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Innovative Communication Solutions

2013 CARA Repeater Conference Presentation

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Agenda

Antenna Theory- How do the various antennas work

Antenna Patterns- How can we control the pattern

Antenna Components- What are they and their Importance

Antenna Installations- How are the various antennas Installed

Low PIM Antennas- What are they and why chose them

Antenna Testing- How to test to verify proper operation

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Agenda (Continued)

New Products- Antennas

Types of Filters- Principle of operation and when to use which one

Filter Products- Choosing the right product for your application:

Ferrite Isolators, Circulators & RF Loads- How do they work, and why do we need them

Interference Control- What is it, and how can we minimize it's effect

New Products- Filters

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Innovative Communication Solutions

Antenna Theory

How Do Various Types of Antennas Work?

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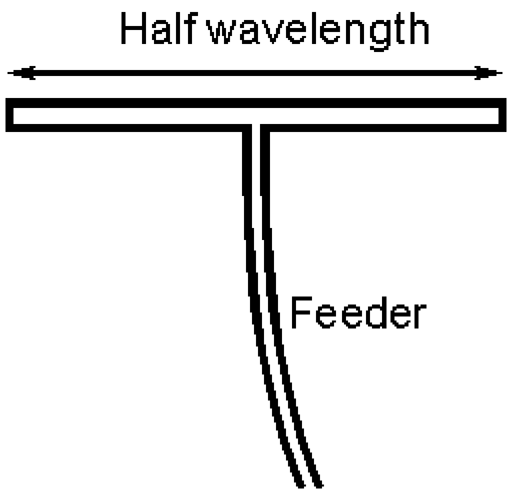
The Folded Dipole

- Offering a wide bandwidth and a considerable increase in feed impedance (when compared to standard dipole)
- Formed by taking a standard dipole and then taking a second conductor and joining the two ends, making a complete loop.
- If the conductors in the main dipole and the second or "fold" conductor are the same diameter, then a fourfold increase in the feed impedance occurs.
- This gives a feed impedance of around 300 ohms.



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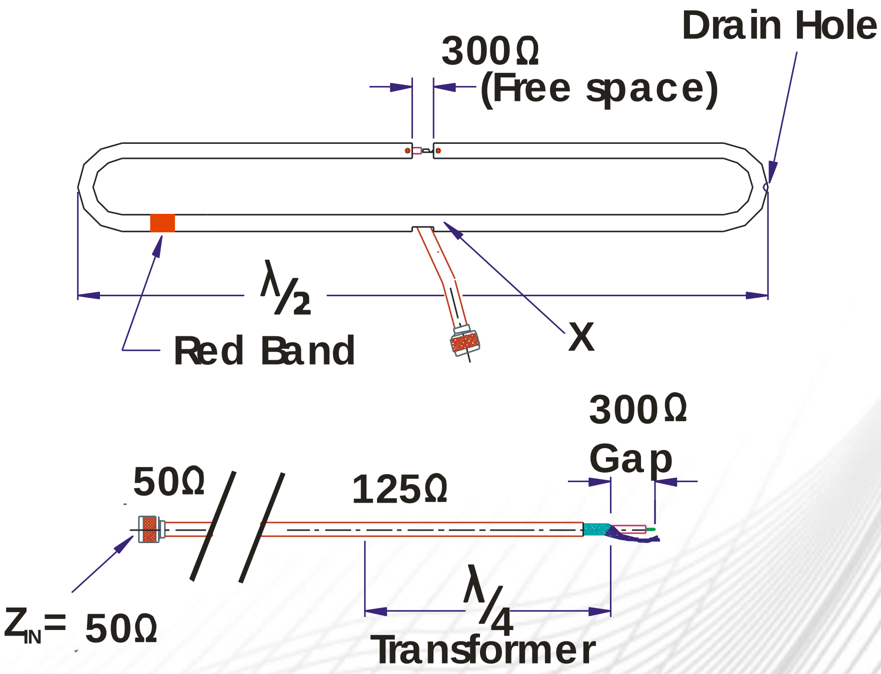
The Folded Dipole

The driven element of choice for dipole arrays, yagis, corner reflectors BECAUSE

- Inherently Broadband
- Reliable waterproofing
- Neutral mounting point (x)
- Low leakage of radiating currents onto cable braid
- Quarter wave transformers provide matching for yagis, corner reflectors, and dipole arrays



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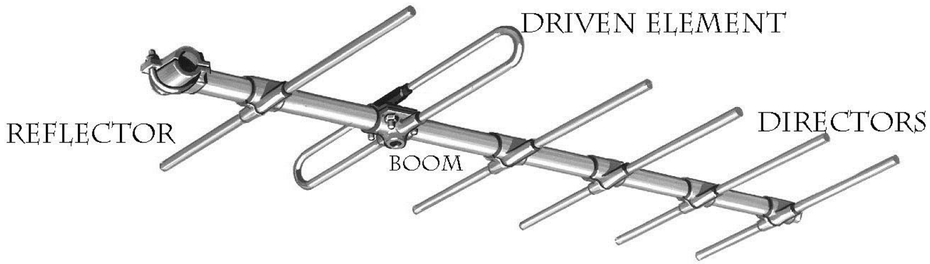
The Yagi Antenna



- Yagis consist of a various number of elements, which dictates the gain of the antenna.
- Offer outstanding durability and performance.
- All elements including the folded dipole are maintained at DC Ground potential for lightning protection.
- All elements on these antenna are attached to the boom with solid cast aluminum clamps.
- This series of antennas are supplied as a standard mount or, as an end-boom mounted unit.
- Also available in multiple-unit arrays for added gain.
- Horizontally or vertically parallel kits of ‘H’ frames can readily be supplied to mount two or four Yagis with a common feed.

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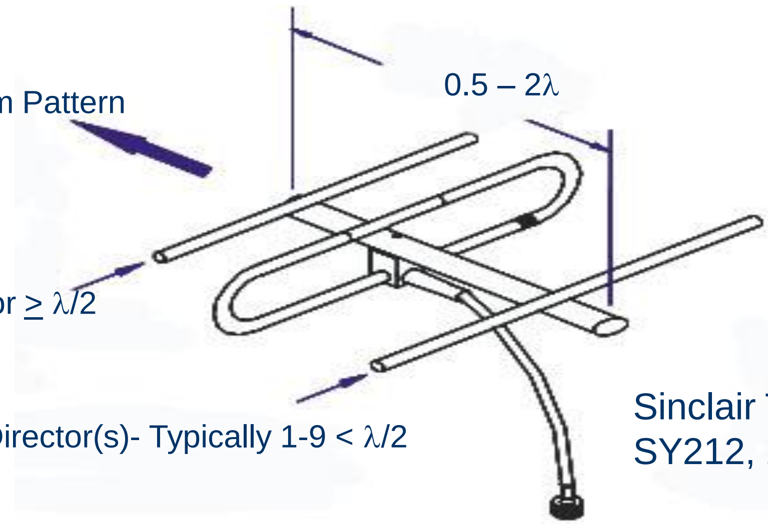
Yagi Antennas



Sinclair Types:
SY212, 206, 312, 307, 406, and 415

- least expensive way of obtaining high gain
- low wind load
- severely detuned by ice coating - do not use if system is to operate under icing conditions

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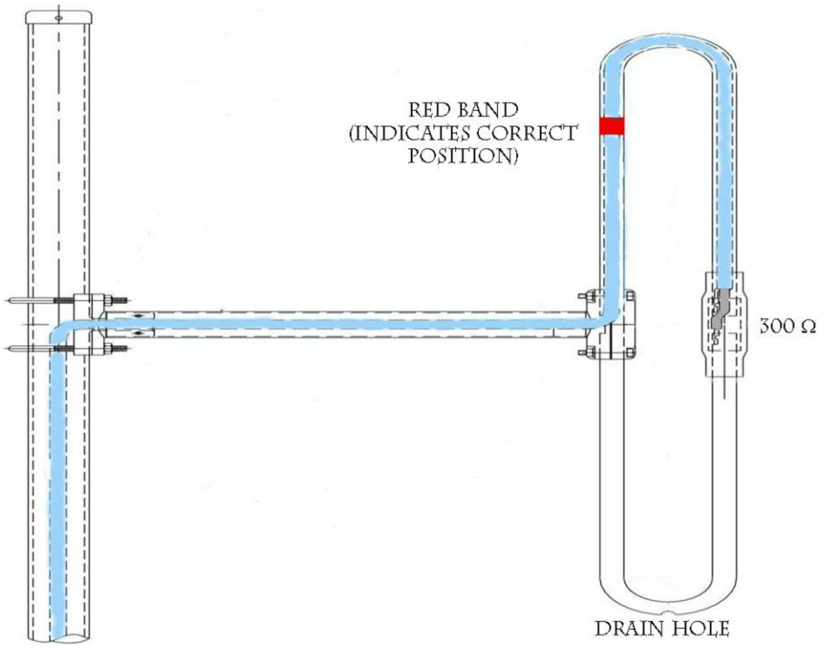
Dipole Arrays



- Utilizes a folded dipole (as explained before).
- Has a drain hole opposite the side with the red band.
- Red band indicates which end is up.
- Polarization dictated by orientation of dipole
  - When dipole is in the vertical direction (as shown above), then Vertically Polarized
  - When dipole is in the horizontal direction, then Horizontally Polarized.

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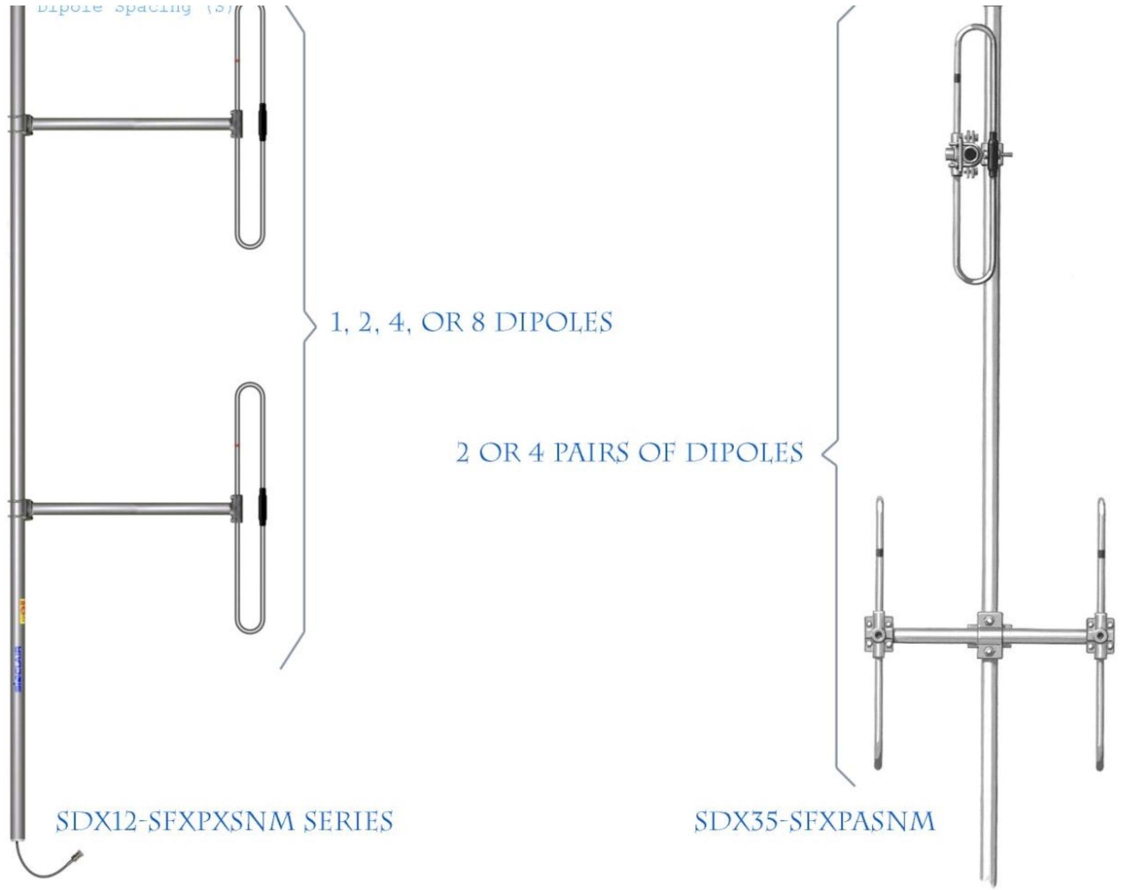

Broadband (Multicoupling)
S=λ/4 offset pattern
S= λ/2 bi-directional pattern
Side or top mount on tower
Moderate wind load
Good immunity to damage by lightning
Only slight detuning with ice coating

- Broadband (Multicoupling)
- 3 or 6 dB omni pattern
- Top mount above tower only
- Moderate to high wind load
- Good immunity to damage by lightning
- Only slight detuning with ice coating

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OMNIs

End-fed (E):

- Antenna is fed from the bottom and all the radiators are fed in series.
- The sources of radiators are co-phased by the phasing coils.
- Downtilt is achieved by trimming the coils and maybe length of radiators if necessary

Cooperate-fed (C):

- All the radiators are fed in parallel.
- Power splitting is realized by harnesses.
- Amplitude and phase can be changed individually by the harness

Hybrid-fed (H):

- End-fed and cooperate-fed are used at the same time to feed all the radiators.
- Typical structure is feeding the antenna in the center by cooperate-feeding, thus the antenna is divided into two parts.
- Then radiators in two the parts are in series-fed, i.e., end-fed

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Collinear OMNI Antenna

- an array of dipole antennas mounted such that every element of each antenna is in an extension of its counterparts in the other antennas in the array
- is usually mounted vertically, in order to increase overall gain and directivity in the horizontal direction
- When stacking dipole antennas in such a fashion, doubling their number will, with proper phasing, produce a 3 dB increase in directive gain

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Types of Collinear OMNIs

SC323, SC369, SC320, SC329,
SC233, SC229

- aesthetically pleasing
- low wind load
- light weight
- Omni patterns
- 118-137 MHz, 1 dBd gain (SC6172)
- 225-400 MHz, 3 dBd gain (SC6185)
- Dual band 118-137 and 225-400 MHz, 1 dBd gain (SC6175)

SC381

- aesthetically pleasing
- low wind load
- light weight
- Omni patterns
- 380-512 MHz, 6 dBd gain
- Available in low PIM

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Ground Plane

- Typical application is for roof mount on a local dispatch operation
- Usually used with a “radio in a tray” style of dispatch system
- Typically broad band in operation
- Usually environmentally rugged
- Usually field adjustable ground rods

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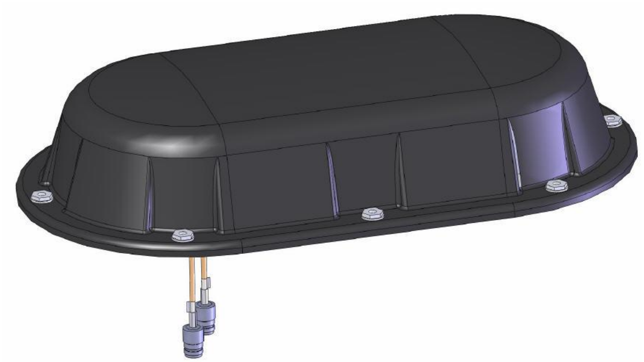
Multiband Antennas

- Upgradable & Multifunctional
- Broad Bandwidth
- GPS Capability
- Low Profile Design
- Ideal for Slightly Curved Surface



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Mobile Antennas

An antenna with a single driven element and a ground plane.

The whip antenna is a stiff but flexible wire mounted, usually vertically, with one end adjacent to a ground plane.

can also be called a half-dipole antenna.

The length of the whip determines its wavelength, although it may be shortened with a loading coil anywhere along the antenna.

Whips are generally a fraction of their actual operating wavelength, with half-wave and quarter-wave whips being very common.

Vertically mounted causes the whip antenna to have vertical polarization.

Whips are thought of as omni-directional, because they radiate equally in all directions in a horizontal plane, although they have a conical blind zone directly above them.

Weather proof base with integral sealing gasket

Stainless steel ferrule for corrosion resistance

Exterior finish will not chip or flake and is resistant to Ultra Violet radiation

Highest quality components and material are used throughout to provide maximum performance, reliability and life

Available accessories:

- Stainless steel shock spring
- Mounting kit

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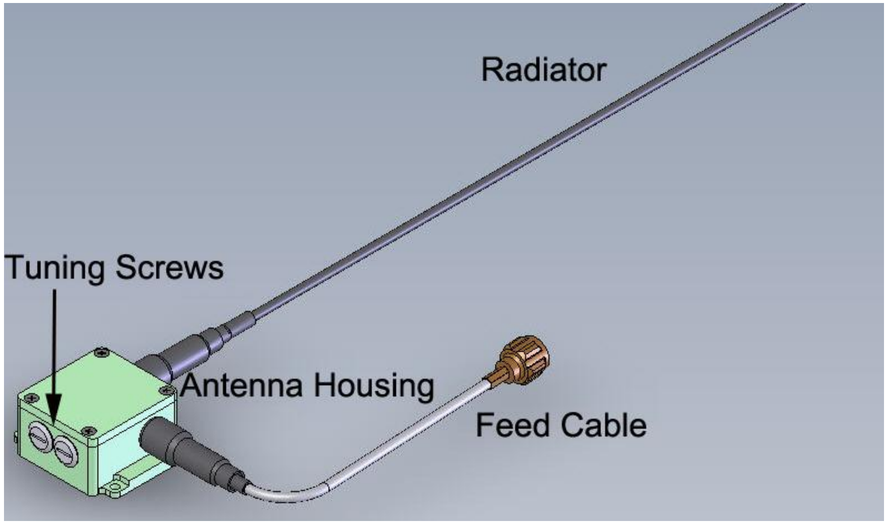
Covert

- Rugged aluminum enclosure.
- Chromate Conversion Coating, on all surfaces.
- Raised grounding area, on bottom side.
- Four point mounting, ensures grounding contact.
- Sealed grounding area, protect CDG mating surface.
- O-Ring sealed bolted top cover.
- O-Ring sealed connector holes.
- O-Ring & cap sealed tuning capacitor access holes.
- Connector is weather proofed by shrink tubing.
- Double sleeved antenna radiator wire.



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Covert (Continued)

Model Number	Frequency (MHz)	Bandwidth* Min-Max (MHz)	Connector	Power (Watts)	Length Inches(mm)	Gain (dBd)
VHF						
SHA211-SF1SNM	138 - 150	3 -24	N (male)	50	28 (711)	Unity
SHA211-SF2SNM	150 -174	3 - 24	N (male)	50	28 (711)	Unity
UHF						
SHA311-SF1SNM	380 - 430	20 - 50	N (male)	50	19 (490)	Unity
SHA311-SF2SNM	430 - 470	20 - 40	N (male)	50	19 (490)	Unity
SHA311-SF3SNM	470 - 512	20 - 42	N (male)	50	19 (490)	Unity
800 MHz						
SHA411-SF1SNM	746 - 806	60 - 80	N (male)	50	8 (203)	Unity
SHA411-SF2SNM	806 - 869	63 - 80	N (male)	50	8 (203)	Unity

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Panel Antennas

- Typical construction - radiating elements and circuit board mounted inside a UV protected radome
- Usually high front to back ratio
- Extremely tight pattern control, beam shaping and side lobe suppression
- Primary application in frequency re-use networks such as Cellular and PCS

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Corner Reflector Antennas

- Typically parabolic or “U” shaped metallic reflector
- Used for high gain, high directivity applications such as point to point communications

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Mobile & Train Antennas

- Typical application is for roof mount on a train or bus
- Supplied in either cast aluminum radiator or radome protected circuit board
- Extremely environmentally rugged
- Usually low profile design
- In essence the are a whip antenna, folded over and fed at various points so that the impedance is 50 ohms.
- Require a ground plane of sufficient size in order to function properly.
- Ground plane forms a reflector or director for the antenna.

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Antenna Patterns

How Do We Interpret and Control the Pattern?

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The “Ideal” Antenna

There are two important ‘ideal’ antennas that are non-realizable but that demonstrate some critically important antenna principles as well as serving as ‘standards’ by which most antennas are referenced to:

- Isotropic Point Source (IPS)
- Ideal Short Dipole

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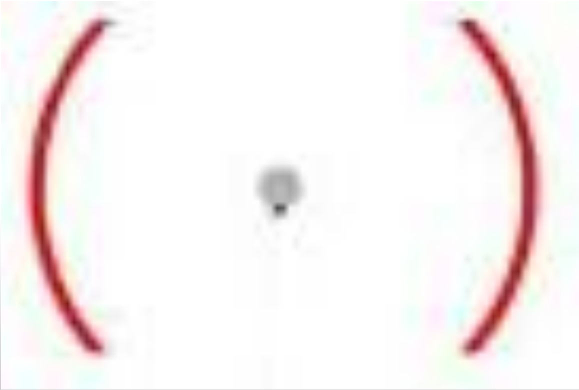
Isotropic Point Source (IPS)

- An ideal antenna that can be envisioned as a very tiny sphere that takes up no space, i.e., ‘point’ and that radiates perfectly spherical waves in 3 dimensional space.
-
- Wave fronts would appear as perfectly spherical balls that are ever expanding outwards from the location of the IPS.
- It would appear like the well-known circular ripples in water except that the circles are replaced by spheres expanding outward in 3 dimensions.
- In the spherical coordinate system they are waves radiating in the purely radial direction and they are exactly equal in ‘size’ in all directions.



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dBd vs. dBi

dBd

- refers to the antenna gain with respect to a reference dipole antenna.
- A reference dipole antenna is defined to have 2.15 dBi of gain.
- Converting between dBi and dBd is as simple as adding or subtracting 2.15 according to these formulas:

$$dBi = dBd + 2.15$$

$$dBd = dBi - 2.15$$

dBi

- The antenna gain with respect to an "Isotropic Radiator" .
- Antenna with 2.15 dBi of gain focuses the energy so that some areas on an imaginary sphere surrounding the antenna will have 2.15 dB more signal strength than the strength of the strongest spot on the sphere around an Isotropic Radiator.

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Power Density of IPS

- If EM power is put into the antenna then the radiated power from the antenna will be the same at all points on any sphere centered at the IPS.

- This means then that the well-known 2 dimensional, polar antenna power pattern will be a perfect circle centered on the point source.

- The power density around the IPS could be found by taking the input power (say it is W watts) and simply divide it by the area of a sphere enclosing the IPS.

- Since the area of a sphere is $4*\Pi*R^2$ then

$$Pr = W / (4*\Pi*R^2),$$

where R is the radius of the enclosing sphere.

Note that we assumed that no power is dissipated in the IPS (no resistive losses) – we assumed that every bit of power put into the antenna is radiated.

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Field Regions

In general, for any antenna, the general definitions of the field regions in the space surrounding the antenna are:

Near-field region: $R << 2\ D^2/\ \lambda$, where D is the maximum dimension of the antenna aperture.

