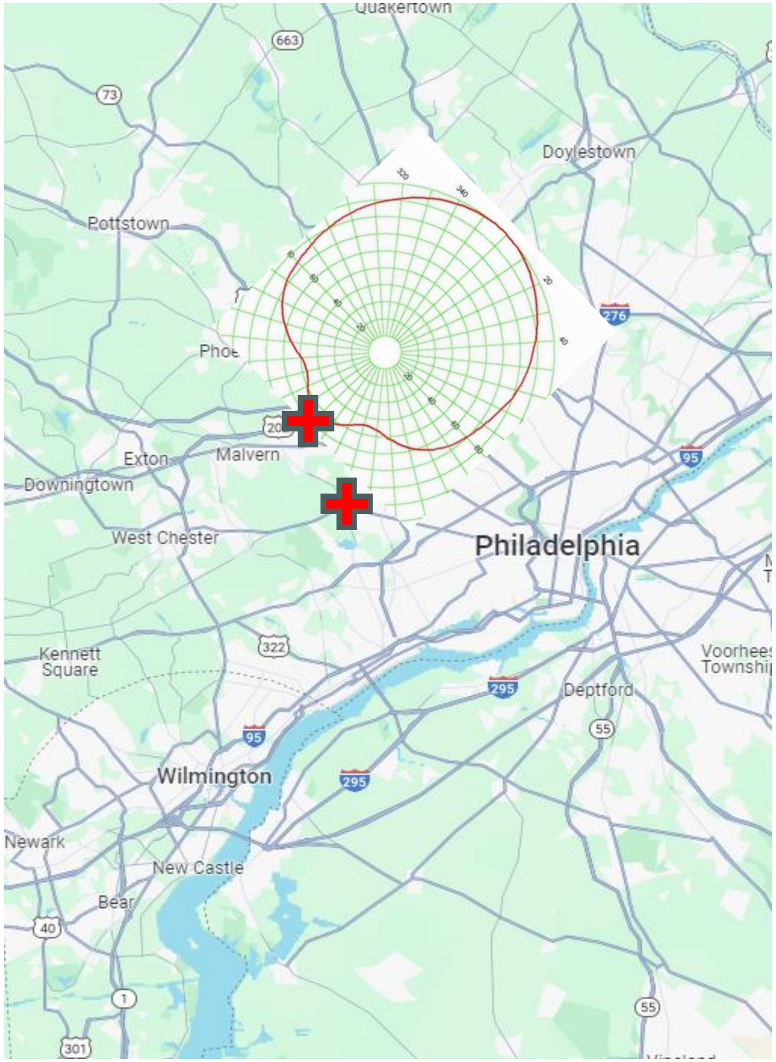




MARC Repeater Systems Explained

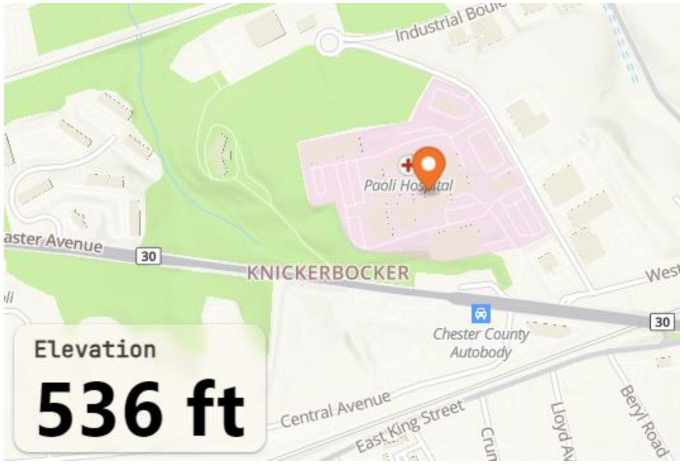
The cardioid antenna pattern is pointed northeast from Paoli towards King of Prussia,