The near-field region is further broken down to:

Reactive near-field: $0 < R < \lambda / 2\pi$

Radiating near-field: $\lambda / 2\pi < R < 1 - 3\lambda$ (depends upon the specific antenna)

Transition region: $1 - 3\lambda < R < 2\ D^2/\ \lambda$

Far-field region: $R > 2\ D^2/\ \lambda$

Antennas are designed to meet a set of specified characteristics in their far-field region. The gain, pattern, beam width, front-to-back ratio, etc. are all specs that apply in the far-field region of the antenna.

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Far-Field Measurements

Most antenna measurement ranges are ‘far-field ranges’ which necessarily require that the far-field condition be met, i.e., the AUT (antenna under test) and the range antennas must be separated by at least $2\ D^2/\ \lambda$. This set the minimum length of the range (minimum real estate).

A few examples of the minimum far-field distance for a few typical VHF and UHF antennas:

Frequency (MHz)	***D (feet)***	***$2\ D^2/\ \lambda$ (feet)***
125	19	91.68
300	08	38.99

The directivity of a very short dipole is 1.5 with respect to an IPS, this can be expressed in dB as 1.76 dBi.

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Radiation Pattern

- It is a 3-D figure
- In commercial practice, measurements in the vertical and horizontal planes are only documented
- Generally, only pattern in the horizontal plane is of immediate interest
- For antennas that can be vertically or horizontally polarized (i.e.. Yagi or Corner Reflector), usually specify polarization and patterns given in both V and H-planes
- Charts often calibrated with a linear decibel scale

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The E and H-Plane

- An antenna is a transducer which converts voltage and current on a transmission line into an electromagnetic field in space, consisting of an electric field and a magnetic field traveling at right angles to each other.
- An ordinary dipole creates electric field, creating a pattern with larger amplitude in planes which include the dipole.
- The electric field travels in the E-plane; the H-plane, perpendicular to it, is the field in which the magnetic field travels.
- When we refer to polarization of an antenna, we are referring to the E-Plane.
- However, for three-dimensional antennas like horns, dishes, and lenses, it is important to consider both the E-plane and the H-plane, in order to fully utilize the antenna and achieve maximum gain.

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λ/4 Vs. λ/2 Spacing

- Refers to spacing of dipole with respect to the mast.
- Two standard options: ½ wave and ¼ wave.
- Also available is 3/8 wave (special).
- ½ wave also known as bi-directional
- ¼ wave also known as offset.
- ¼ wave offers slightly more gain (0.5 dBd) vs. the ½ wave.

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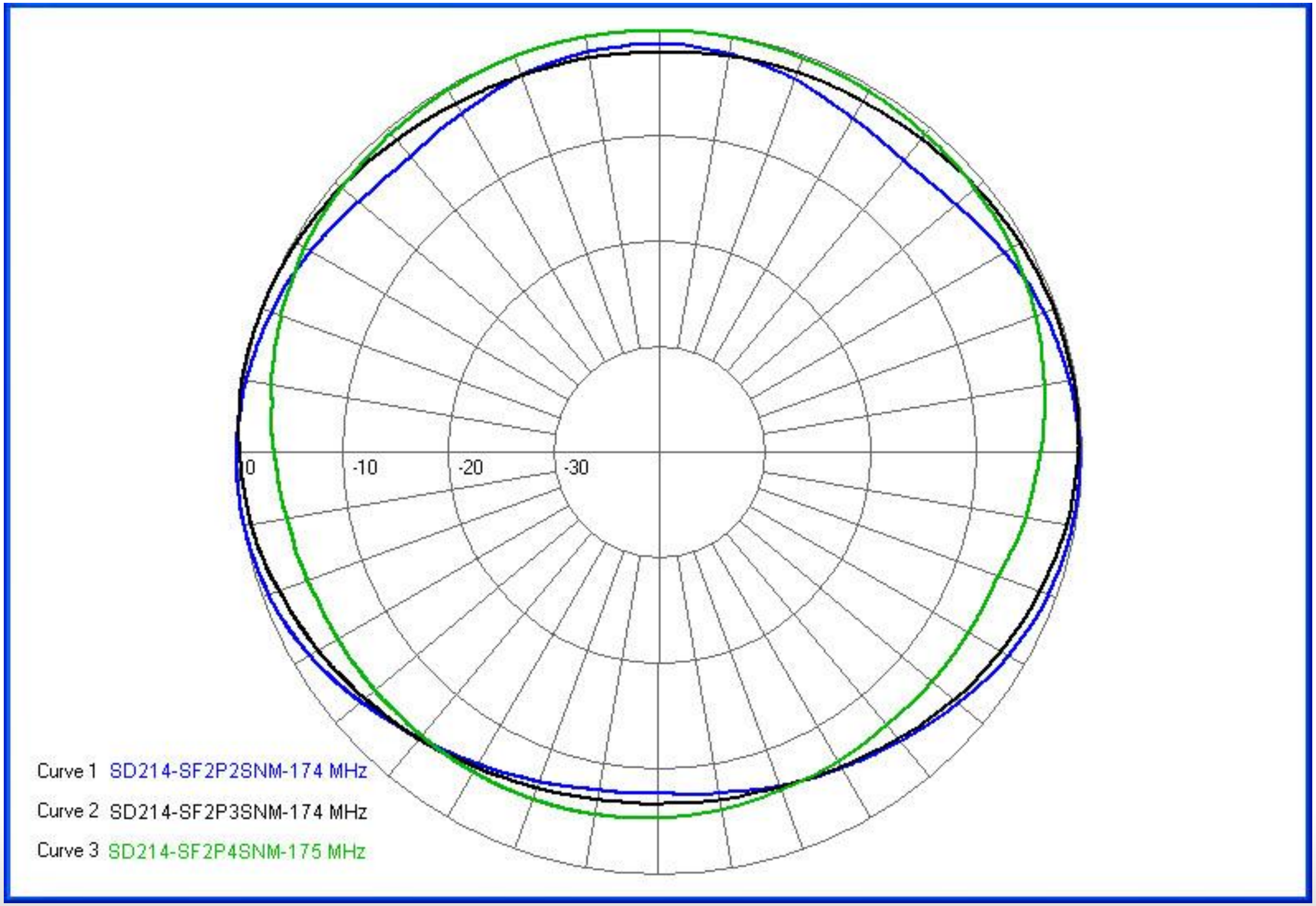
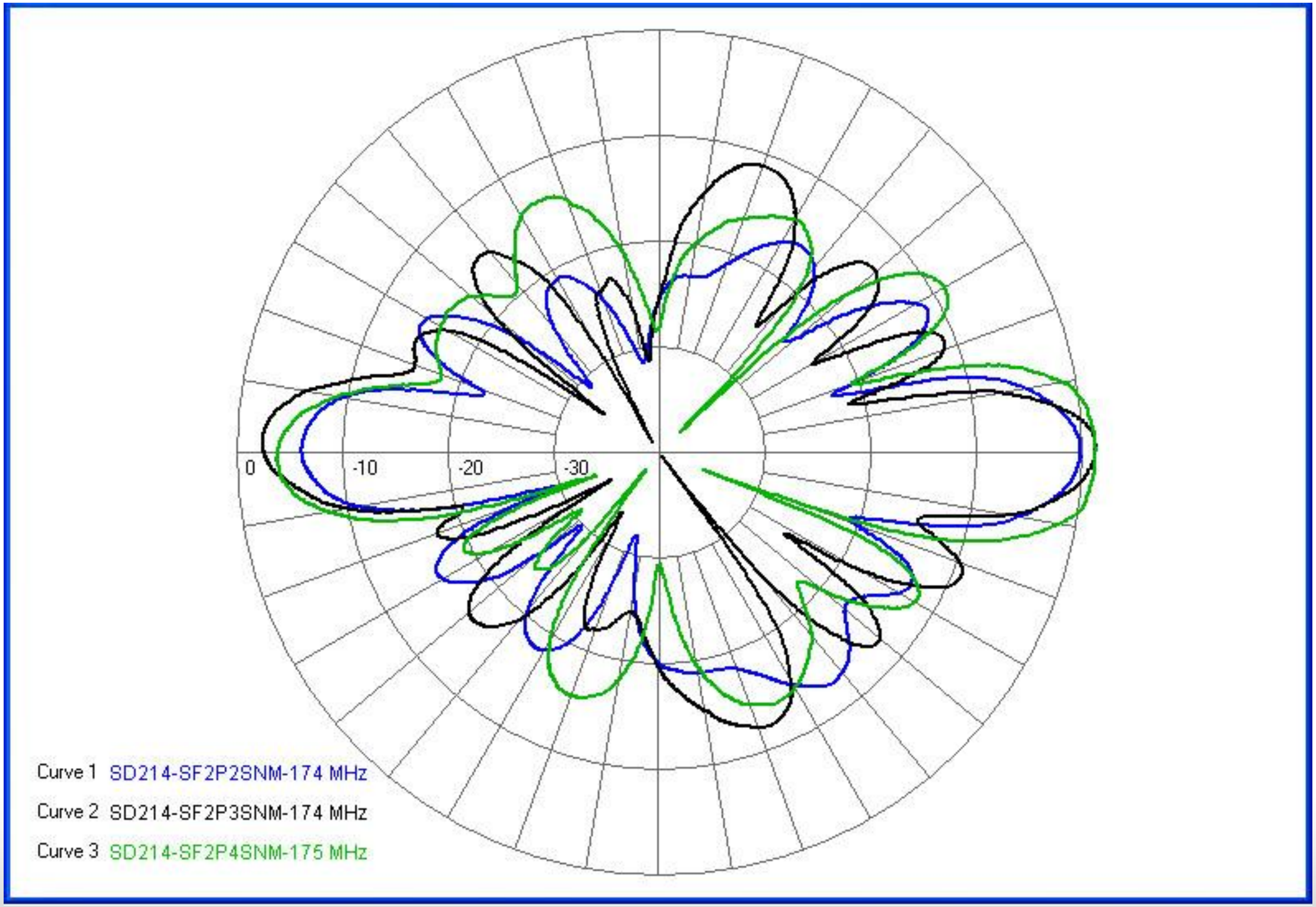
P2, P3, and P4 Horizontal Patterns



P2, P3, and P4 Vertical Patterns



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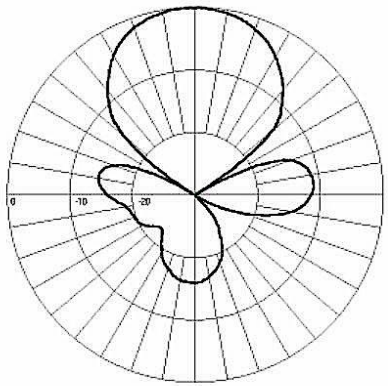
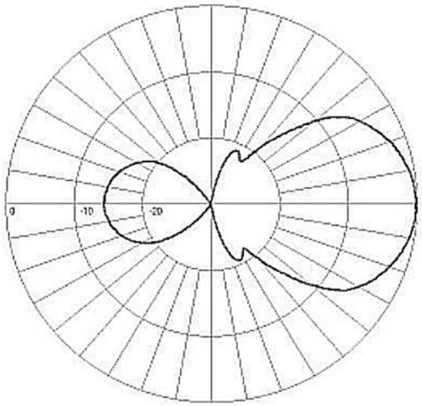
Antenna Patterns



Azimuth



Elevation

Pattern Chart Format as used on Sinclair's Website

Characteristics of these Charts:

- In order to orient the cuts to the antenna, a statement of the antennas polarization is required. Some antennas can be installed either vertically or horizontally polarized.
- The radials are spaced at 10 deg. intervals, while the display range is 30dB normalized to 0.
- The gain at the pattern maximum must be stated (specification) in order to convert the values to absolute terms (dBd)
- Digitized data is available (on request) in most of the common commercial formats

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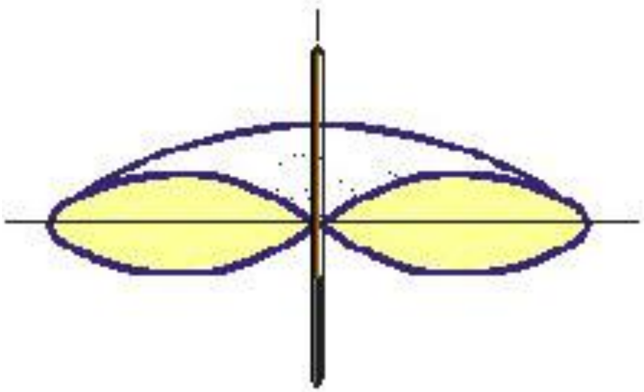
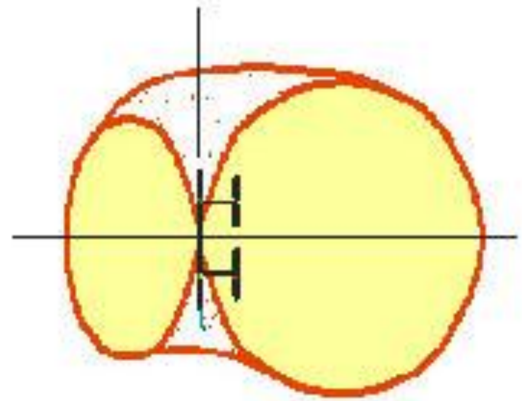
Typical Patterns

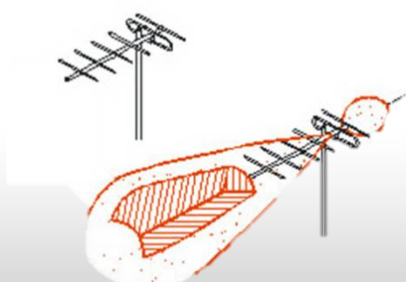
Collinear Omni (SC Series)



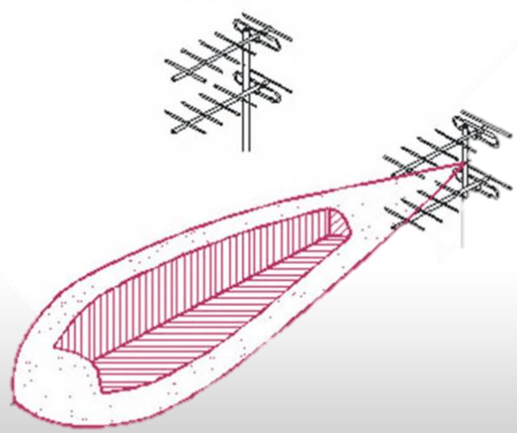
Dipole (SD Series)



Typical Single Bay Yagi



Typical Stacked Yagi (2 Units)



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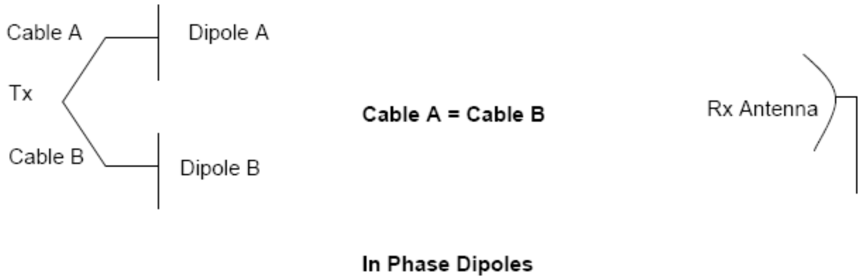
Pattern Shaping



- Gain is achieved by changing the shape of the pattern to put the radiation where you want it (shaping the pattern).

Phasing:

- One way to shape an antenna pattern is by making the phase of the current on one element different than the phase of the current on another element (input signals to the two elements are at different points in their cycle).
- This causes the radiation from the two elements to be in or out of phase as seen from a point at some distance from the two elements (far-field).
- Consider the case of two dipoles positioned vertically one above the other and separated a distance of around one wavelength between their centers.
- If the two dipoles are connected by cables of the same length to a transmitter, the power from the transmitter will arrive at each dipole at the same instant and the dipoles will start radiating in the same direction at the same time.
- An antenna several kilometers away from each dipole will receive the two waves exactly together and they will add up to give a stronger signal.
- The two dipoles are “in phase”.

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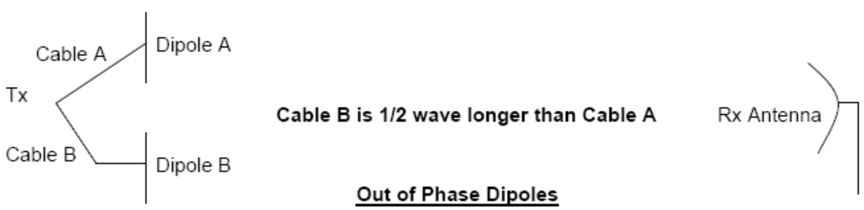
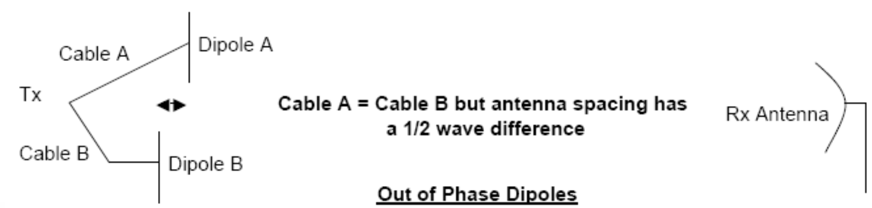
Pattern Shaping

- If cable B is lengthened by one-half wavelength or any odd multiple of a half-wavelength (1/2, 3/2, 5/2, etc.), the power from the transmitter will arrive at dipole B half a cycle later than dipole A.
- Consequently, radiation from dipole B will arrive at the receive antenna out of phase with radiation from dipole A and the two waves will cancel out.
- The two dipoles are “out of phase”.
- The same “out of phase” cancellation would occur if the cable lengths were kept the same but dipole A was moved half a wavelength closer to the receive antenna.
- The radiation from dipole B would arrive at the receive antenna half a cycle later than that from dipole A.
- When B was going plus, A would be going minus and the received signals would cancel out.





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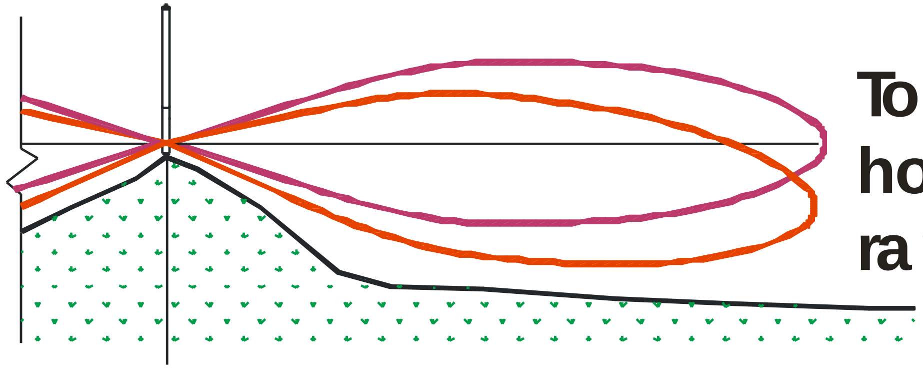
Pattern Downtilting

DownTilt Required

To beam signal into shadowed area



To limit horizontal range

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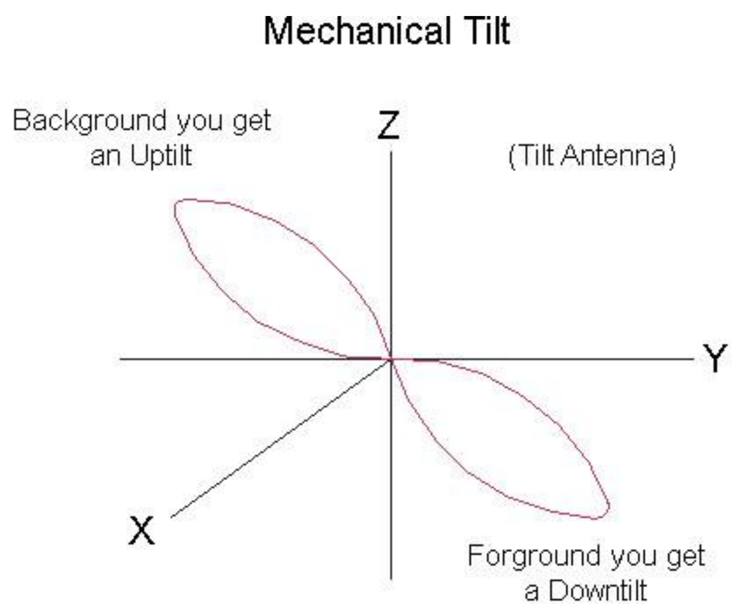
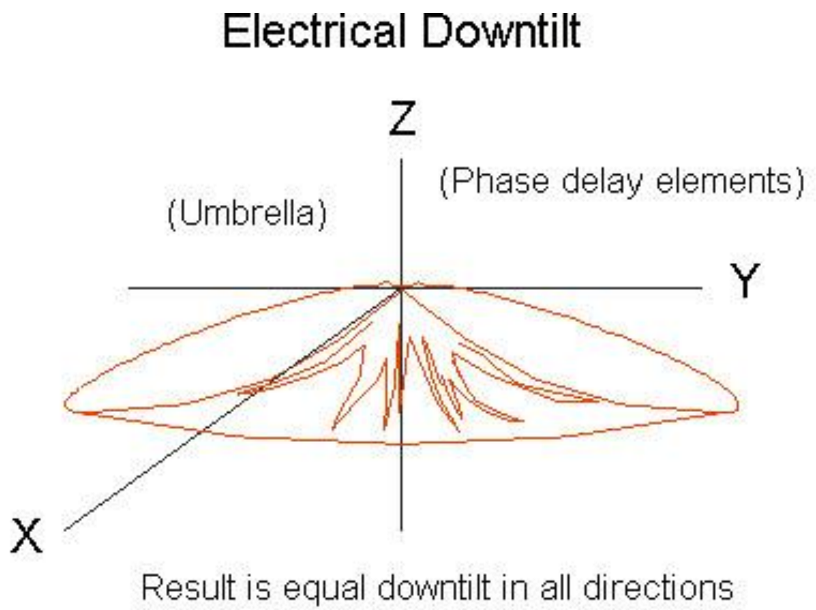
Mechanical vs. Electrical Downtilt





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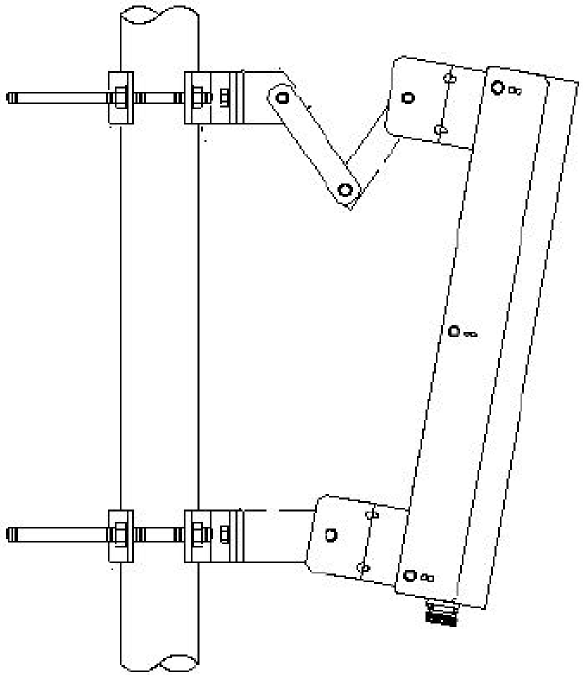
Mechanical Downtilt



- The main beam is tilted downward by physically tilting the antenna away from the vertical.
- Mechanical downtilt does not apply to Omnis
- It really only applies to sectoral antennas that have narrow horizontal beamwidths (60 degrees or less).
- If the pattern is tilted 5 degrees at the front, the sides (3 dB points) will not tilt at all.
- The narrower the azimuth pattern, the more uniform the tilt will be across the 3 dB beamwidth of the antenna.