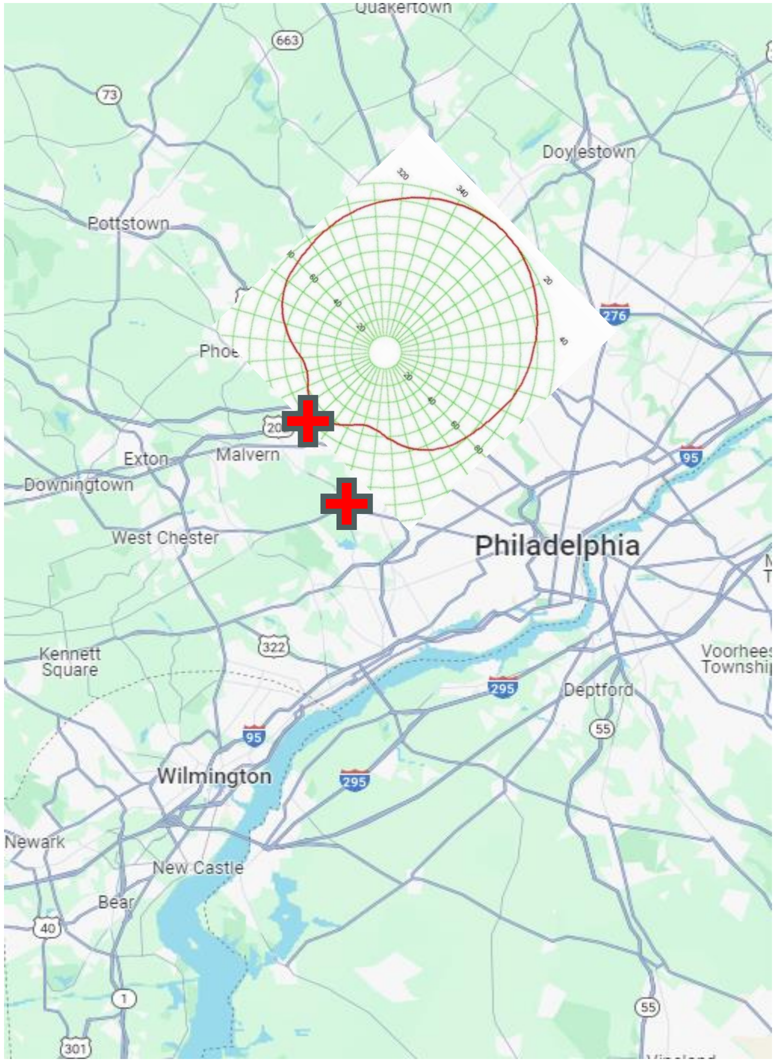
The primary coverage of The MARC Paoli VHF repeater (145.13 MHz) then extends to Royersford (on US 422) and to North Wales (on US 202).



MARC Repeater Systems Explained

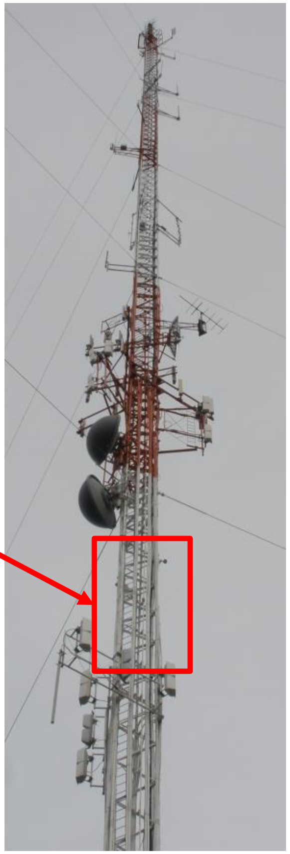
The MARC Paoli VHF repeater antenna is on an 18 foot parapet on 4 story building or ≈60 feet. The ground elevation is 536 feet.



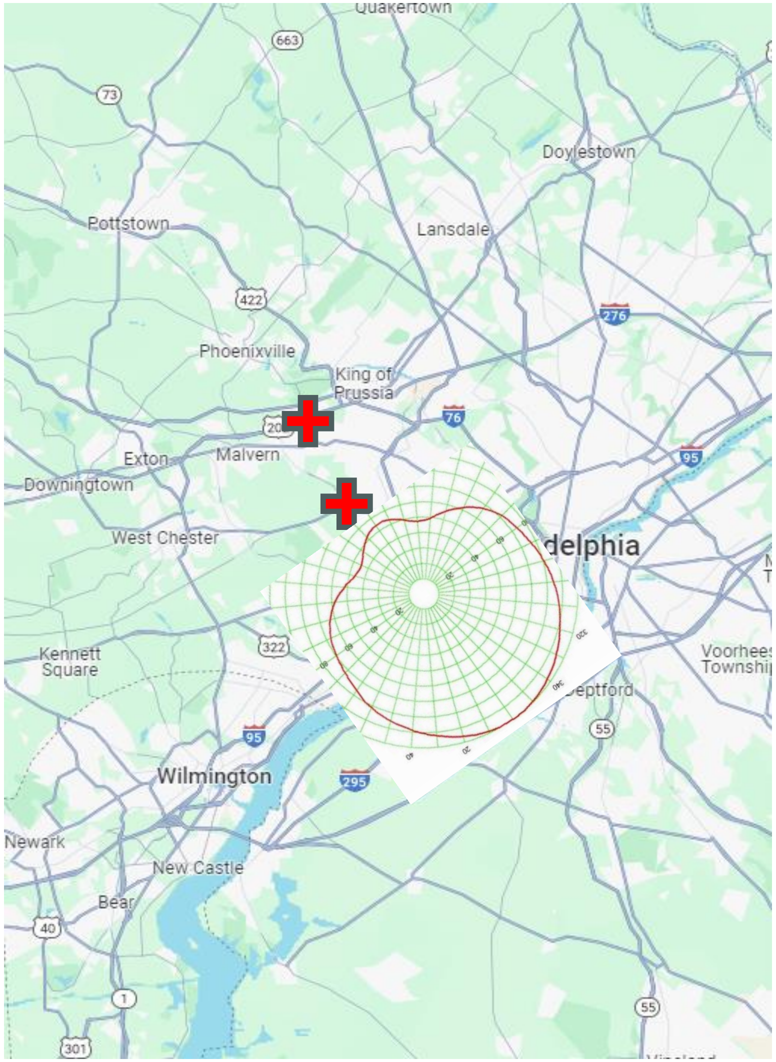


MARC Repeater Systems Explained

The MARC Newtown Square VHF repeater (147.06 MHz) has a slight cardioid antenna pattern because, although it is an omnidirectional vertical antenna, it is mounted to the side of the tower.