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Electrical Downtilt

- The main beam is tilted downwards electrically by feeding the elements (dipoles) of the array with currents of different phase.
- The advantage: The beam is tilted evenly over the entire beamwidth of the antenna (for a given operating frequency).
- Usually, the sidelobes (in the vertical pattern of the antenna) increase as the amount of electrical downtilt is increased.
- The resulting loss in gain is not a problem but the power radiated by the upper sidelobe may cause interference in neighboring systems.
- For this reason, system designers like to see the upper sidelobe thirty degrees or more above the main beam.
- Electrical downtilt is not constant over the operating bandwidth of the antenna. (It does vary slightly with frequency).

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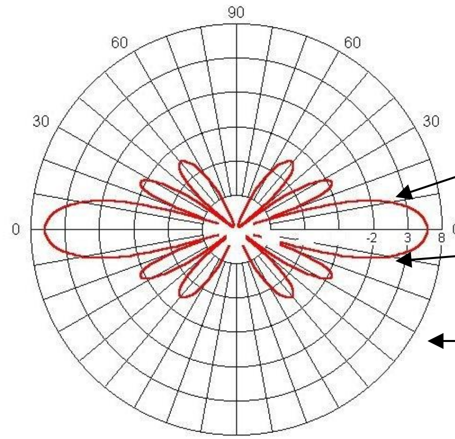
Improving Local Coverage

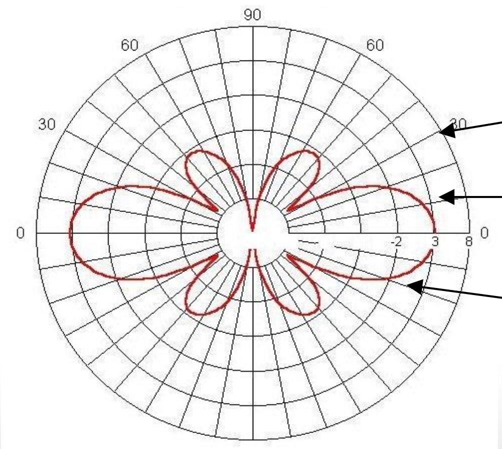


- Use lower gain antenna

*HPBW = 18 deg

*lower 3 dB point 9 deg below horizon

6 dBd omni antenna --- 0 deg DT



3 dBd omni antenna --- 0 deg DT

*HPBW = 36 deg

*lower 3 dB point 18 deg below horizon

*more gradual roll off

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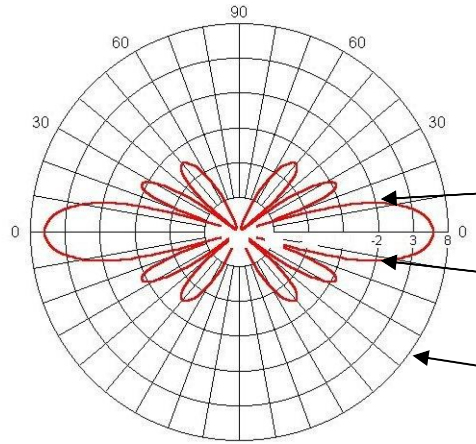
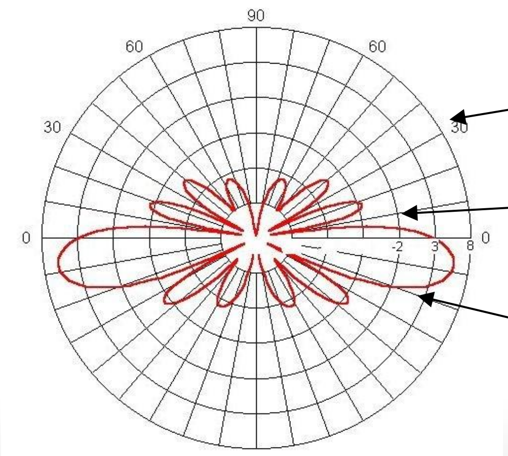
Improving Local Coverage





Pattern Downtilting

HPBW = 18 deg

lower 3 dB point 9 deg below horizon

6 dBd omni antenna --- 0 deg DT

6 dBd omni antenna --- 9 deg DT

upper 3 dB point on the horizon
(3 dB gain reduction vs. 0 DT case)

lower 3 dB point 18 deg below horizon

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Antenna Components

What They Are and Why They're Important

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Types of Cables

Frequency (MHz)	138
Temperature (C)	25
VSWR	1.50
Length (in)	1200
Length (ft)	100

Cable	Loss	Power	Zo
RG 11	2.71	638	75
RG 58C	6.04	170	50
RG 63	1.83	691	125
RG 83	2.39	1339	35
RG 142	4.67	1856	50
RG 188	3.14	923	50
RG 196	15.96	190	50
RG 213	2.71	831	50
RG 214	2.71	831	50
RG 302	4.67	1856	75
RG 303	4.67	1856	50
RG 393	2.54	4871	50

Frequency (MHz)	450
Temperature (C)	25
VSWR	1.50
Length (in)	1200
Length (ft)	100

Cable	Loss	Power	Zo
RG 11	5.59	328	75
RG 58C	12.43	92	50
RG 63	3.63	402	125
RG 83	4.41	797	35
RG 142	8.66	1035	50
RG 188	6.01	554	50
RG 196	29.84	117	50
RG 213	5.59	420	50
RG 214	5.59	420	50
RG 302	8.66	1035	75
RG 303	8.66	1035	50
RG 393	4.88	2712	50

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Connectors and Junctions

- Provides an interface from a transmission line to other electrical devices with minimal signal degradation.

Type	Max. Operating Freq.	Avg. Power (kW)*	Size
SMA	18 GHz	0.4	Miniature
N	11 GHz	0.3	Medium
7/16 DIN	7.5 GHz	2.5	Medium

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Connector Parameters

- Easy to Install
- Solderless
- Self-Flaring
- Intermod
- Low VSWR
- Waterproof

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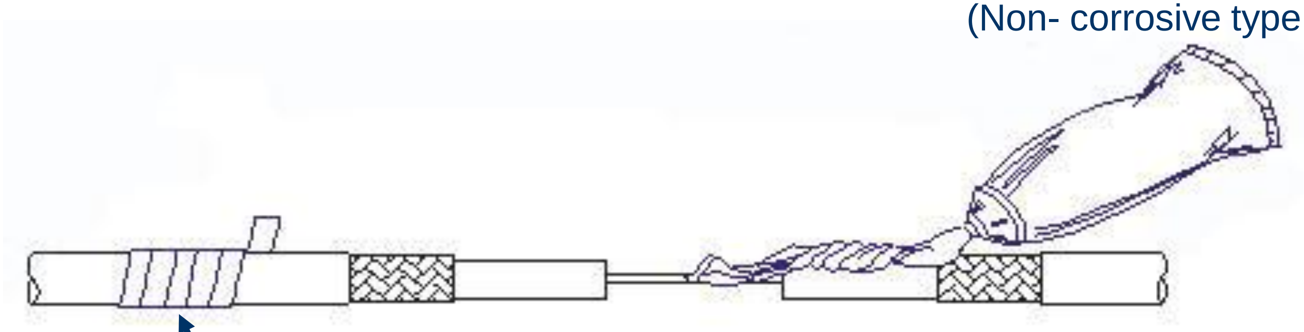
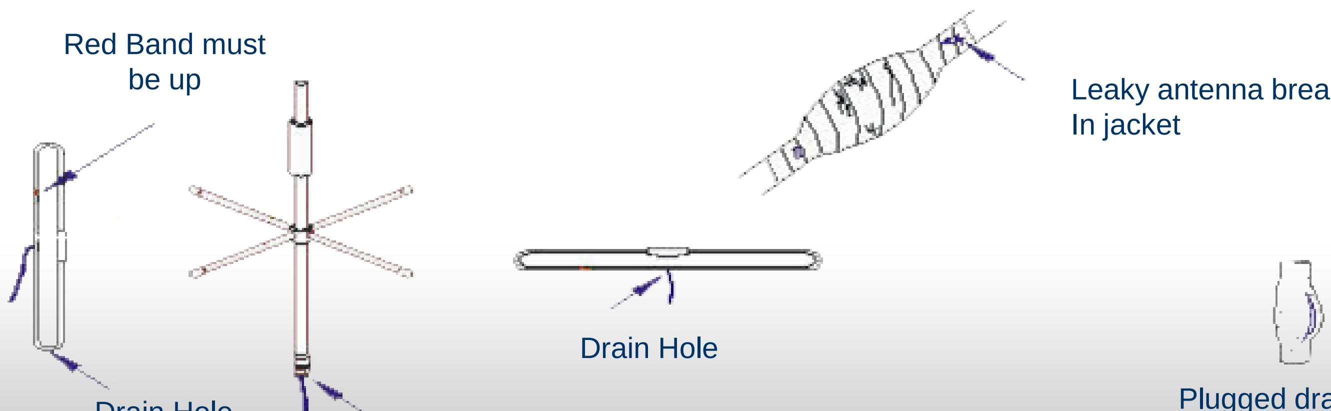
Waterproofing

- 1. Cable Protection



- 2. Antenna Protection



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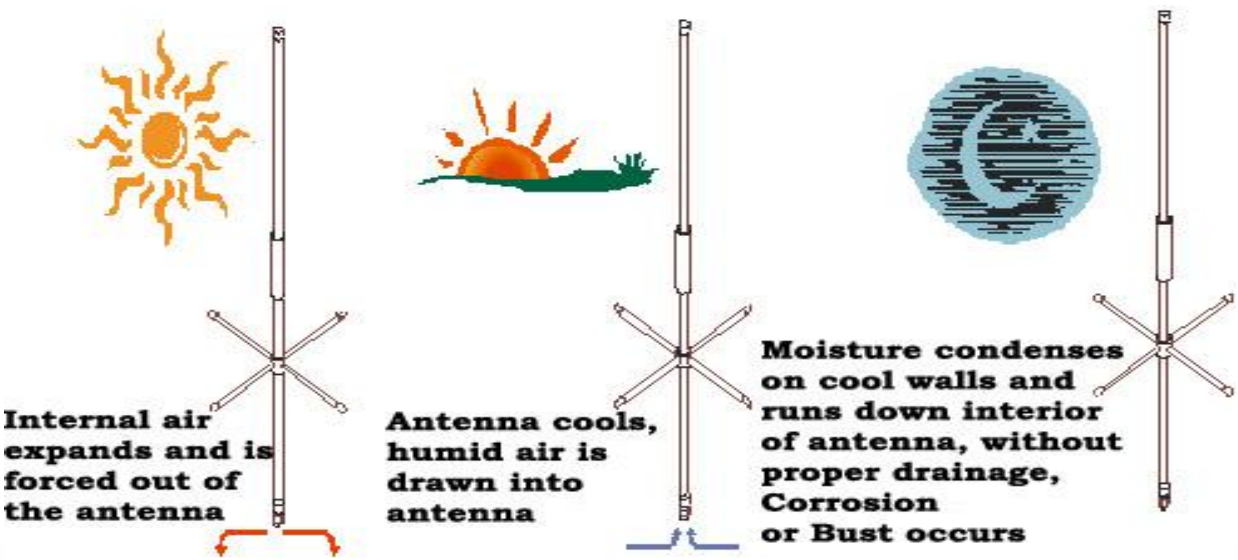
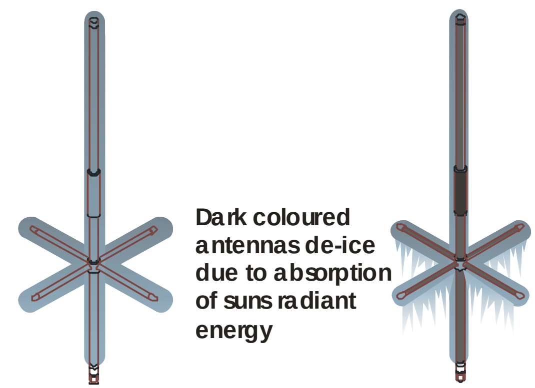
UV Protection

Damage to plastics:

- Causes surface cracking
- Chemical breakdown of material
- Rubber parts and tape rots
- Sinclair materials are specially selected





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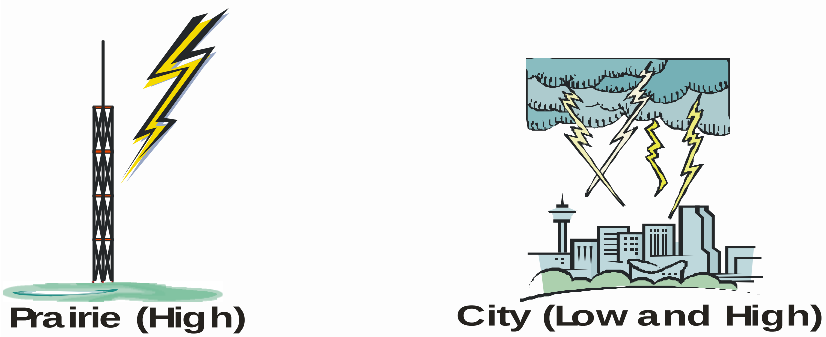
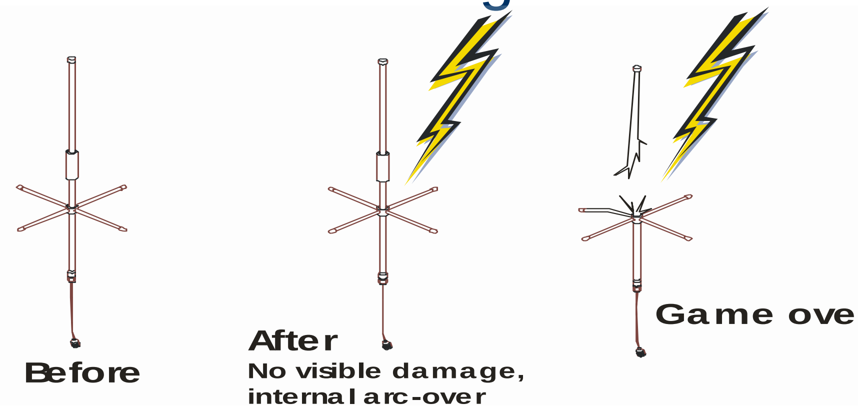
Lightning Protection

Probability

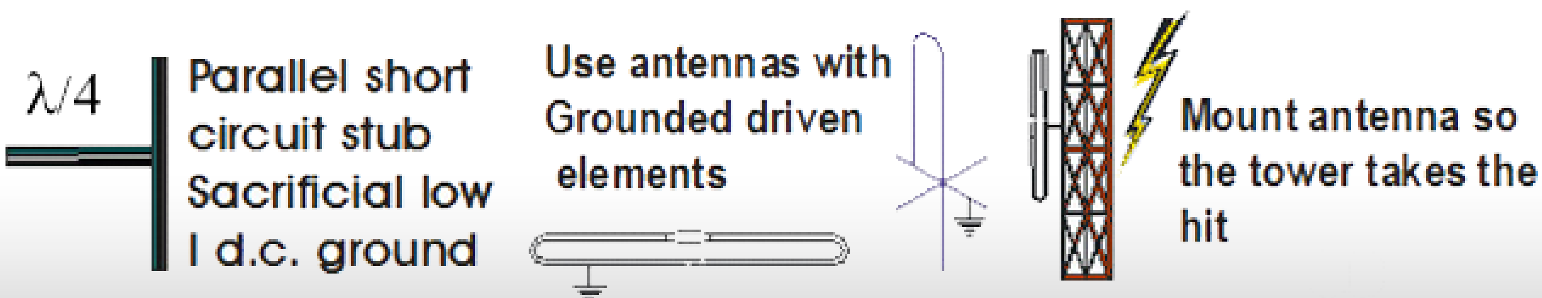


Nature of Damage



Protection

- Observe good ground practice
- Use surge protectors in coaxial runs



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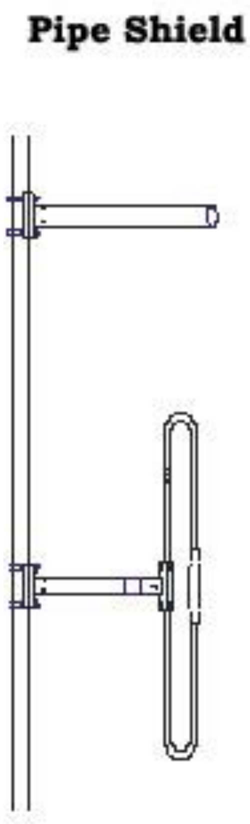
Ice Guards

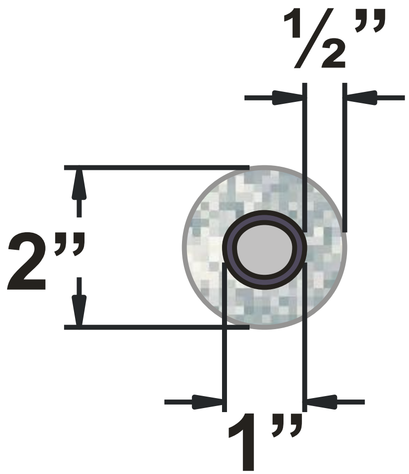
Mechanical Effects

- Large increase in dead weight
- Large increase in projected area results in wind damage
- Falling ice is a hazard

Electrical Effects

- Deteriorates performance of wide band or high performance antennas
- Severely de-tunes narrow band antennas (Yagi)
- Should use broadband or heated arrays





This figure shows a 1” piece of pipe
With ½” of radial ice on it.

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How Can Antennas Be Installed?

ANTENNA INSTALLATIONS

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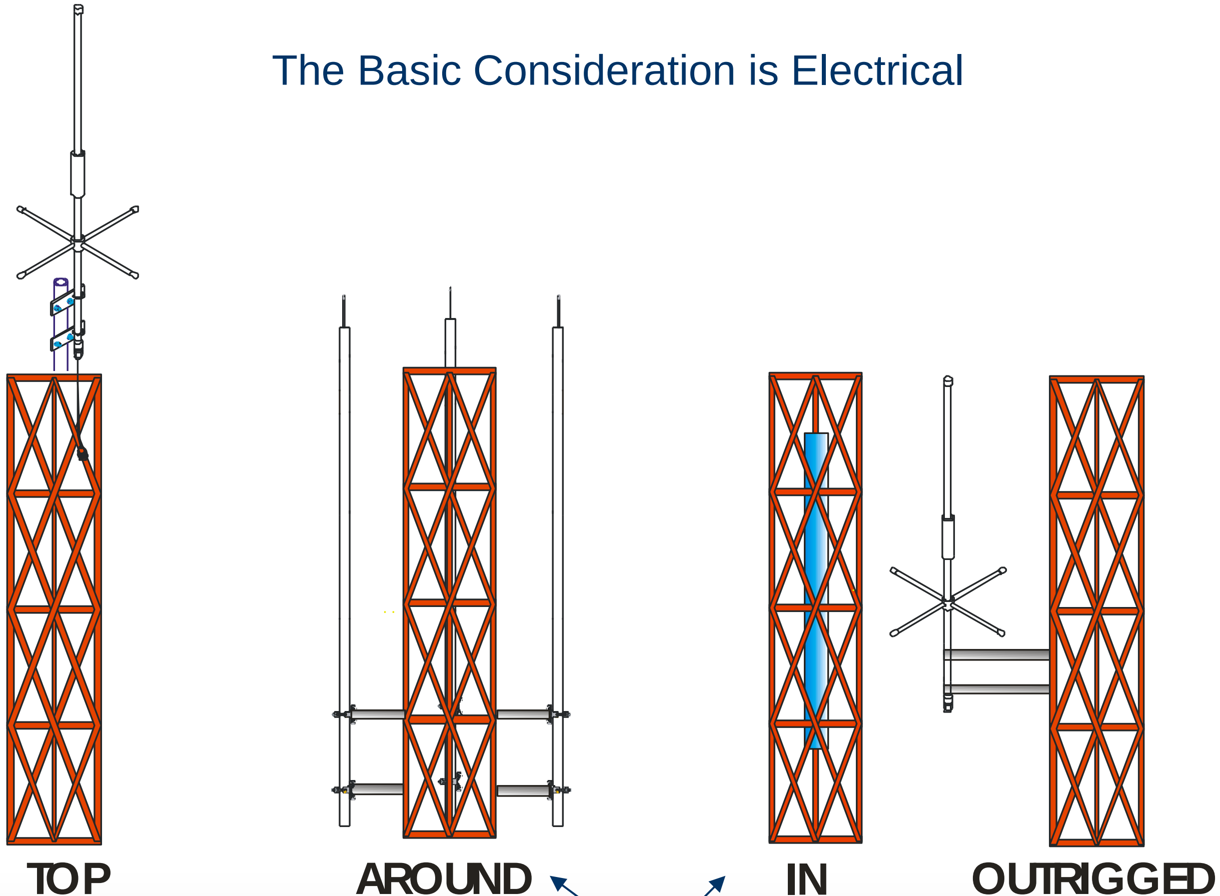
Antenna Installation