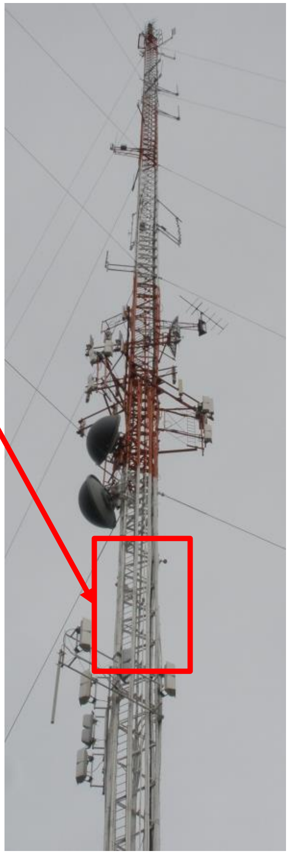


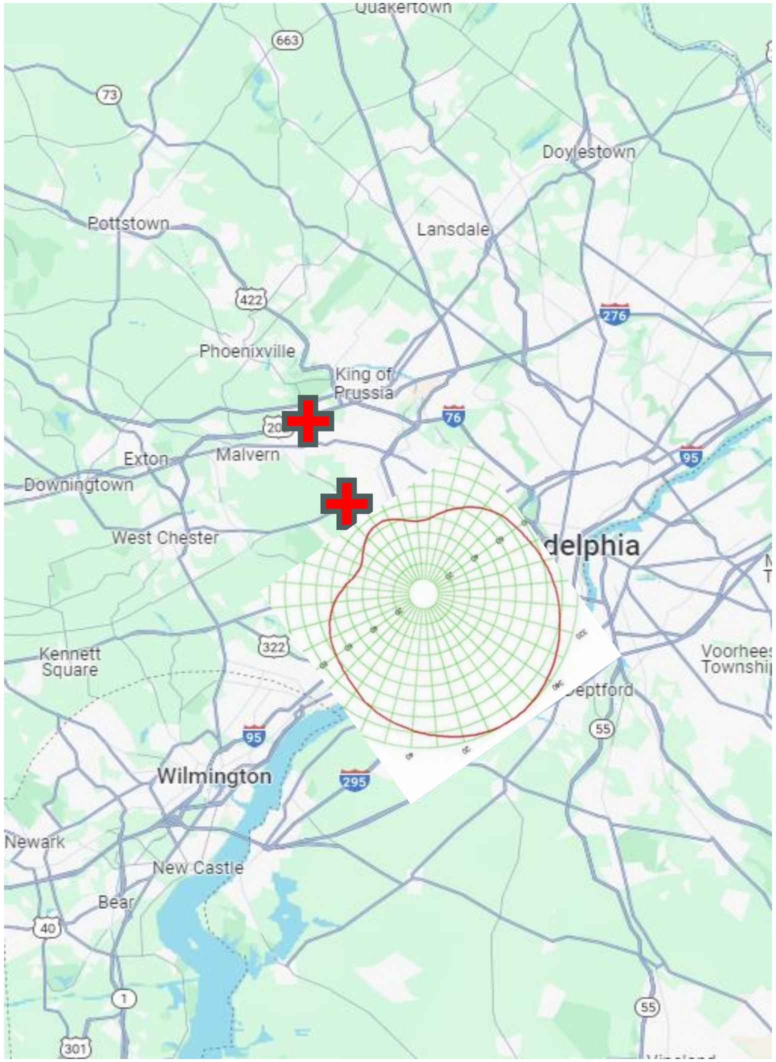
The main lobe of the pattern is to the southeast.



MARC Repeater Systems Explained

The MARC Newtown Square VHF repeater antenna is mounted at the 240 foot level of the 800-foot broadcast tower. The ground elevation is 418 feet.

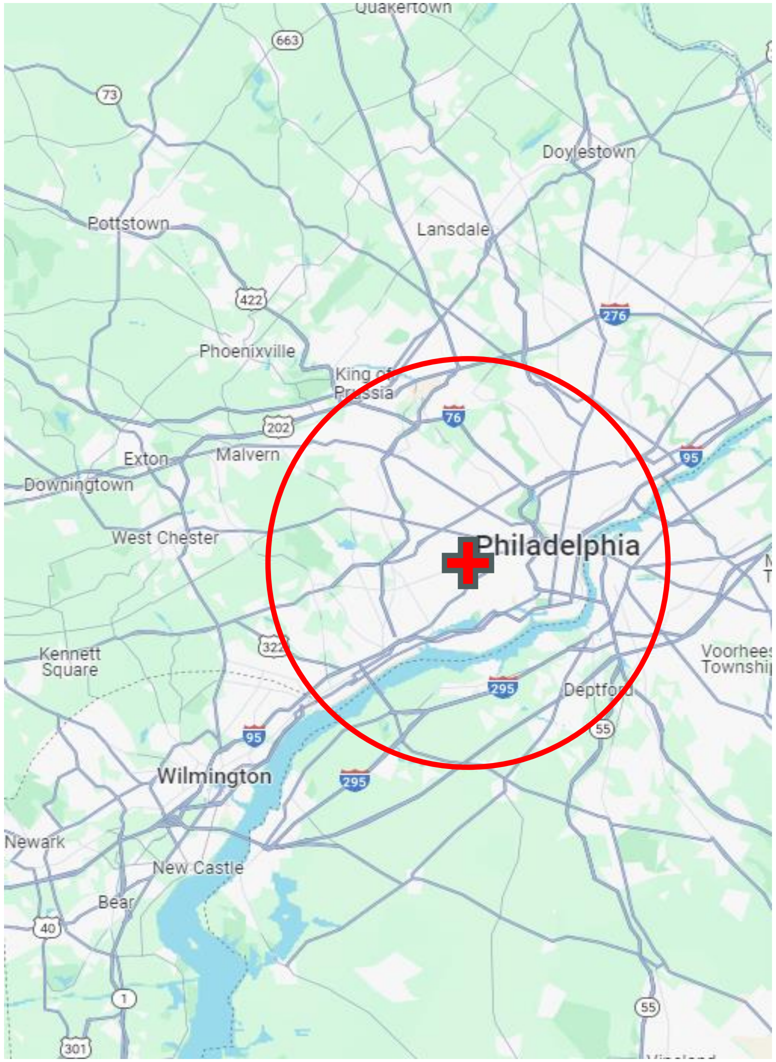




MARC Repeater Systems Explained

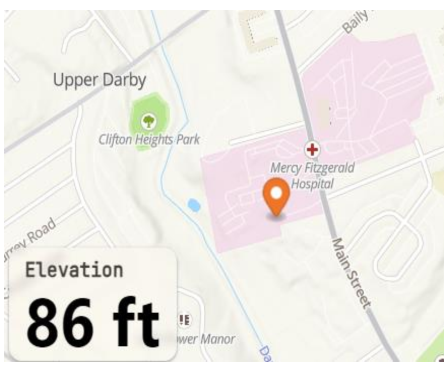
The MARC Darby VHF repeater (147.36 MHz) uses an omnidirectional vertical antenna mounted at the top of the tower.

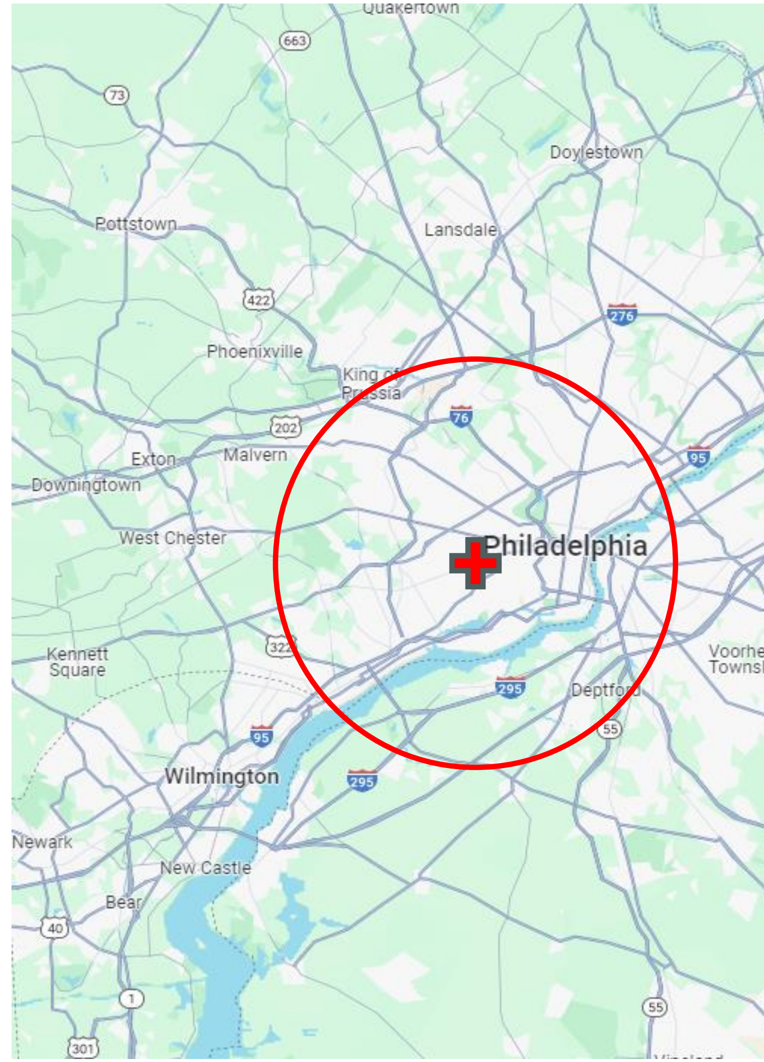
The antenna pattern then is omnidirectional except for adverse terrain.