The Basic Consideration is Electrical



Best Circularity
-Standard Antennas

Good Circularity
Special Antenna
Matched to tower

Offset Pattern
Standard Antennas

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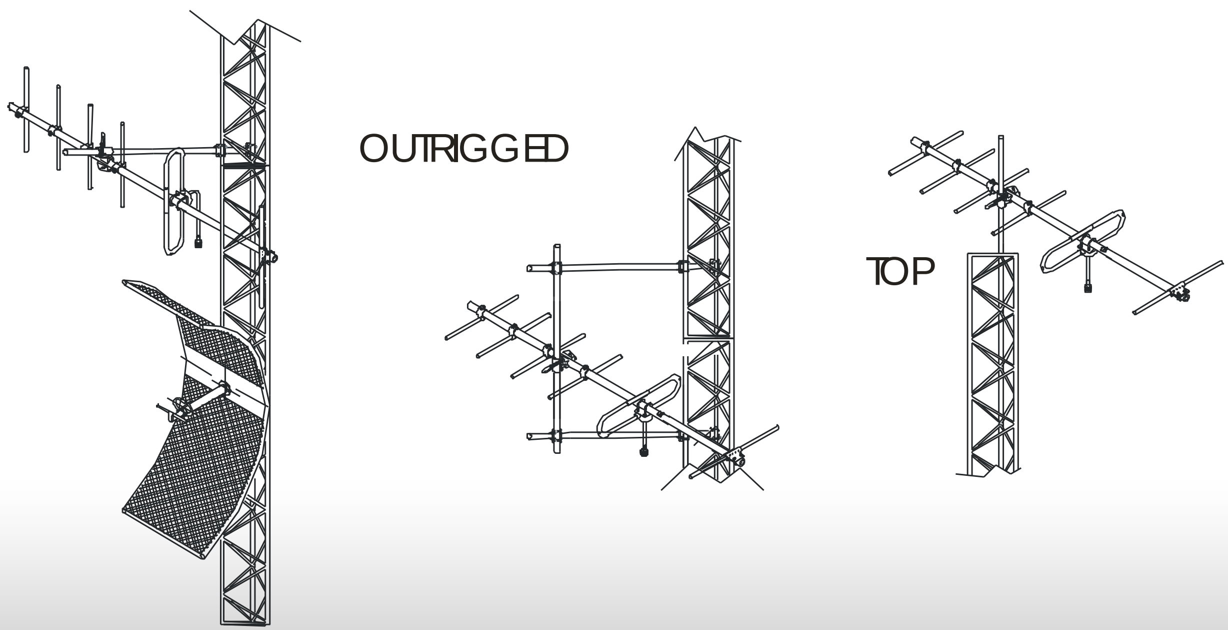
Antenna Installation

Unidirectional Antennas:
The basic consideration is mechanical

Tower has little effect on pattern with proper clearances
Mounting and bracing large antennas is easier if side mounted



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Sinclair Antenna Models	Clamps: Antenna to Tower Leg or Support Pipe					
	Clamp Included	**Qty Required**	**Round**	**60°**	**90°**	**wall, pole**
SC229 Series, SC320 Series	**Clamp005**	2	Clamp006A OR Clamp147			Clamp017A OR Clamp136
SC225-M Series, SC225-H Series	**Clamp005**	2	Clamp147, Clamp15, OR Clamp130			Clamp017AS OR Clamp136
SC233 Series, SC233M Series	**Clamp135**	1	Qty 2- Clamp015A			Clamp017AS OR Clamp136
SC281-H Series, SC412-H Series		2	Clamp006C			Clamp136A
SC323 Series, SC323-H Series	**Clamp130**	2	Clamp005			Clamp017A OR Clamp136
SC329-H Series, SC369H Series	**Clamp130**	2	Clamp005, OR Clamp120			Clamp017AS OR Clamp136
SC381-H Series		2	Clamp006C			
SC488 Series, SC488-H Series	**Clamp130**	2	Clamp147, OR Clamp005			Clamp017A OR Clamp136
SC489 Series, SC489-H Series, SC420-H Series	**Clamp130**	2	Clamp147, OR Clamp015			Clamp017A OR Clamp136
SC432D-H Series, SC432T Series, 432T-H Series		2	Clamp006B, OR Clamp147			Clamp017A OR Clamp136
SC433 Series	**Clamp130**	1	Clamp147, OR Clamp005			Clamp017A OR Clamp136
SC746-HL Series		2	Clamp147, Clamp130, OR Clamp005			Clamp017A OR Clamp136
SC479-HL Series		2	Clamp006B, OR Clamp147			Clamp017A OR Clamp136
SD110 Series, (6 Clamps <35.5 MHz; 4 Clamps for >35.5 MHz)		6 or 4	Clamp017, Clamp033, OR Clamp130	Clamp035 OR Clamp042	Clamp122	Clamp017A OR Clamp136
SD112 Series, (12 Clamps <35.5 MHz; 8 Clamps for >35.5 MHz)		12 or 8	Clamp017, Clamp033, OR Clamp130	Clamp035 OR Clamp042	Clamp122	Clamp017A OR Clamp136
SD114 Series, (24 Clamps <35.5 MHz; 16 Clamps for >35.5 MHz)		24 or 16	Clamp017, Clamp033, OR Clamp130	Clamp035 OR Clamp042	Clamp122	Clamp017A OR Clamp136

For a complete listing, please see our Clamp Selection Guide on our website at www.sinctech.com

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Images of Various Clamps

For a complete listing, please see our Clamp Selection Guide on our website at www.sinctech.com

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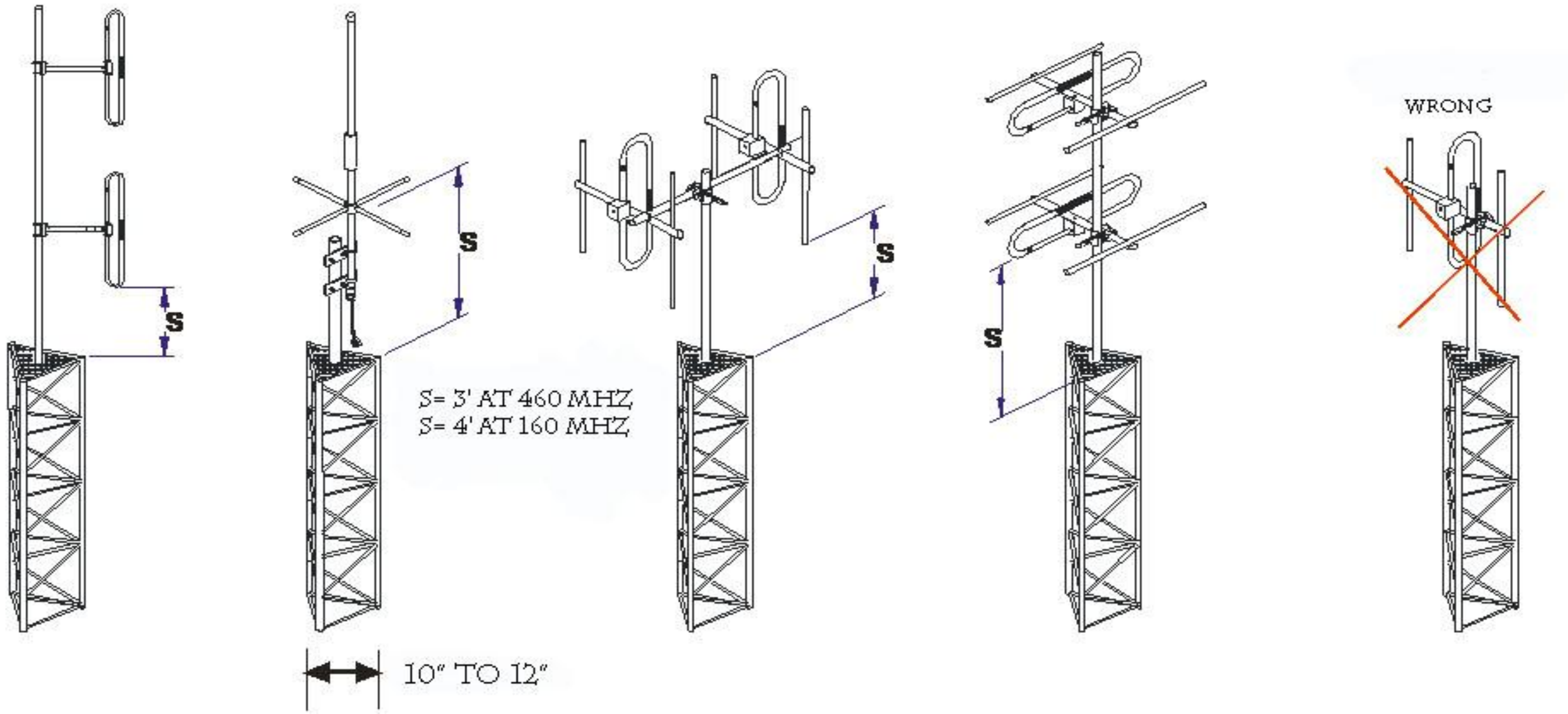
Top Mount



Advantages of top mounts
Does not distort omni patterns
Minimum effect on VSWR (TV)
Clear of guy wires
Less chance of Intermodulation
Best advantage of height
Minimum torque about tower axis
Mounting arrangement is simple

Disadvantages of top mounts
Less accessible for service
More prone to lightning damage

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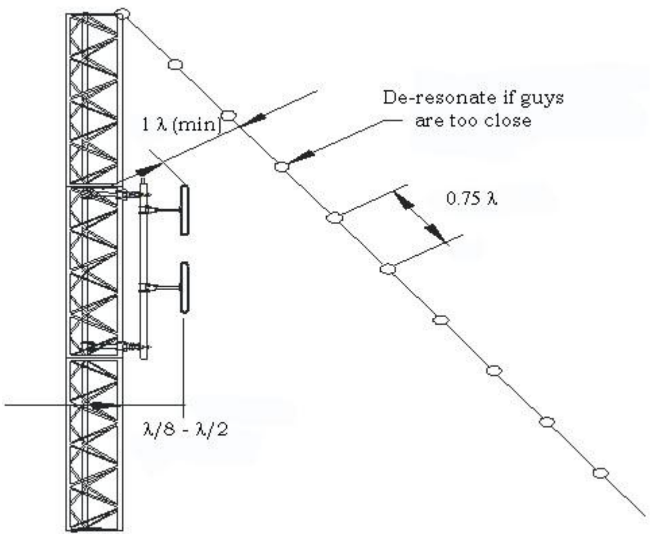
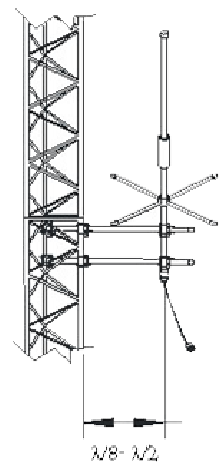
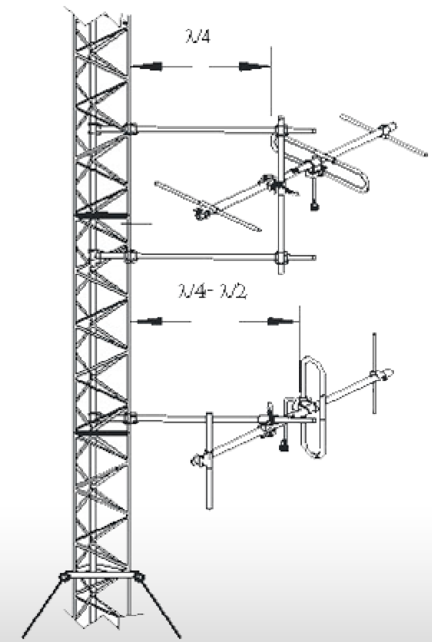
Side Mount

- **Advantages of Side Mounts**
- Greater use of existing towers
- Better lightning protection
- More secure mounting for large antennas

- **Disadvantages of Side Mounts**
- Distorts omni antenna pattern
- Some effect on VSWR
- May require use of Torsion Resistor or ice protector
- Mounting hardware more complex and costly







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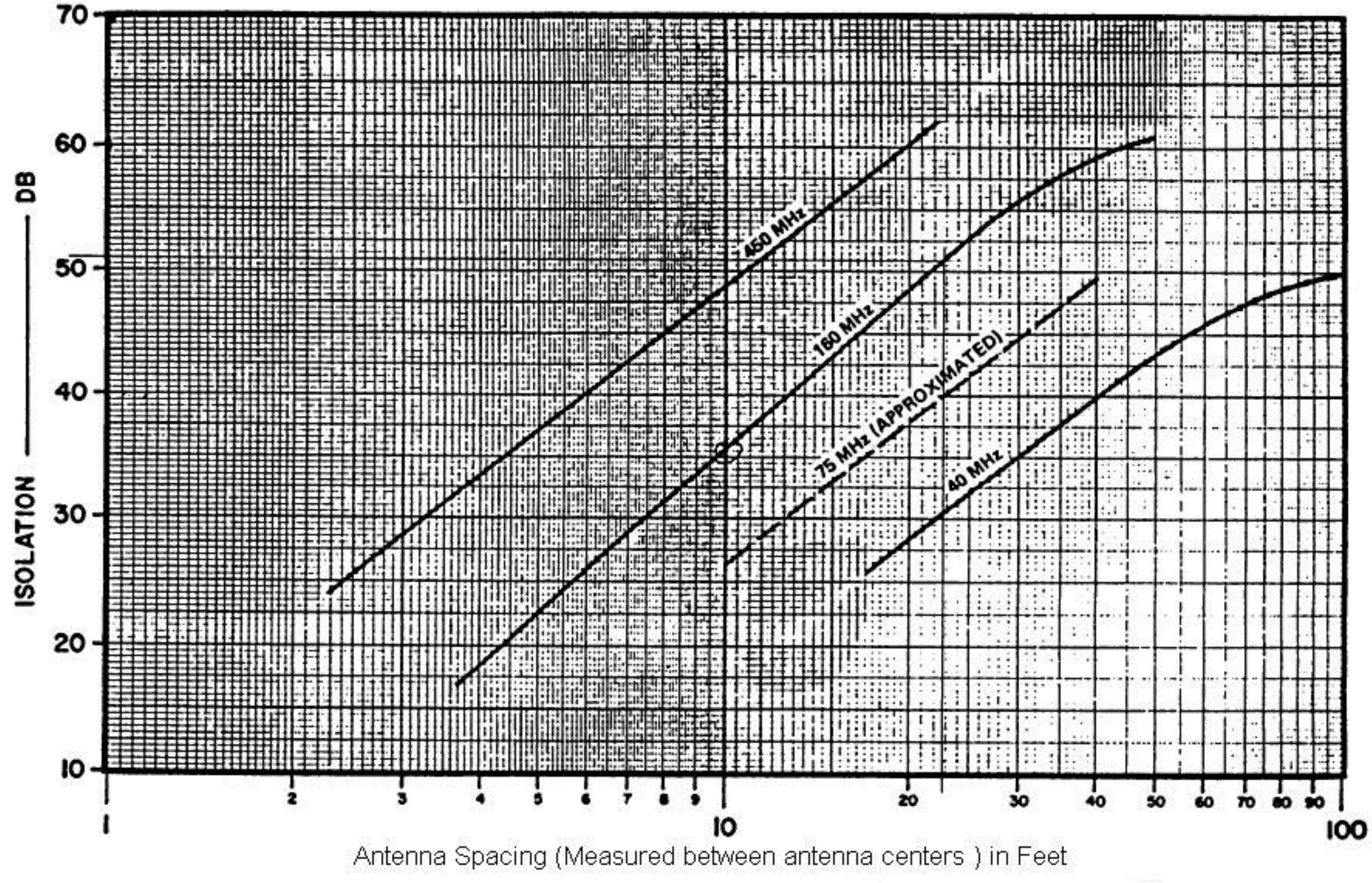
Antenna Spacing



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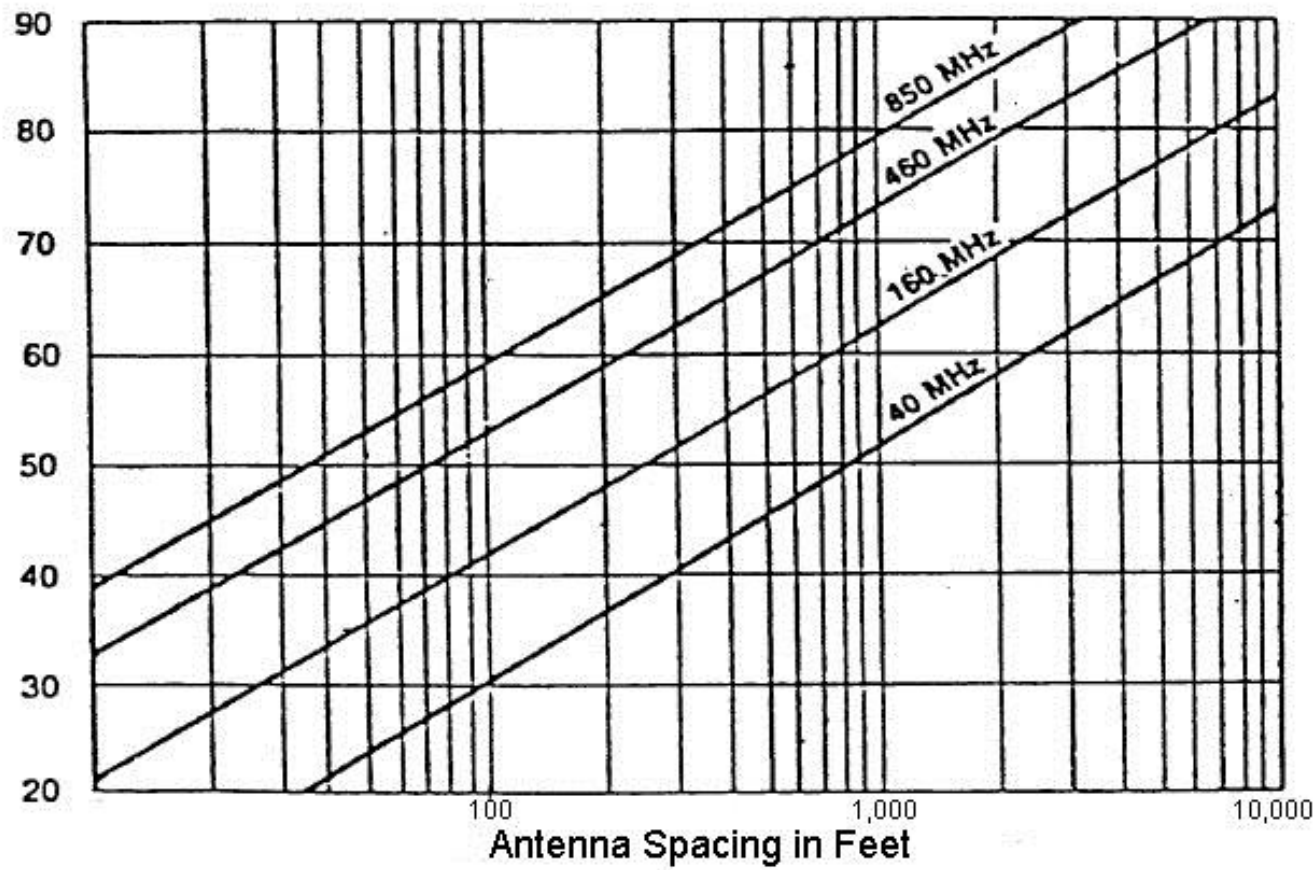
Antenna Spacing



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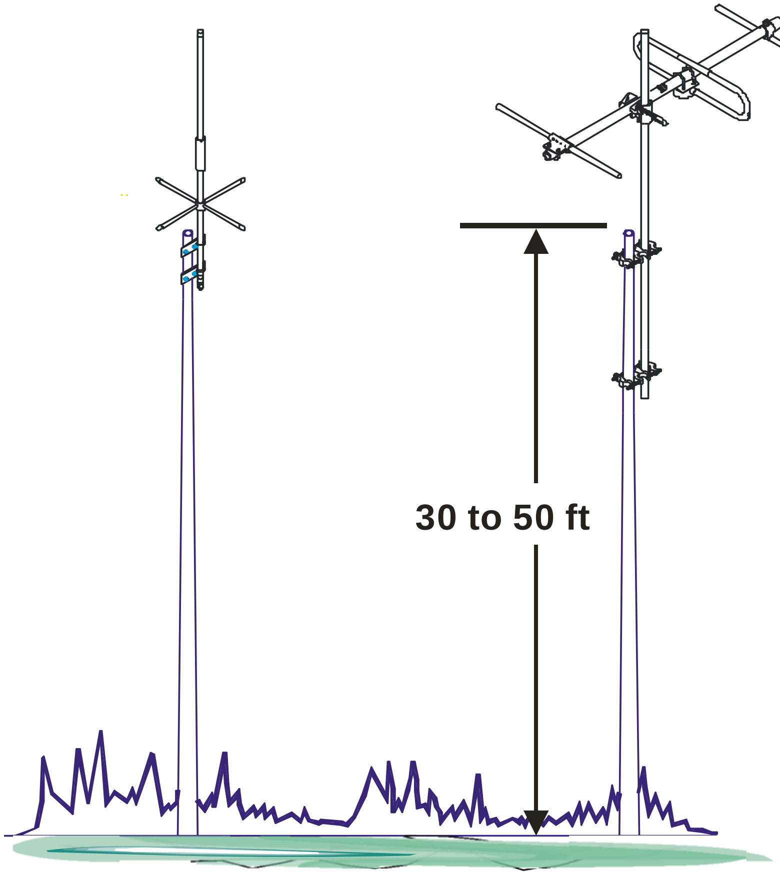
Antennas Towers



Advantages

- Low cost
- Readily available
- Attachment of antennas simple

Disadvantages

- More difficult to climb
- Height limitation
- May require guys

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Which to Choose

ANTENNA COATINGS

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Anodizing

The surface coating standard for Sinclair Technologies antennas made from aluminum tubing or pipe is guided by a Military or ASTM specification.

Anodizing

The expected life in an outdoor environment in regards to corrosion and fading is according to our vendor (Dependable Anodizer) 10 to 15 years.

Anodizing and there processes like cleaning, etching, anodizing, coloring and sealing are governed by the military specification as stated below:

MIL-A-8625F, Type II, Class 2
Dyed: Black Satin or Shiny
The typical film thickness is 20 micrometer

MIL-A-8625F, Type III, Class 2
Dyed: Black Satin or Shiny
The minimum film thickness is 50 micrometer

The color is deposited by a metal salt solution (tin dye) into the pores of the aluminum, for light and weather resistant surfaces.

Commercial anodizing uses a similar process as the military specification, with an average film thickness of 50 micrometer.

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Coatings

The expected life in an outdoor environment in regards to corrosion protection is

according to our supplier’s opinion is about 10 to 15 years.

Paint coatings are specified as following:

a) Top Coat: For extra corrosion protection against serve environment i.e. salt moisture etc. we specify an additional undercoat:
b) Primer: Epoxy Primer
c) Wash Primer

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Coating Continued

- If the major reason to specify the surface coating on antennas is ice and snow shedding then the coating should be chosen by the color and the thermal conductivity.

- The resin is the better insulator and would therefore slow down the worm-up of the underlying metal.

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What is the Difference?

CLAMPS VS. WELDED

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Welded Collars vs. Clamps

- **Propose:**

- To Determine the strength and weaknesses of clamping vs. welding as a fastening method of boom and dipole to the antenna mast.

- **Analysis System:**

1) COSMOS Works Release # 05
2) EXCEL, using standard engineering formulas

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Disadvantages of Aluminum Welding

The inherent disadvantage of aluminum welding is that the welding creates considerable distortion and reduces the ultimate and yield strength of any aluminum structure by about 50% in all welded areas.

Result:

- larger sized structural members
- distortion, rework after welding
- hence increased weight and cost.

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Advantages of Aluminum Welding

- Smoother connections for current flow
- No friction of connecting parts
- No dissimilar metals to cause oxidation
- Cosmetically more appealing.

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Analysis Setup

The attached analysis models show two methods of fastening.

a) clamped method uses the aluminum mast, two galvanized u-bolts, castled clamp bolted to extruded boom. (galvanic Group #Al 14,15, Z16)

b) welded method uses the aluminum mast, a hub (extra heavy wall extruded tubing) welded to the mast.

c) extruded boom inserted into the hub using SS set-screws. (galvanic Group #Al 14,15, SS 9)

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Analysis Result

With identical wind and ice loadings the stress results are as following:

a) Clamped Method: 1.302e+004 psi, max. von Mises Stress

b) Welded Method 1.428e+004 psi, max. von Mises Stress

c) Welded Method with Gusset 1.474e+004 psi, max. von Mises Stress

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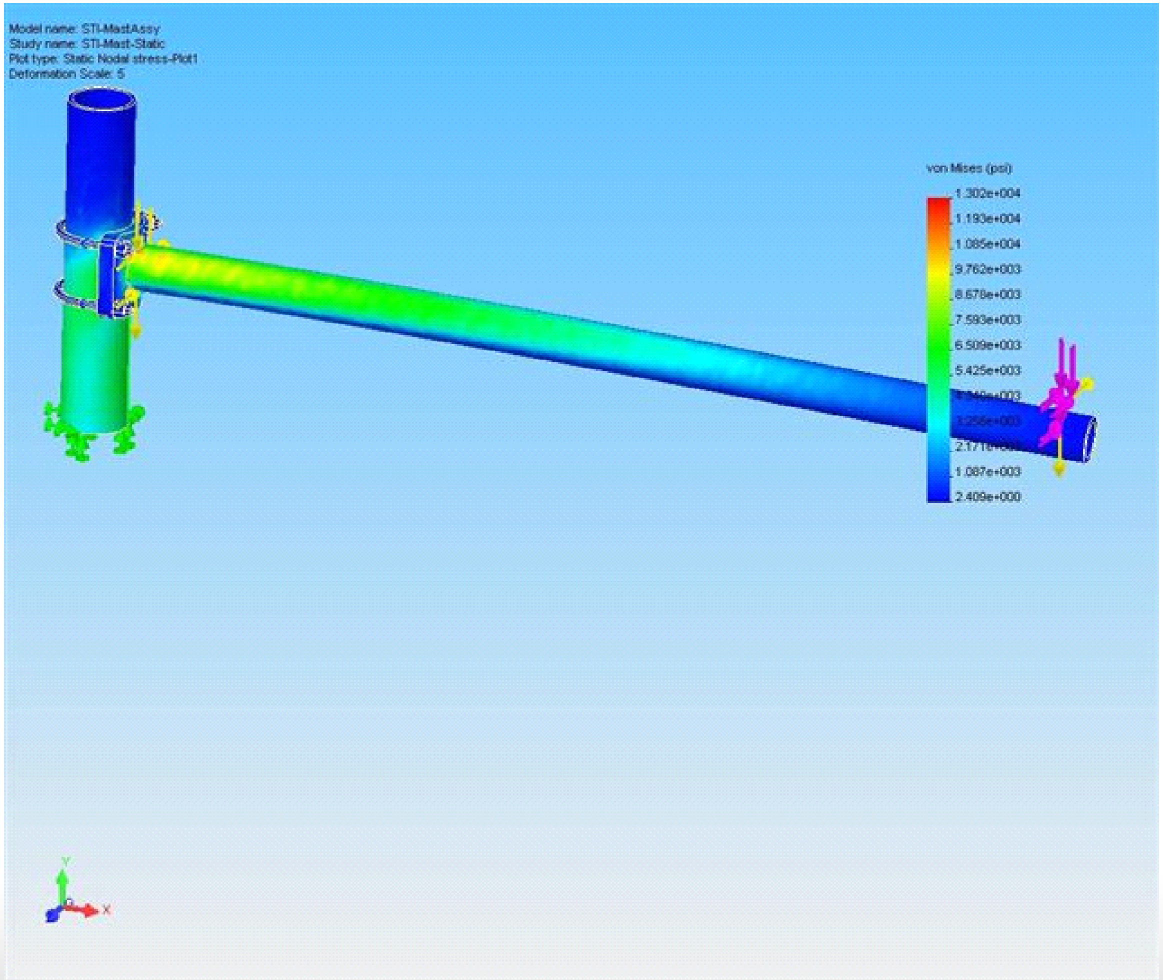
Clamped Method



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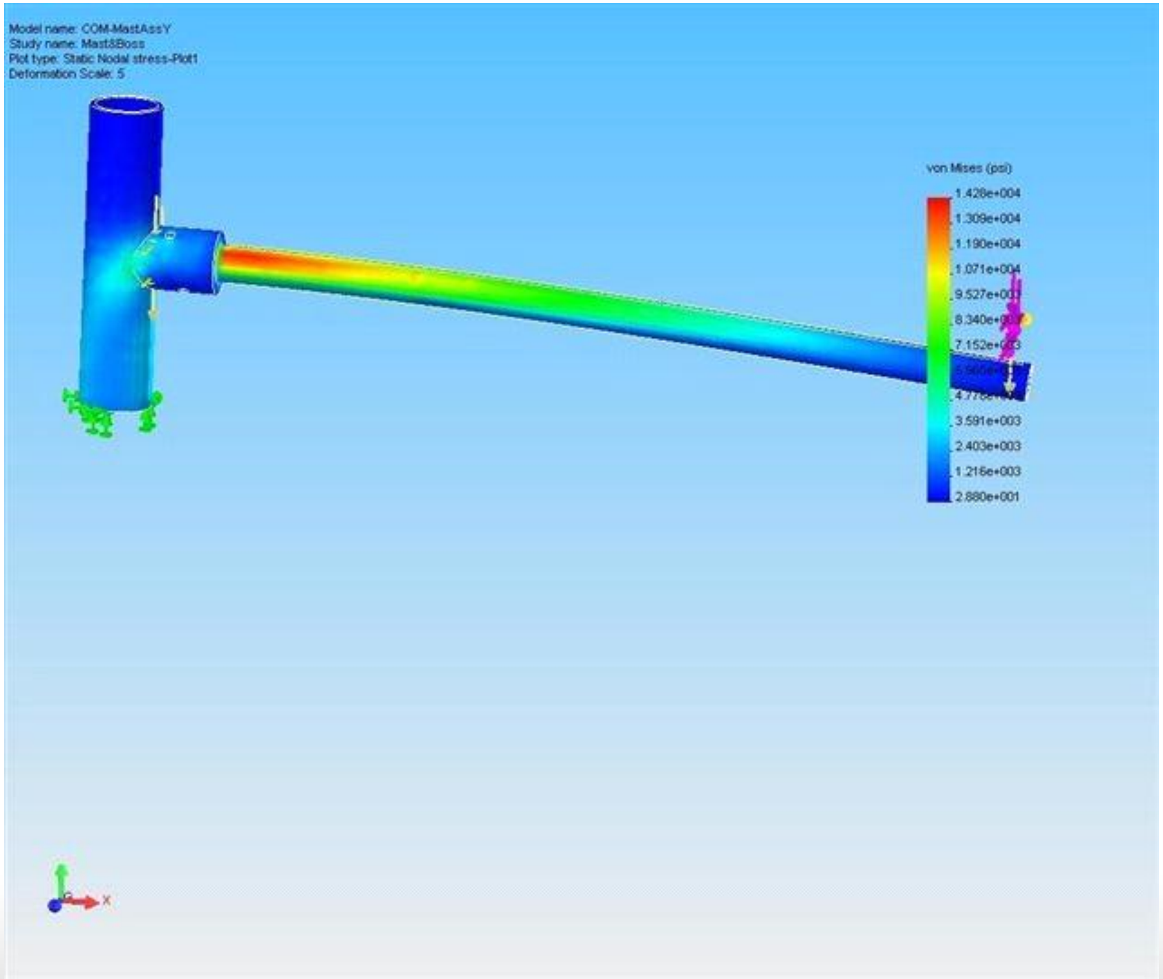
Welded Collar



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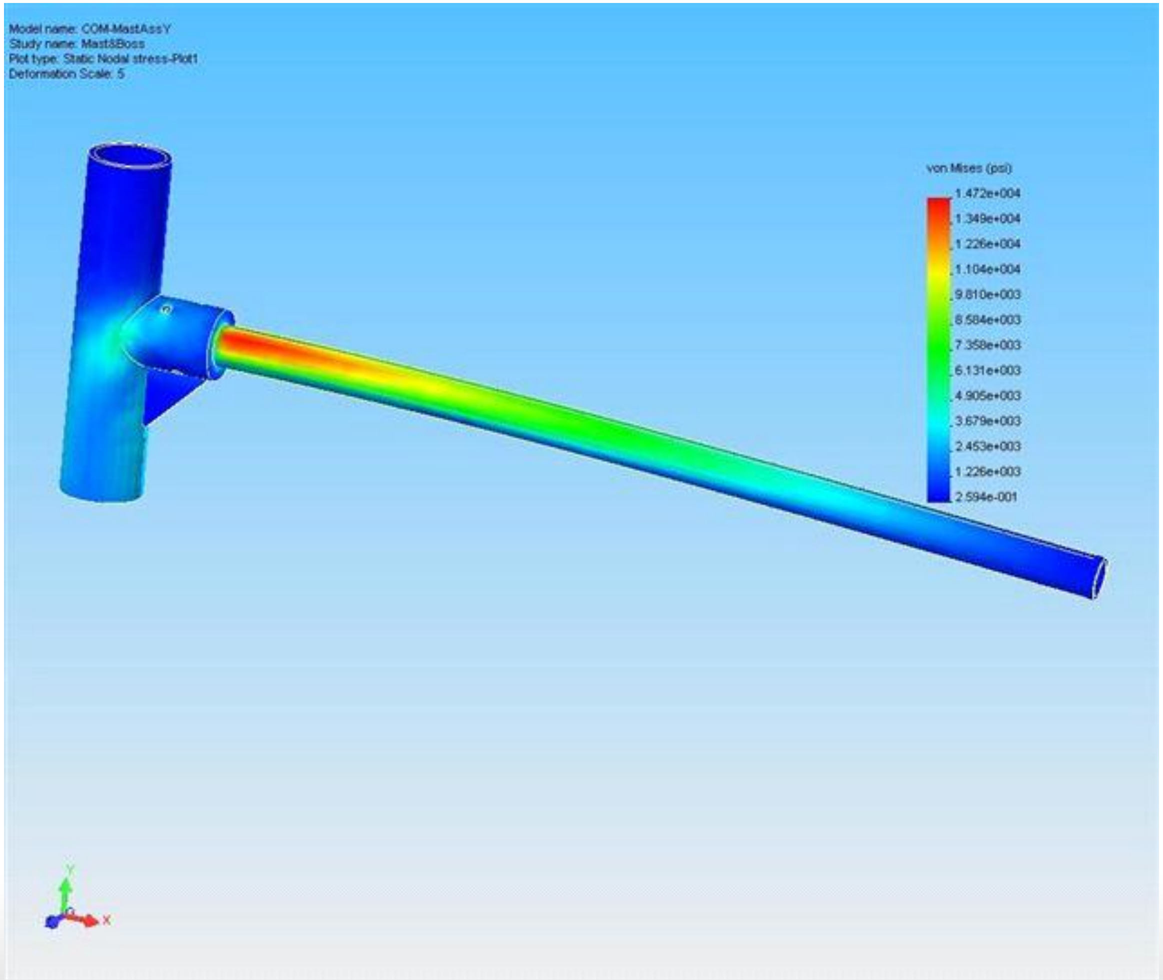
Collar with Rib



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Factor of Safety

With identical wind and ice loadings the stress results are as following in the

high stress area at the boom end:

a) Clamped Method:

SF=Fy/Sw → 21,200/13,100= 1.63

b) Welded Method b):

SF=Fy/Sw → 10,900/13,100= 0.83

c) Welded Method with Gusset same results as the no gusset method.

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What Are They and Why Use Them?

LOW PIM ANTENNAS

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What is Passive Intermodulation (PIM)?

- Generated whenever multiple RF signals are present in a conductor of RF energy.
- Any non-linearities in the signal path, whether through an amplifier or an antenna system for example, will cause a mixing of the fundamental RF signal frequencies and the creation of new signals at different, mathematically related frequencies.
- These new signals, or intermod products, can become a source of interference if not carefully controlled.
- New undesired byproducts can interfere with the original desired RF signals.
- Is present to some extent in all antenna designs (how much depends heavily on the type of materials used and how the antenna is physically constructed).
- The Intermodulation products of greatest concern are the so-called odd-order products, since these will exist at frequencies that are close to the original fundamental signal frequencies.
- The 3rd order and 5th order products have the potential to cause the greatest harm, since their signal level can be substantial, and their frequencies are most likely to fall within co-sited receiver frequency bands.
- PIM is Intermodulation that occurs in passive devices, such as antennas, tower structures, and antenna clamps.

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What are the Effects of PIM?

- Can severely degrade communication system performance by reducing receiver sensitivity and limiting effective coverage range.

- Also cause interference with other communication systems and violate regulatory requirements.

- Ongoing increases in frequency congestion and site density are compounding PIM problems in the field and are driving the need for higher performance antennas.

- System configurations that specify PIM rated antennas can avoid the possible severe performance degradation that can occur with non-PIM rated antennas.

- Often end up with higher final system costs due to special or custom filtering requirements for PIM related problems.

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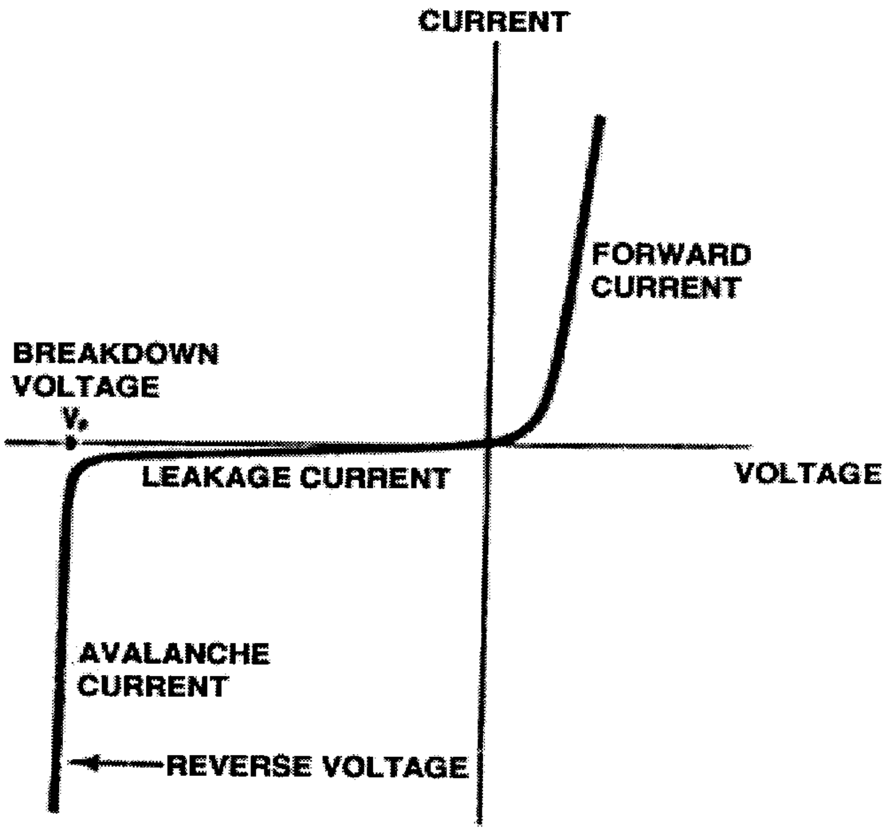
PIM Generation Mechanisms

Joint/Contact Effects:

- Corrosion produces metal oxides in mechanical joints carrying RF currents.
- Electron tunneling (diode effect) and microscopic arcing then promote non-linear current generation modes, causing PIM.



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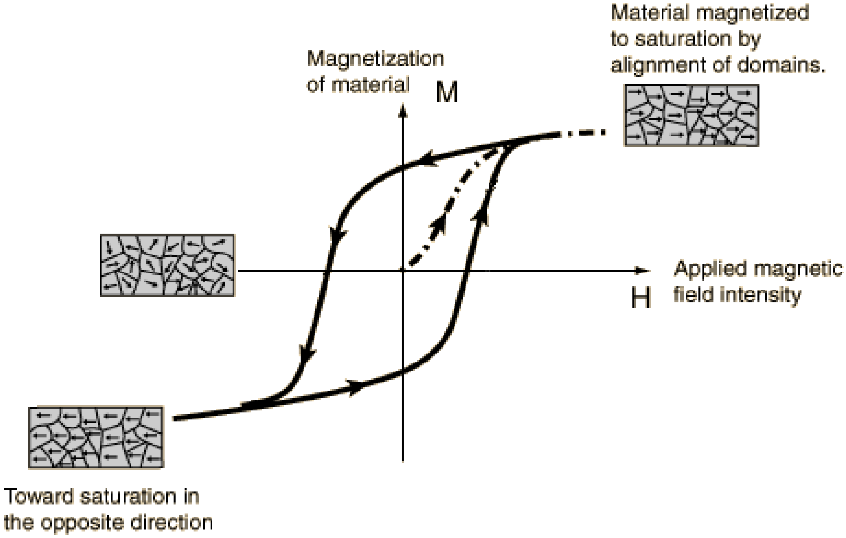
PIM Generation Mechanisms

Hysteresis characteristics of ferromagnetic material:

- Currents produced have non-linear nature
- Material follows a non-linear magnetization curve



PIM Sources in Passive RF

Mechanical Joints:

- Soldered, brazed, welded joints (*Best joint for low PIM)*
- Bolted or clamped joints *(Problem unless joints are clean and tight)*
- Spring finger joint *(Avoid if possible)*
- Crimp joint *(Avoid if possible*

Surface finish:

- If surface finish is too rough, the signal repeatedly transitions through metal and surface-oxide layers, thereby creating the same effect as poor pressure contact.

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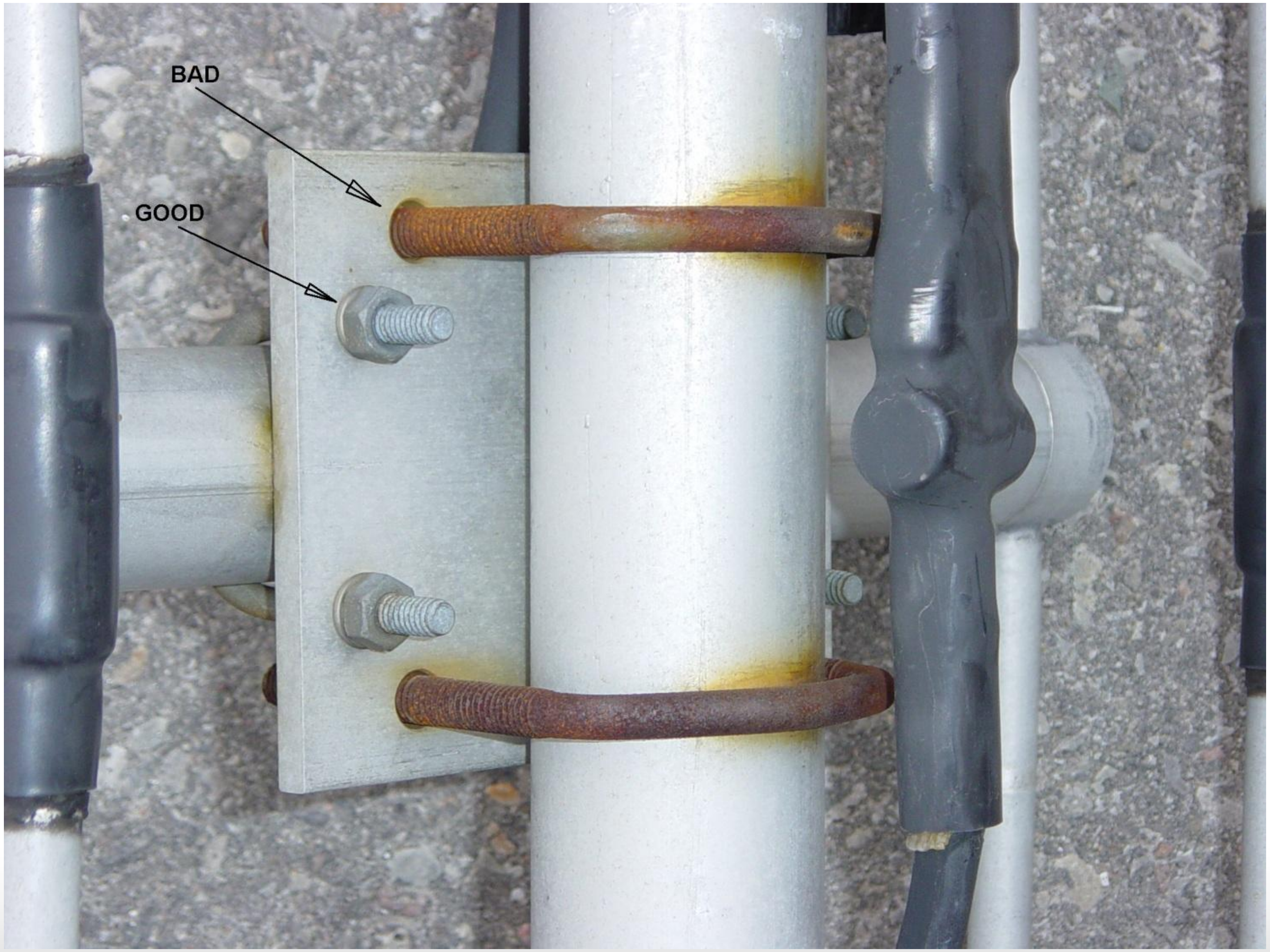
PIM Sources in Passive RF Products



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PIM Sources in Passive RF

Material Selection:

- Ferrous metals in base materials or plating (e.g. nickel)
- Coaxial cable with steel inner conductor
- Coaxial cable with unsoldered braided outer conductor
- Non PIM rated connectors with crimped cable connections
- Spring contacts made from BeCu alloys containing cobalt

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Guidelines for Low PIM Product Design

- Avoid ferromagnetic materials
- Minimize number of joint contact points
- Avoid dissimilar metal contact
- Use soldered joints whenever possible
- Avoid rough surfaces where possible

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Guidelines for Low PIM Product Design

- Ensure sufficient torque for connectors
- Use PIM rated 7/16” DIN connectors where possible
- Connectors w/ Ag plated/soldered center pin
- Avoid crimp joints *(e.g. connector to cable)*
- Use soldered braided or semi-rigid coaxial cable

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Performance of Low-PIM RF Products

- Product performance typically rated by 3rd order PIM levels relative to 2 X 20 watt input carrier frequencies

- Low-PIM products should be -150 dBc or better

- Bottom line: low-PIM products result in superior system performance

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Explanation of PIM Levels

- PIM specifications must always be referenced to the power level of the two fundamental RF signal sources, which for testing purposes will always be set to the same level.
- A PIM specification of -150dBc (150dB below carrier) for example will indicate that the actual PIM level generated by the antenna is 150dB below the carrier input level of the RF signal sources.
- The measurement of PIM in antennas requires sophisticated PIM test facilities
- Even the most fastidiously constructed test bed itself will generate intermodulation products, referred to as the residual IM.
- Typically, a good antenna may exhibit a PIM spec of -140dBc, which means that the residual test bed IM must be at least -150dBc for this to be able to be measured reliably.
- This level of residual IM can only be achieved by paying a great deal of attention to the design and layout of the test bed, and through the use of the highest quality combining equipment, cables and connectors.