MARC Repeater Systems Explained

The MARC Darby VHF repeater antenna is on a 50-foot tower on a 10 story building or ≈160 feet. The ground elevation is 86 feet.





MARC Repeater Systems Explained

MARC Fusion Repeaters

MARC was an early adopter of the Yaesu Fusion repeater system with the initial DR-1 installed at Paoli UHF (445.675 MHz) in 2015.

MARC now has two Yaesu Fusion DR-2X repeaters at Paoli UHF (445.675 MHz) and Darby UHF (444.050 MHz).

MARC Repeater Systems Explained

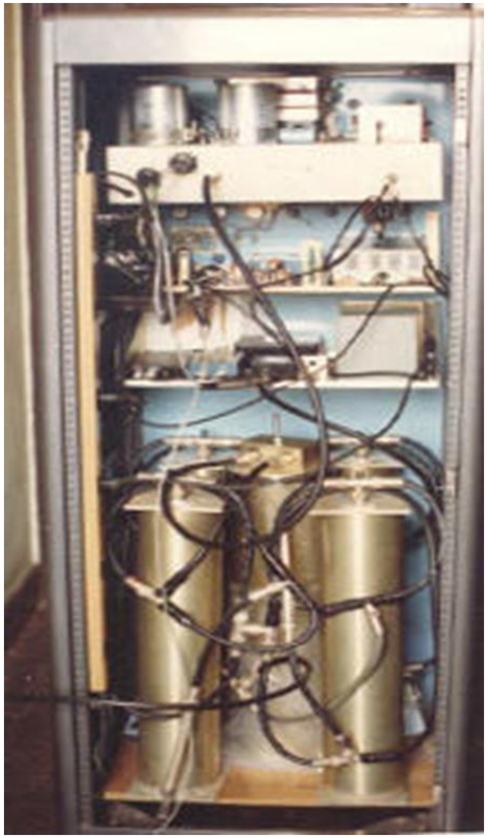
The Yaesu Fusion repeaters can be linked to a *Room* by a *Node Control* station.

Steve K3FZT is the control for the Darby UHF repeater (444.050 MHz) which is connected to the popular *Kansas City Wide Room* and other Fusion nets.

Dennis K3DS is the control for the Paoli UHF repeater (445.675 MHz) which is connected to the *Keystone Wide Room* or the *East Coast Room*.

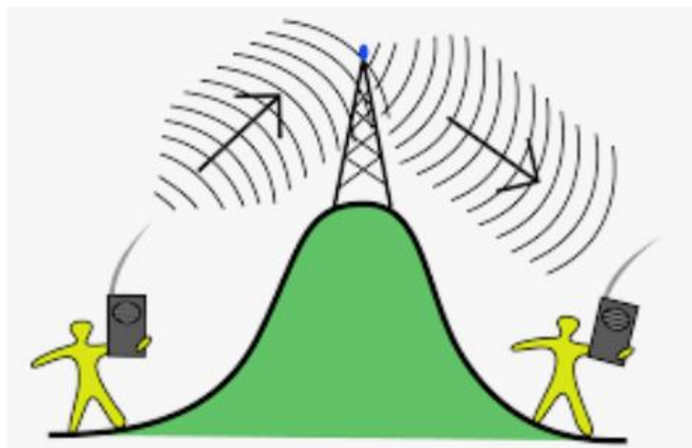
MARC Repeater Systems Explained

MARC has come a long way since the initial 147.06 MHz repeater was installed in 1975!

Then	*A Little Later*	*Now*
		

MARC Repeater Systems Explained

Dennis Silage K3DS



Questions?

MARC Repeater Systems Explained

Dennis Silage K3DS