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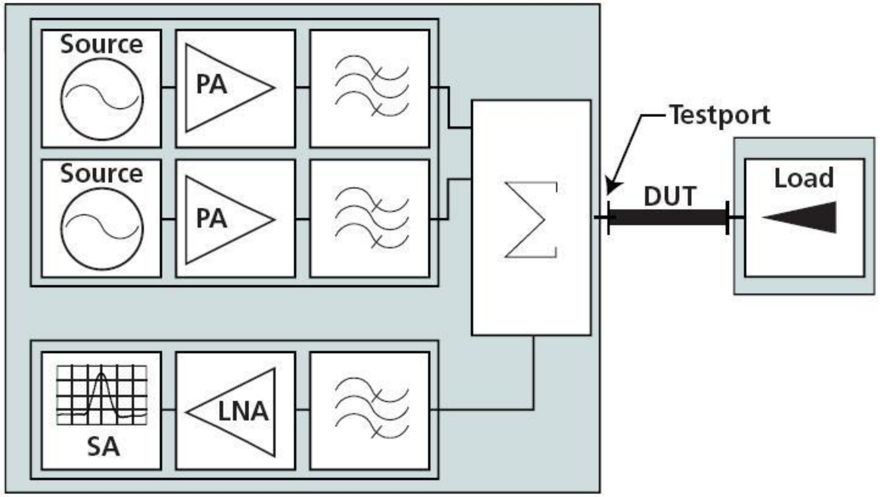
Measurement Test Setup

- PIM measurements are done according to IEC standard 62037-2.
- Consists of two signal sources, a summation and directional coupler module, and a spectrum analyzer.
- Low PIM loads and test cables are required accessories.
- Set each source to a specific frequency [F1 and F2] and power level (43dBm), sum the two signals and apply them to the antenna and analyze any reflected signals on the spectrum analyzer.
- Signals appearing to the analyzer except for the incident F1 and F2 signals are generated by PIM.
- The level of the PIM signal is measured in dBm and compared back to the reference source (Carrier) signals to define the PIM value in dBc



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Available Low PIM Antennas

- **SC432D-L - PIM Certified Series** - Collinear omni antenna, Dual ports, 0/3 dBd gain, low PIM, 746-869 MHz
- **SC432T-HL - PIM Certified Series** - Triple collinear omni antenna, 0dBd gain, low PIM, 746-869 MHz
- **SC433-L - PIM Certified Series** - Collinear omni antenna, 2.5 dBd gain, low PIM, HD, 750-960 MHz
- **SC488-HL - PIM Certified Series** - Collinear omni antenna, 10 dBd gain, low PIM, HD, 806-960 MHz
- **SC488-L - PIM Certified Series** - Collinear omni antenna, 10 dBd gain, low PIM, 806-960 MHz
- **SE414-AL - PIM Certified Series** - Enc. 4 dipole array, 8-11 dBd gain, low PIM, 746-960 MHz
- **SE414-L - PIM Certified Series** - Enc. 4 dipole directional, 7.5 dBd gain, low PIM, 746-960 MHz
- **SE419-AL - PIM Certified Series** - Enc. 9 dipole array, 12-15 dBd gain, low PIM, 806-960 MHz
- **SE419-L - PIM Certified Series** - Enc. 9 dipole directional, 10 dBd gain, low PIM, 746-960 MHz
- **SC323-HL- PIM Certified Series** - Collinear omni antenna, 3 dBd gain, low PIM, 380-430 MHz
- **SC329-HL- PIM Certified Series** - Collinear omni antenna, 6 dBd gain, low PIM, 380-470 MHz

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Available Low PIM Antennas (Continued)

- **SC381-HL- PIM Certified Series** - Collinear omni antenna, 6 dBd gain, low PIM, 380-512 MHz
- **SD310-HL- PIM Certified Series** - 1 dipole antenna, 1.5/2.0 dBd gain, low PIM, HD, 370-512 MHz
- **SD312-HL- PIM Certified Series** - 2 dipole antenna, 4.0/4.5dBd gain, low PIM, HD, 370-512 MHz
- **SD314-HL- PIM Certified Series** - 4 dipole antenna, 7.0/7.5 dBd gain, low PIM, HD, 370-512 MHz
- **SD318-HL- PIM Certified Series** - 8 dipole antenna, 10 dBd gain, low PIM, HD, 370-512 MHz
- **SC229-L - PIM Certified Series** - Collinear omni antenna, 6 dBd gain, low PIM, 138-174 MHz
- **SC281-HL - PIM Certified Series** - Collinear omni antenna, 5 dBd gain, low PIM, HD, 138-174 MHz
- **SD210-HL - PIM Certified Series** - 1 dipole antenna, 1.5/2.0 dBd gain, low PIM, HD, 118-225 MHz
- **SD210-L - PIM Certified Series** - 1 dipole antenna, 1.5/2.0 dBd gain, low PIM, 118-225 MHz
- **SD210R-L - PIM Certified Series** - Low PIM VHF reflector antenna, 60/90/120 degree beamwidth

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Available Low PIM Antennas (Continued)

- **SD212-HL - PIM Certified Series** - 2 dipole antenna, 4.5/5.0 dBd gain, low PIM, HD, 118-225 MHz
- **SD212-L - PIM Certified Series** - 2 dipole antenna, 4.5/5.0 dBd gain, low PIM, 118-225 MHz
- **SD214-HL - PIM Certified Series** - 4 dipole antenna, 7.0/7.5 dBd gain, low PIM, HD, 118-225 MHz
- **SD214-L - PIM Certified Series** - 4 dipole antenna, 7.0/7.5 dBd gain, low PIM, 118-225 MHz
- **SD218-L - PIM Certified Series** - 8 dipole antenna, 9.5/10 dBd gain, low PIM, 118-225 MHz
- **SC489-HL- PIM Certified Series** - Collinear omni antenna, 9 dBd gain, low PIM, HD, 928-941 MHz
- **SX400/500 PIM Certified Series** - Dual cross polarized, 14.5/ 16 dBd gain, low PIM, 806-960/1710-2170 MHz
- **SP330 PIM Certified Series** - Cross polarized panel antenna, 12 dBd gain, low PIM, 85 degree BW, 380-430 MHz

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How to Test and Verify Proper Operation

ANTENNA TESTING

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Criteria for Evaluating Antennas

- Sinclair's VSWR Specs are usually 1.5:1 or 1.6:1 across a specified bandwidth.
- Performance at a ratios greater than 2.0:1 may be unsatisfactory.
- Some refer to match as "Return Loss" in which case rates of 14 dB or 12 dB apply.
- Performance at a R.L. of less than 9 dB may be unsatisfactory.

Test equipment that can be used?

- Check to see that it has been properly calibrated and that any connector adaptors are of good quality. A poorly matched adaptor will invalidate the results.

Wattmeter/Power Meter

These devices are inexpensive and therefore more common but can be inaccurate, particularly if more than one RF carrier is present. The forward power measurement is required to calculate the VSWR or Return Loss number.

Network Analyzer/Spectrum Analyzer with Tracking Generator

These devices do not rely upon the site's transmitter as a signal source. They can produce more accurate and meaningful results but do not subject the antenna to full power where arcing or flashover would occur.

Time Domain Reflectometer

Occasionally, a technician will use a "TDR". This is not an industry recognized instrument for antenna testing, and many manufacturers will not respond to these measurements because the equipment uses pulses rather than RF and does not measure beyond band limiting devices.

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Criteria for Evaluating Antennas (Continued)

Was the measurement taken directly at the antenna's connector?

The technician may have chosen not to perform this test because it requires climbing the tower. This procedure should be done to eliminate jumper cable or down-lead cable factors. These cables could be either defective and cause the problem or be fine and absorbing the reflection which masks the problem.

What is your operational frequency

Check to see if the antenna was ordered for the correct frequency. The technician may also measure the physical length so that we may compare it to a cut chart. This is a crude method. If the antenna is of relatively new and the model number is known, the factory may still have the production test data sheet which will identify its frequency by Serial Number.

Was the antenna erect, free and clear of metal objects when tested

Side mounting too close to the tower can detune an antenna. The required spacing distance between the antenna and any other metal object decreases as the operational frequency increases. Some good numbers per our factory test procedure for omni-directional antennas are from 100 ft. @ 30 MHz to 5 ft. @ 900 MHz.

What is the DC continuity measurement using an ohmmeter

Some antennas have direct ground lightning protection. These normally measure as a DC short between the connector's inner and outer conductor but will be the proper 50 Ohm impedance at RF. See lightning notes in the catalog specs or on the website to determine if this antenna model should measure as an open or a short.

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Criteria for Evaluating Antennas (Continued)

Did you have the opportunity to substitute an identical antenna

If the second antenna measures OK under the same mounting conditions, the first antenna is probably defective. If the second one yields the same bad result, the problem is unlikely to be the antenna. Substitution of a dummy load is an option if a second antenna is not available but the test is less meaningful because it is actually testing only the cable.

When was the antenna installed

It could either be new and defective or had performed nominally for some time before failing. It is a good practice to test products on receipt before transporting them to the job site. Our warranties cover only manufacturing defects, not damage from an improper installation. An example would be mounting a standard antenna upside-down. This would put the drain hole at the top where it could collect water and cause the product to fail over time.

Are the antenna drain holes open

They are placed at the bottom of the antenna for draining internal moisture. Periodic inspection of these openings is the responsibility of the owner.

Is the antenna intermittent

It is a good idea to shake the antenna during the above tests to ensure there are no mechanical intermittents. Poor connections may lead to RF intermodulation products. Water entering the antenna may lead to electrical intermittents which subside when the antenna dries out.

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New Antenna Products

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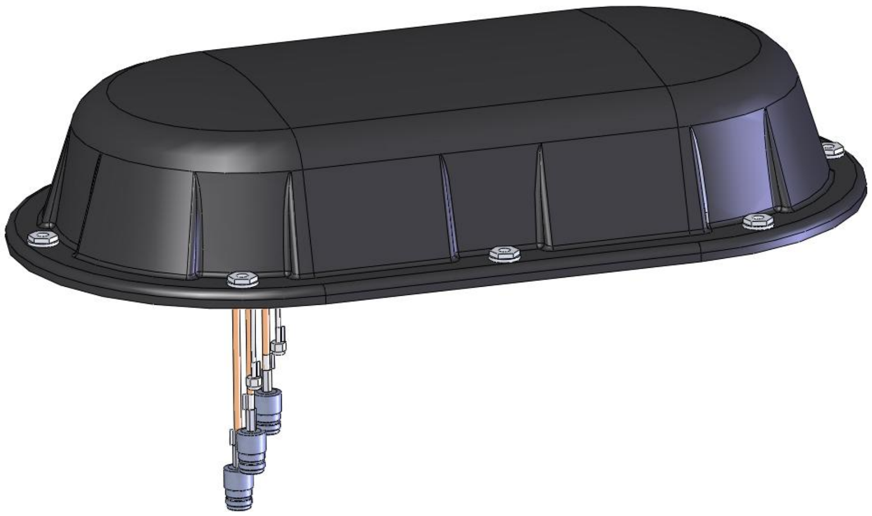
Diversity Low Profile Transport Antenna

SM2600D(PTC-WI-GPS)

- 5 element antenna, one 220MHz PTC, dual 694-2700 MHz full band, one GPS and one WiFi
- The 694-2700 MHz twin elements are expandable for multiple radio system or diversity uses
- A maximum height of 4-1/4 inches complies with restriction for locomotives and other vehicles
- Black weather resistant and fire rated radome provides excellent environmental protection



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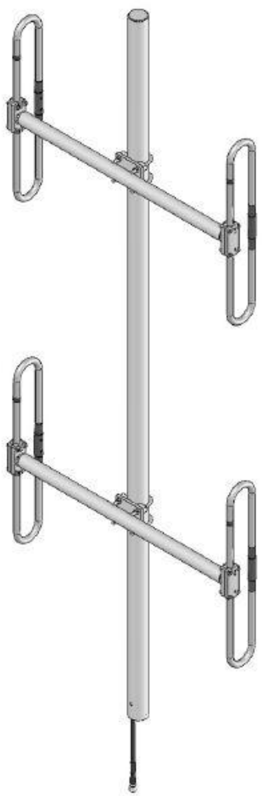
Bi-Directional, 190-225 MHz

SD236-SF3SNM(D00B)

- Wide band, covering the full range of 190-225 MHz
- Bi-directional pattern, perfectly suited for oil pipe, power line, highway and railroad RF coverage
- Heavier duty, black anodized and downtilt models are available on special order
- Easy to install



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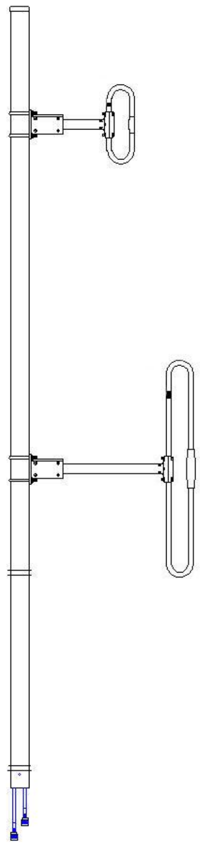
UHF/ VHF, 2 ports, 2.0 gain, 406-512 & 138-174 MHz

- Covers 406-512/ 138-174 MHz.
- 2.0 dBd gain with bi-directional or ½ wave pattern
- Heavy duty: 220 mph rated wind velocity with no ice
- 75 Watts for UHF/ 200 Watts for VHF power handling.



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PIP (Peak Instantaneous Power) Rated Antennas

Marketplace specifications

- Average power ratings of 300-500 W
- PIP ratings were not explored or provided
- Estimated at 10 kW or 10,000 W

Drivers

- Combined Tx's above 8 channels
- 700/800 MHz infrastructure
- Digital Modulation schemes (not FM, C4FM)
- 10-channels, 500 W Average power, >18000 W (PIP)
  - Up to 12-channel systems expected, 25 kW (PIP)
  - Failures observed in other's antennas

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PIP Rated Antennas

Model Number	Frequency Band	Description
SC479-HF1LDF(E5749)	746-869	9.5 dBd Fiberglass collinear omni PIP (25 kW) rated only
SC479-HF1LDF(E5765)	746-869	9.0 dBd Fiberglass collinear omni with Null Fill plus PIP (25 kW) rated
SC412-HF2LDF(E5749)	746-869	11.5 dBd Fiberglass collinear omni PIP (25 kW) rated only
SC412-HF2LDF(E5765)	746-869	11.5 dBd Fiberglass collinear omni with Null Fill plus PIP (25 kW) rated
SE414-SF3P2LDF(E5749)	746-869	7.5 dBd Enclosed dipole bi-directional PIP (25 kW) rated only
SE414-SF3P4LDF(E5749)	746-869	8.0 dBd Enclosed dipole offset PIP (25 kW) rated only
SE414-SF3PALDF(E5749)	746-869	8-11 dBd Enclosed dipole adjustable PIP (25 kW) rated only
SE419-SF3P2LDF(E5749)	746-869	10 dBd Enclosed dipole bi-directional PIP (25 kW) rated only
SE419-SF3P4LDF(E5749)	746-869	10 dBd Enclosed dipole offset PIP (25 kW) rated only
SE419-SF3PALDF(E5749)	746-869	12-15 dBd Enclosed dipole adjustable PIP (25 kW) rated only

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Principles of Operation and When to Use Each

TYPES OF FILTERS

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Cavity Filter

- **Band Pass**
  - Passes a narrow range of frequencies; rejects all others
- **Pass-Thru**
- **Notch**
  - Rejects a narrow range of frequencies; passes all others
- **"Q"-Circuit**
  - Provides both a pass band characteristic and a closely spaced reject band

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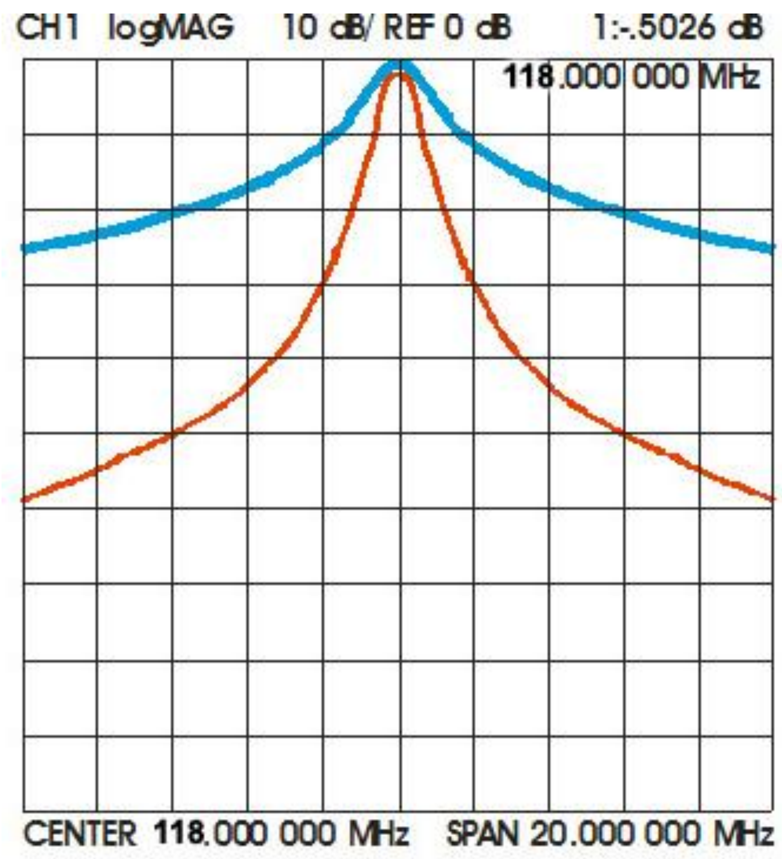
Co-Axial Cavities

- The ‘sharpness’ of the notch and bandpass frequency responses is typically communicated using the concept of ‘Q’ which stands for ‘quality factor.’
- Considering a bandpass response, the response can range from a very sharp peak with a large slope around the peak to a broad pattern with a much smaller slope on either side of the peak.
- The higher the Q, the sharper the peak.
- The same hold for the notch type of frequency response.



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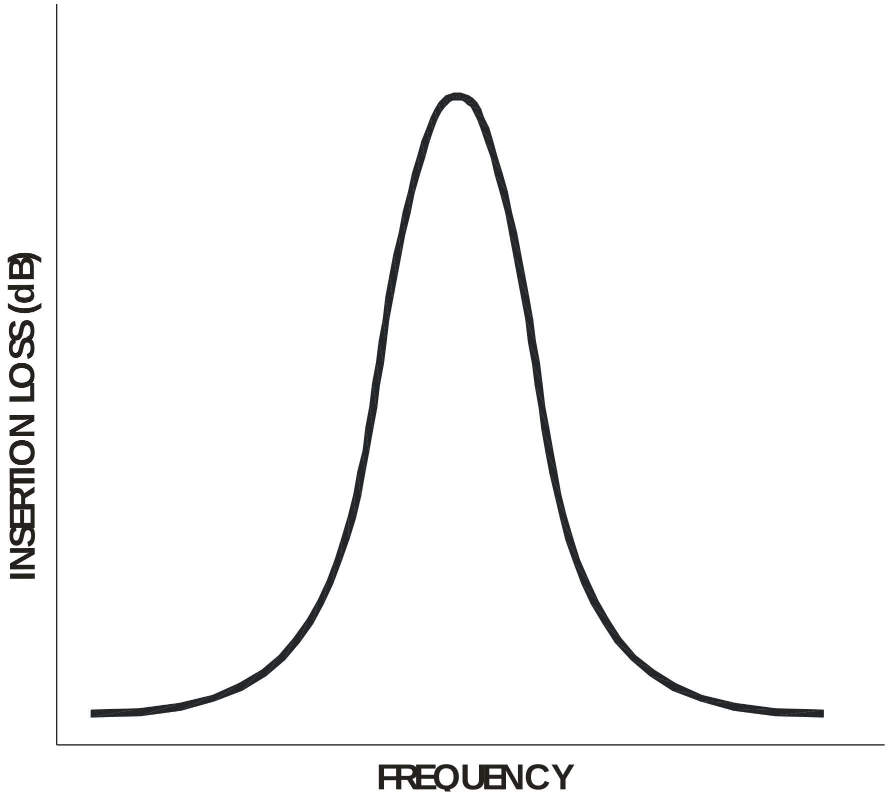
Co-Axial Cavities

Band pass Filter

<u>Purpose:</u>

To pass a specific frequency with minimal loss while attenuating all off-channel signals

Typically has two loops; an input and output loop



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Bandpass Filters

Applications

- Suppress sideband noise of a single transmitter on co-located receiver frequencies
- Protect one receiver from front-end overload by the carriers of co-located transmitters
- Suppress IM generation in one transmitter by protecting it from incoming carriers of co-located transmitters (usually in conjunction with a ferrite isolator)
- Generally, protect *One* from *Many*

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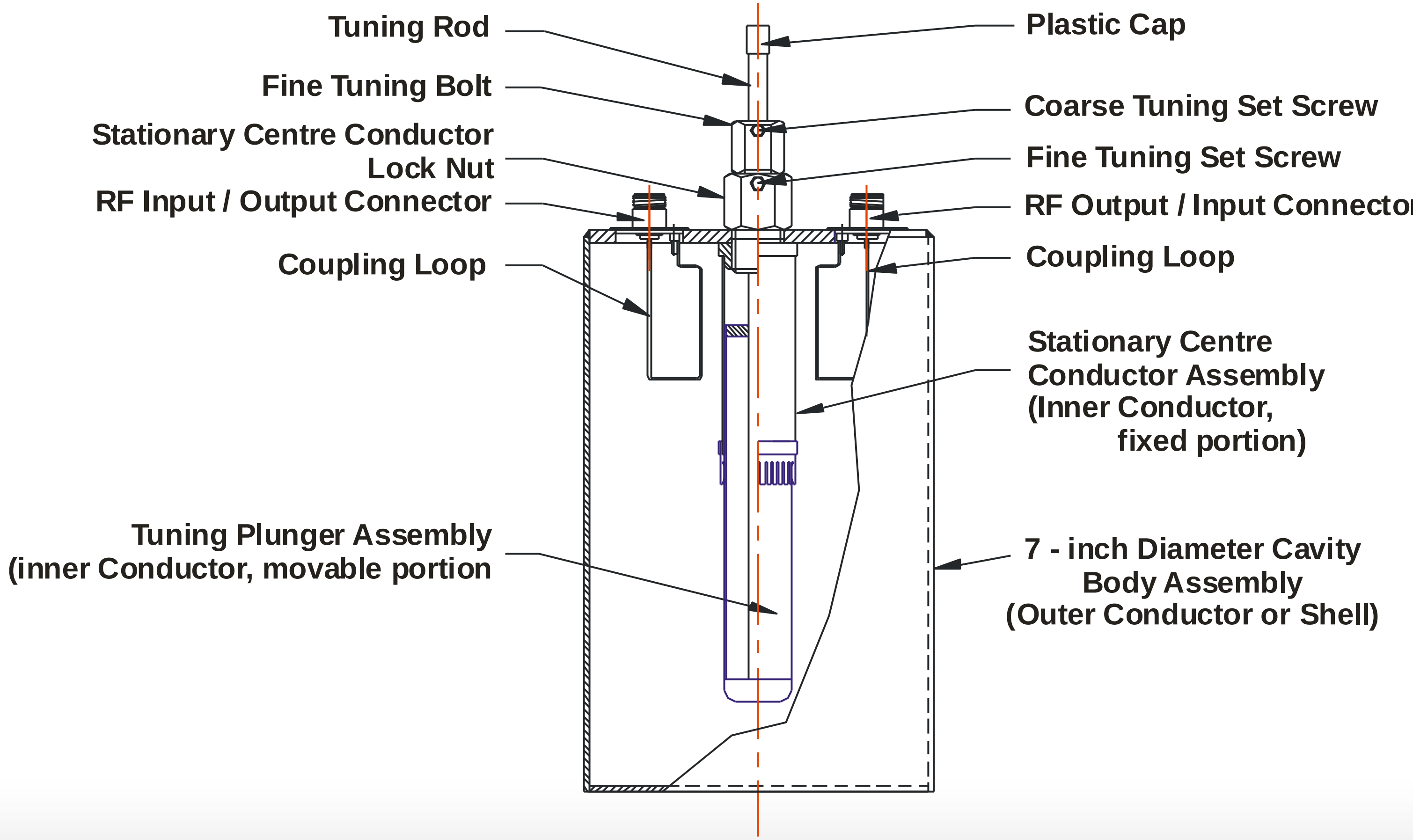
Bandpass Cavity



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Co-Axial Cavity

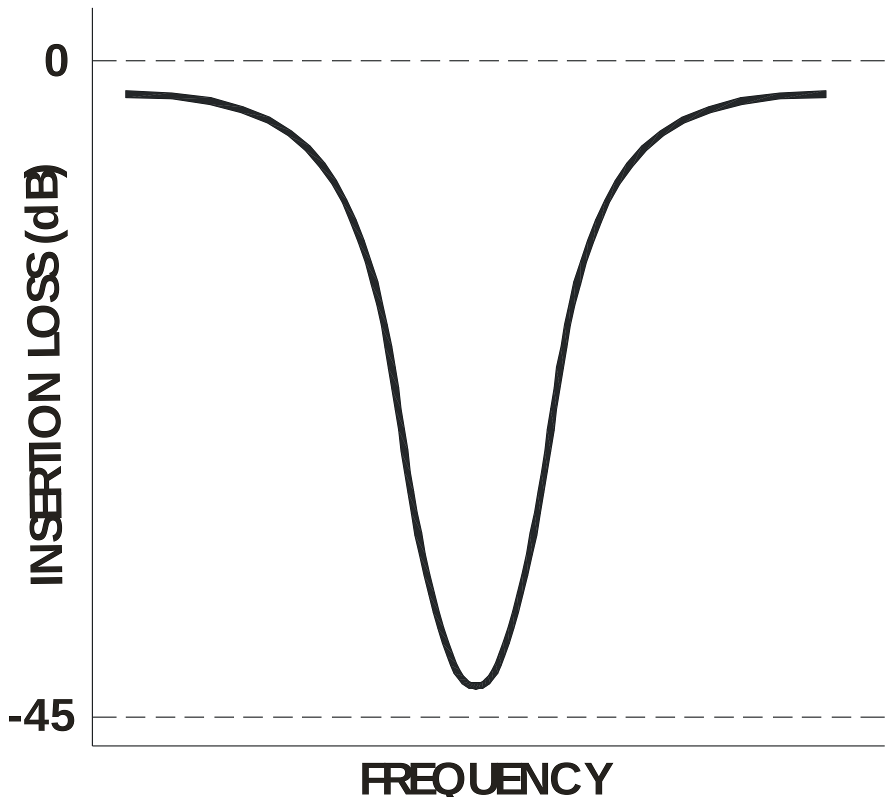
Band-reject Filter

<u>Purpose</u>

To provide maximum attenuation at a specific frequency while

passing all other frequencies with minimal loss

Typically has only <u>one</u> loop, acts as a trap to the resonant frequency.



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Band Reject Filters

Applications

- Suppress sideband noise from multicoupled transmitters on one co-located receiver frequency

- Protect multicoupled receivers from front-end overload by the carrier of one co-located transmitter

- Generally, protect *Many* from *One*

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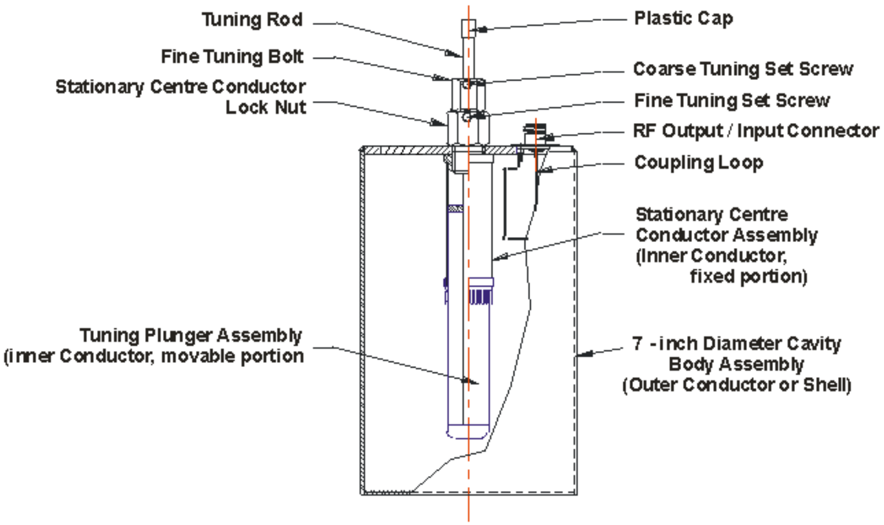
Reject Cavity

Position of the coupling loop determines the notch depth of the cavity.

Pushing the plunger into the cavity lowers its resonant frequency.



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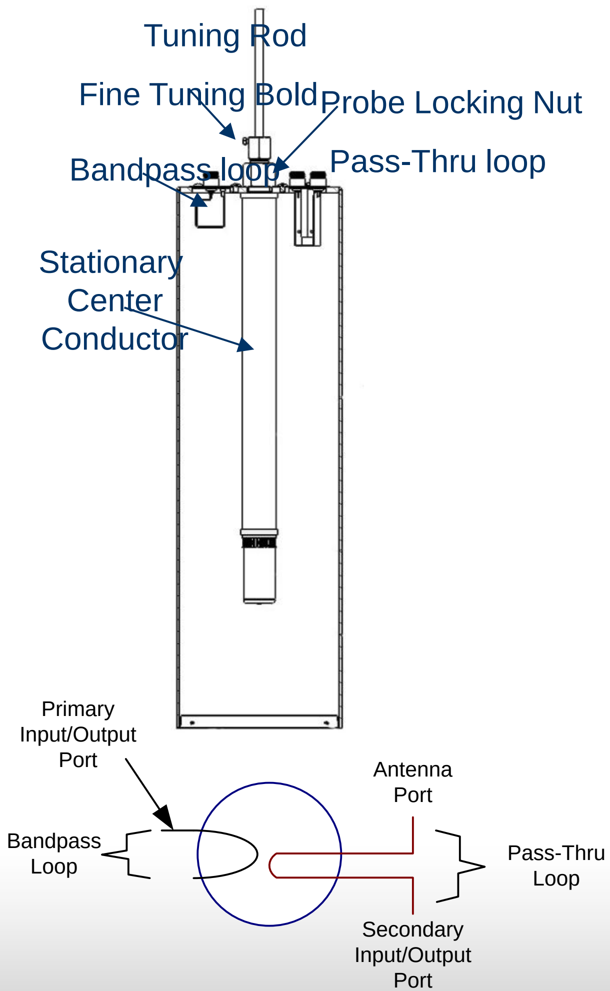
Pass-Thru Cavity



- Three port cavity
- Provides two distinct, isolated signal paths
- First- from a primary input/output port to a common antenna port
  - Exhibits a high- selectivity bandpass response at resonant frequency
- Second- from a secondary input/output port to the antenna port
  - Behaves as a low-loss, 50 Ohm transmission line at frequencies other than resonant

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Pass-Thru Cavity

- Used in conjunction with one or more Sinclair FP bandpass cavities permits the building of expandable multicouplers with frequency spacings down to 75 KHz.

- Expandable multicouplers using the FS Pass-Thru cavity can reduce the number of cavities required "per leg" for combining systems.

- The FS cavity can be tuned over the entire 132-174 MHz range and comes with both course and fine tuning adjustments.

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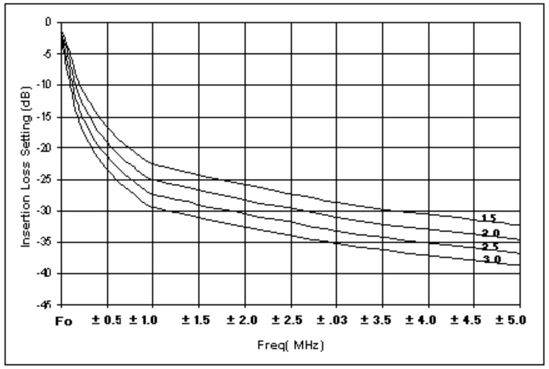
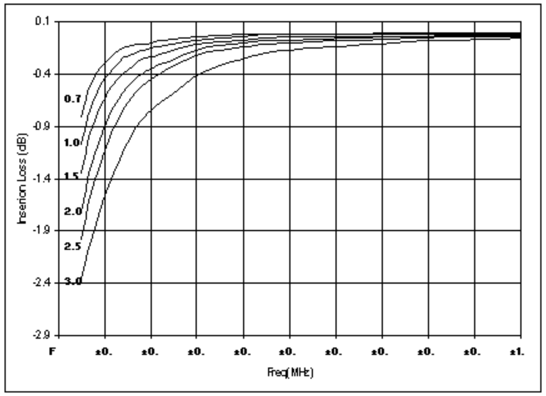
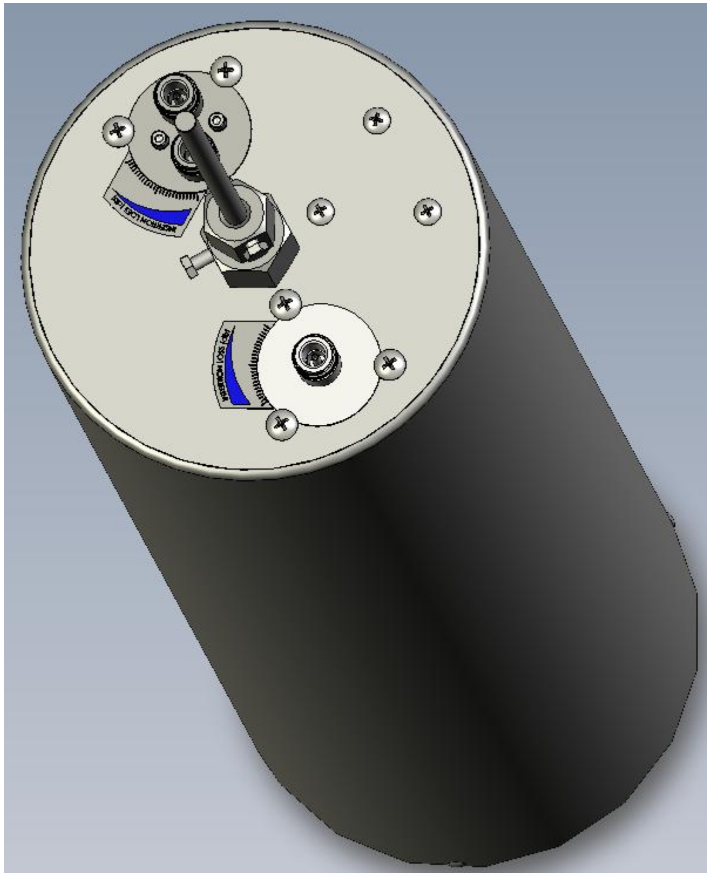
Pass-Thru Cavity

FS-20107-4 7" PT Cavity



FS20107-4 7" PT Cavity Bridging Loss





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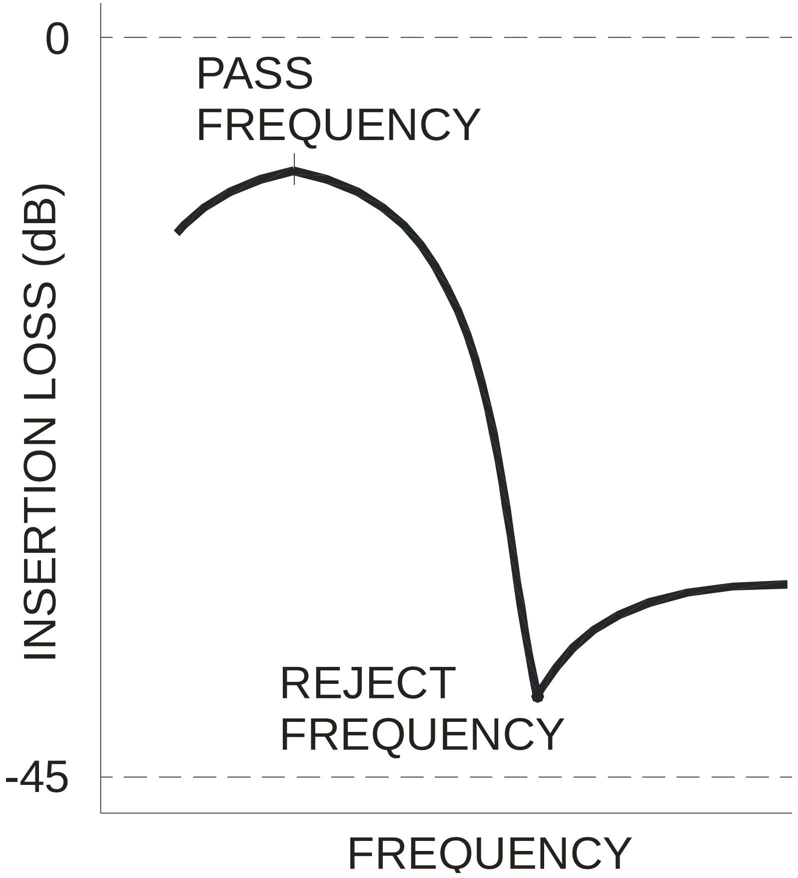
Co-Axial Cavities

Advantages of Q-Circuit Filters

- Allows close pass/reject spacing
- Low Insertion Loss
- Broad Isolation Loss

Cavity has only one loop

Notch capacitor placed in series with loop



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Q-Cavity

Applications

- Suppress sideband noise of a single co-located transmitter on a closely spaced receiver frequency
- Protect a closely spaced receiver from front-end overload by the carrier of a co-located transmitter
- Suppress IM generation in one transmitter by protecting it from an incoming carrier of a closely spaced co-located transmitter
- Generally, protect *One* from *One* at close frequency spacing

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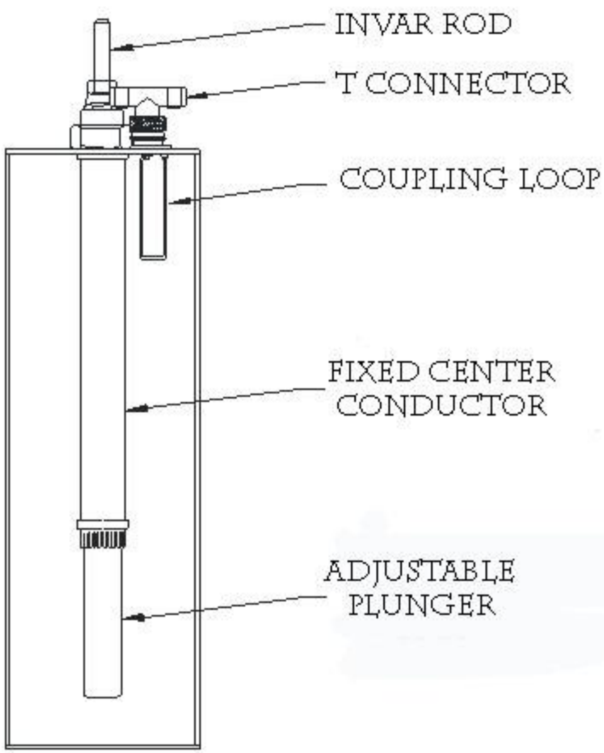
Q-Cavity

Position of the coupling loop determines the pass insertion loss and the notch depth of the cavity.

Pushing plunger into the cavity lowers both its pass & notch frequencies

Turning the capacitor changes the notch frequency



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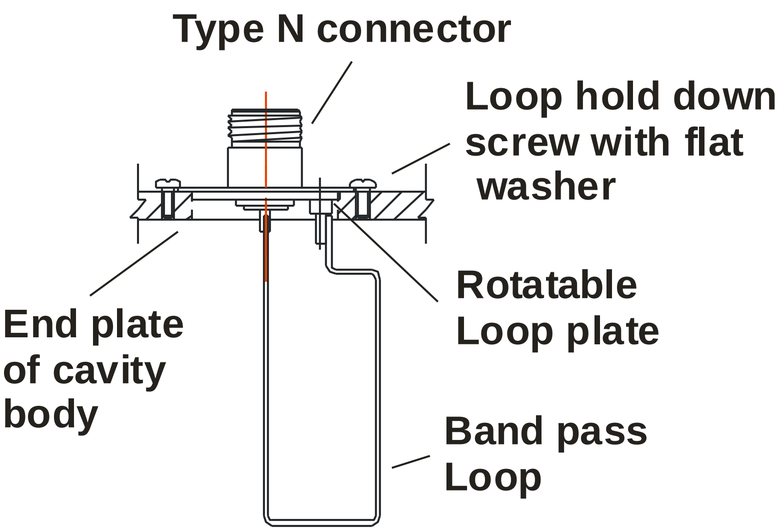
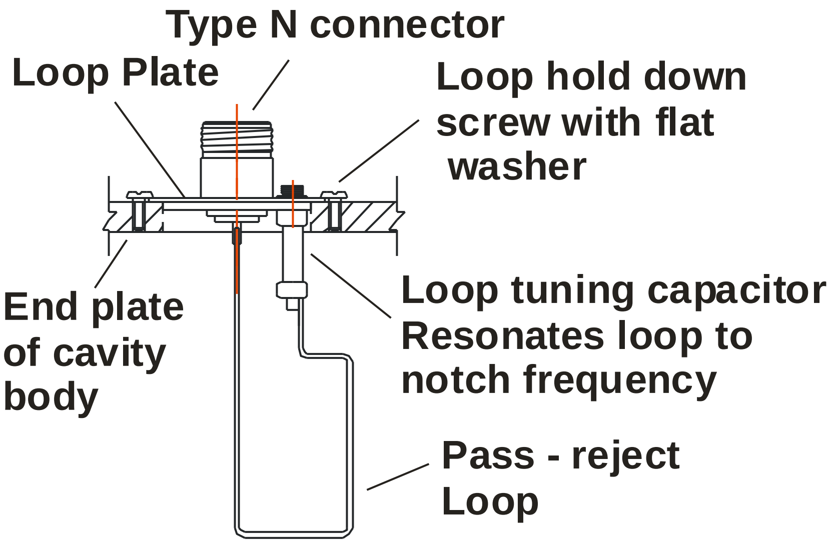
Types of Loops

Typical band pass loop assembly



Typical pass/reject loop assembly



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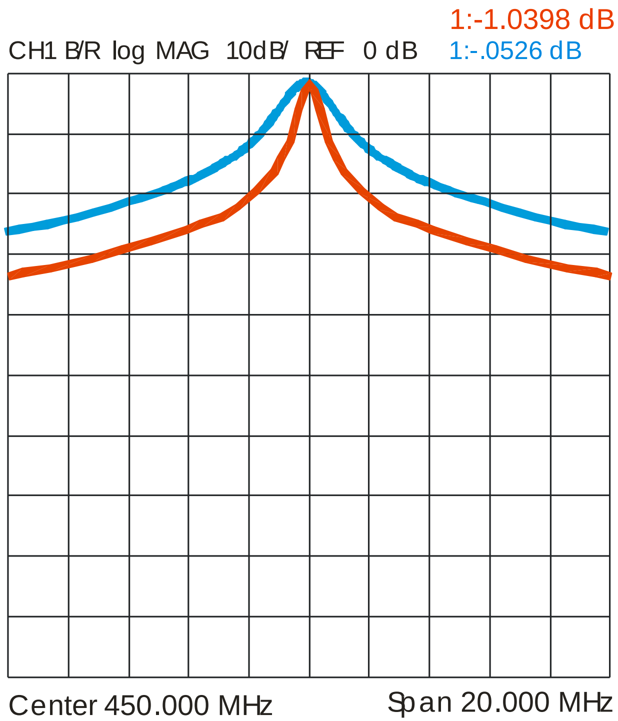
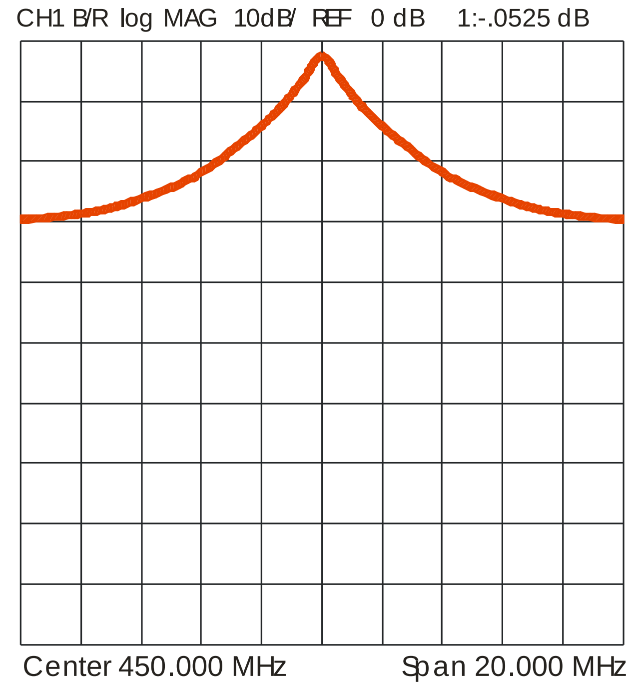
Filter Response Curves



1 Cavity - 7 inch .5 dB loss
- 10 db @ 1.4 MHz

1 Cavity - 7 inch 1 dB loss
- 10 db @ 600 kHz



1 Cavity - 10 inch .5 dB loss
- 10 db @ 900 kHz

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Cavity Construction

- Silver plating
  - Maximizes long term conductivity
- Gold connector pins
  - Minimizes noise and intermodulation
- Probe fingers
  - Maximizes contact area between stationary and moveable probes
- Welded end-cap
  - Maximizes ‘Q’ (cavity efficiency)
- Tuning rod lockdown mechanism
  - Provides temperature compensation

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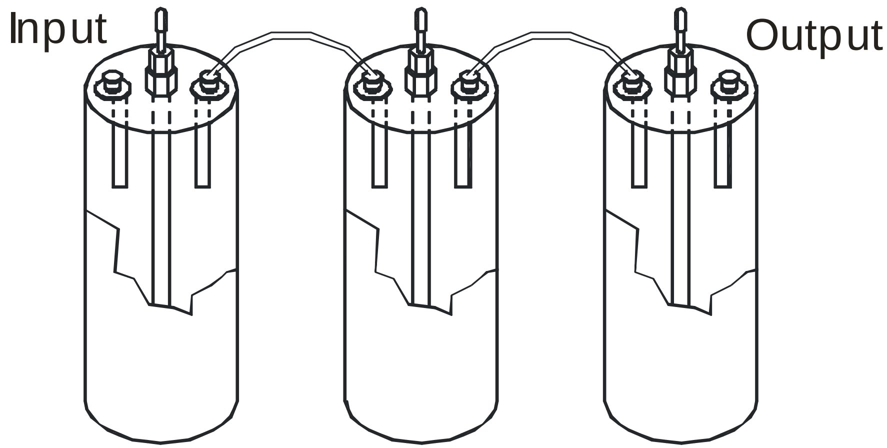
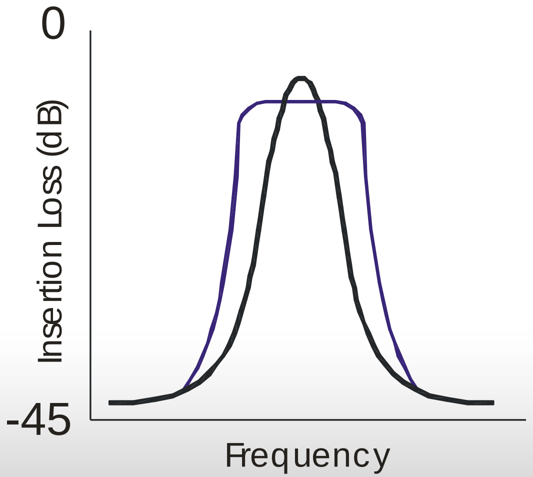
Multiple Cavities

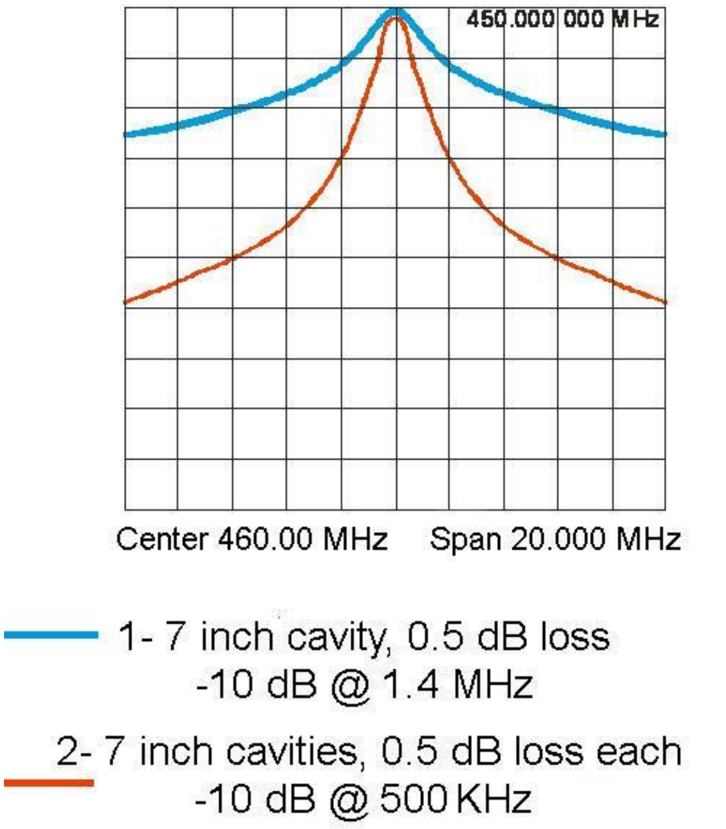
Multiple Cavities are used to:

- Increase Selectivity at Lower Insertion Loss, as compared to a single cavity
- In high power transmit application, reduce power dissipation per cavity
- Create a wider pass band





Multiple Cavity Response Curves



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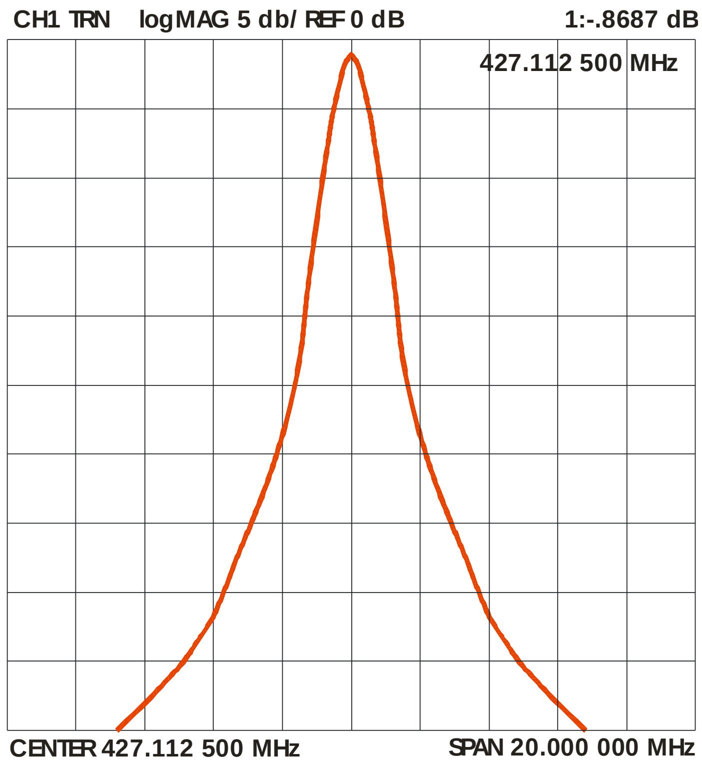
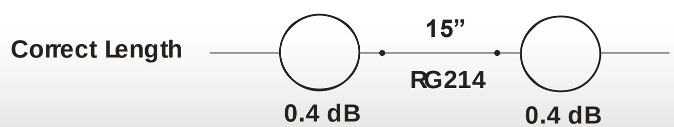
Multiple Cavity Response Curves





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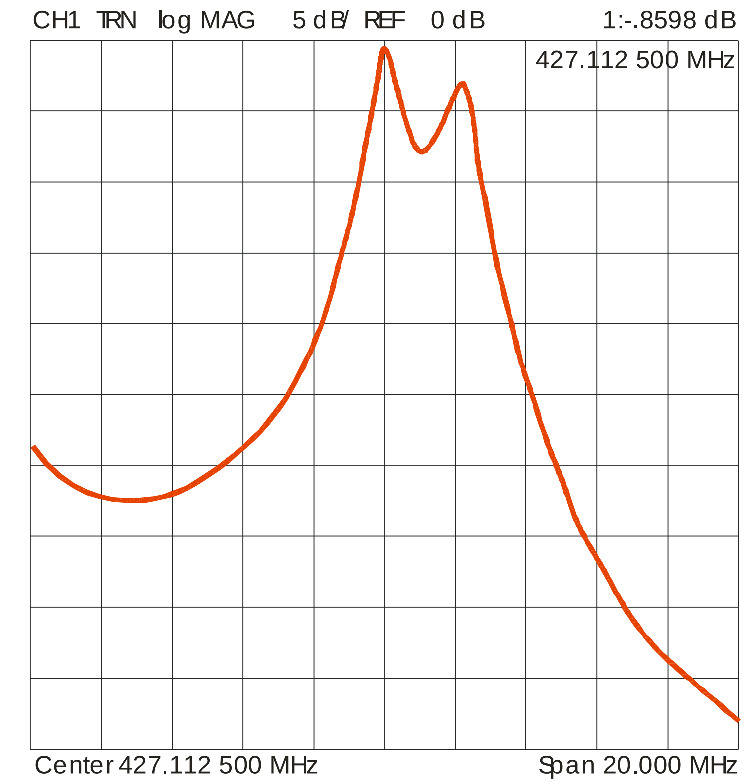
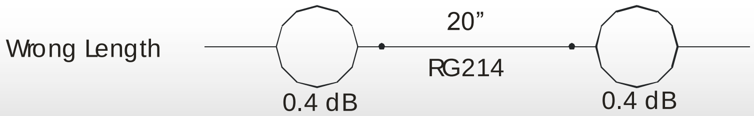
Multiple Cavity Response Curves





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Combline Filters

- Broad pass band characteristic
- Moderate insertion loss
- Compact construction
- Mutual coupling creates a multistage band pass filter.
- Size and performance ideal for application as a Tower Top Amp preselector. Often used as broadband filter in UHF and 800 MHz systems.

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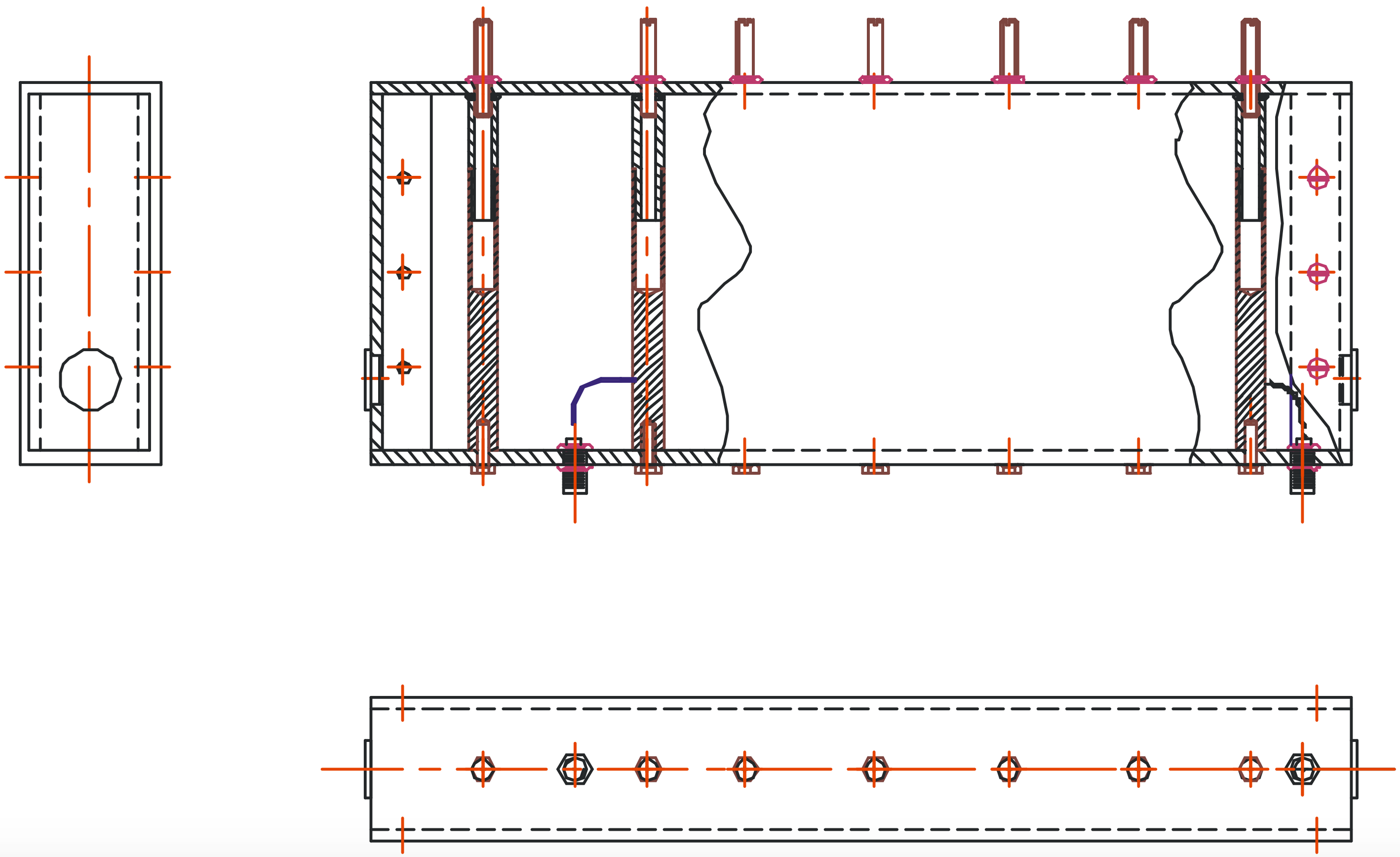
Combline Filter



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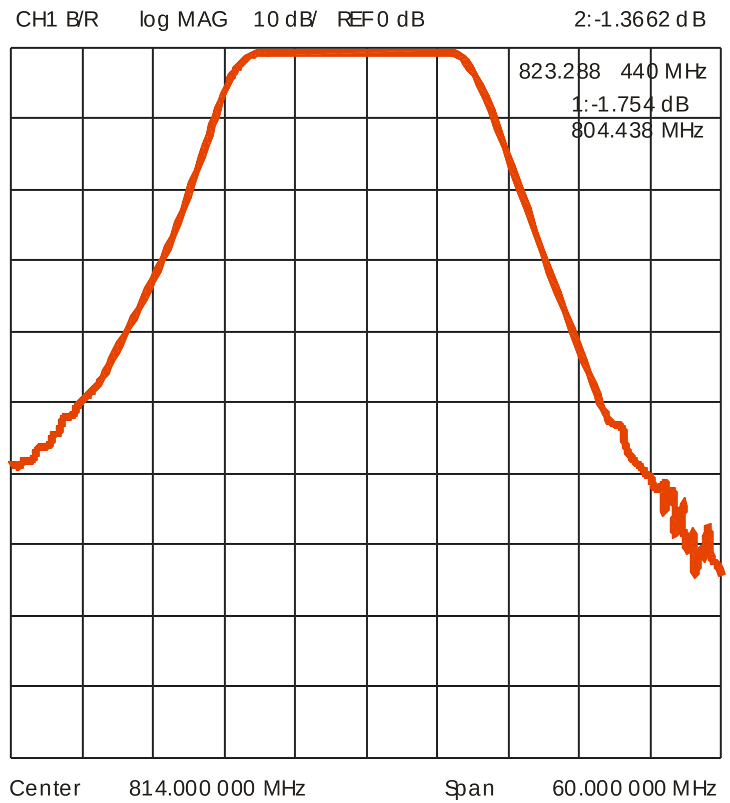
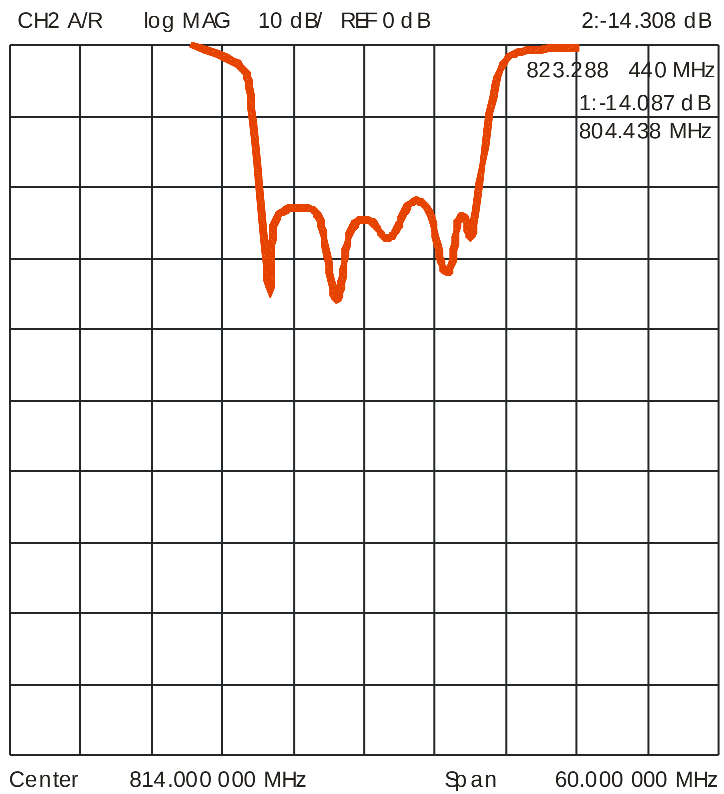
Combline Filters





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Cross-Coupled Filters

A design technique that improves selectivity of a pass band filter by increasing the slopes of the response curves (skirt selectivity) without the need for band-reject filter sections.

HOW?

Add a transmission line segment between appropriate resonators to create a parallel transmission channel. This line segment is tuned to achieve specific phase and magnitude characteristics; unwanted frequencies cancel each other out.

Effectively acts as a band-reject component – creating transmission zeroes (nulls) at the passband edges.

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Cross-Coupled Filters

Advantages:

- Compact – additional volume, for reject sections, is eliminated
- Minimum insertion loss, at a given performance level: there are no additional resonant sections to dissipate power.

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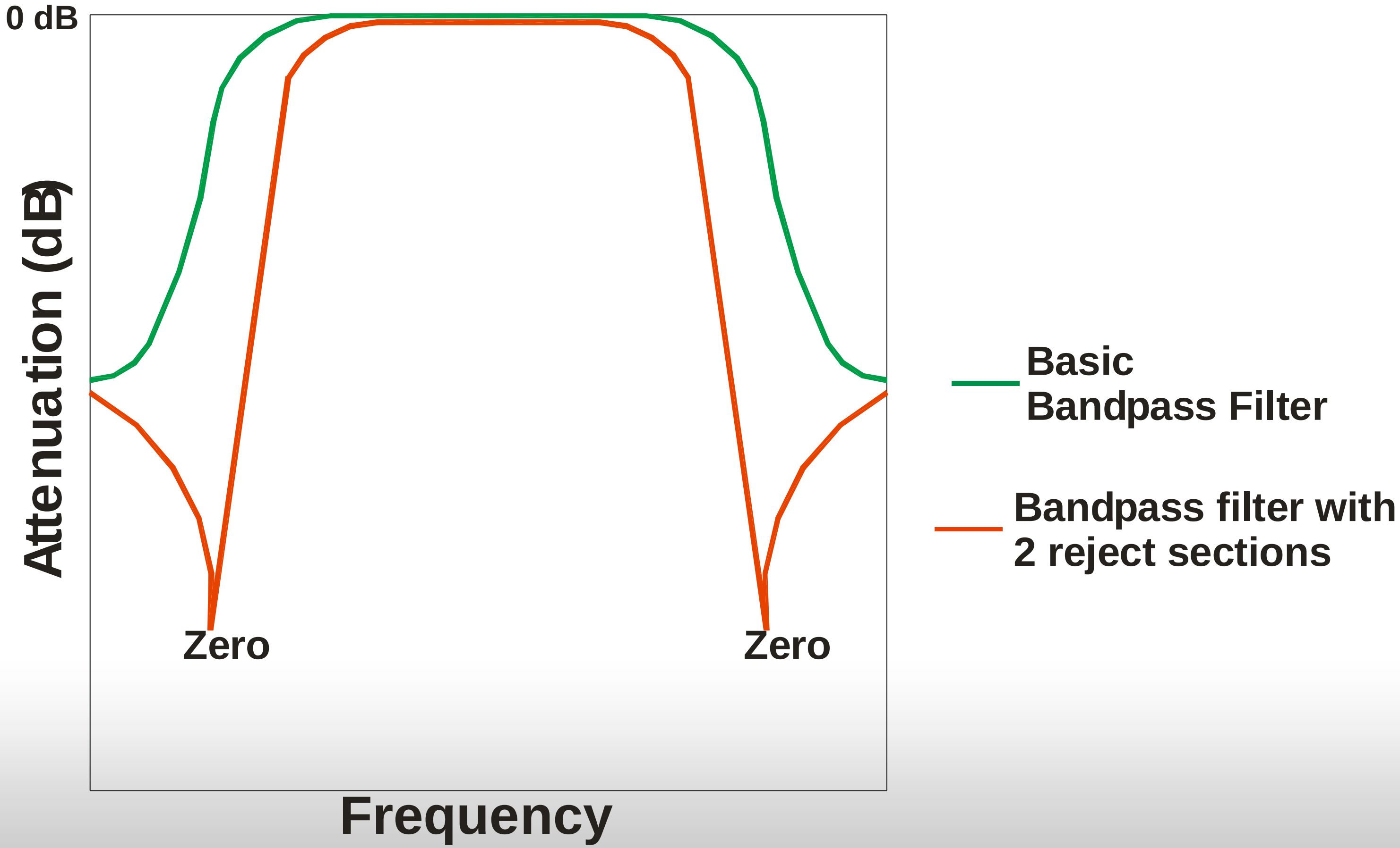
Cross-Coupled Filters

Effect of adding two reject sections to basic bandpass configuration



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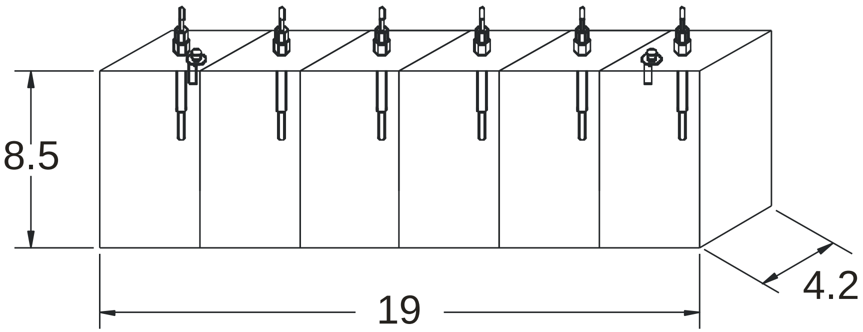
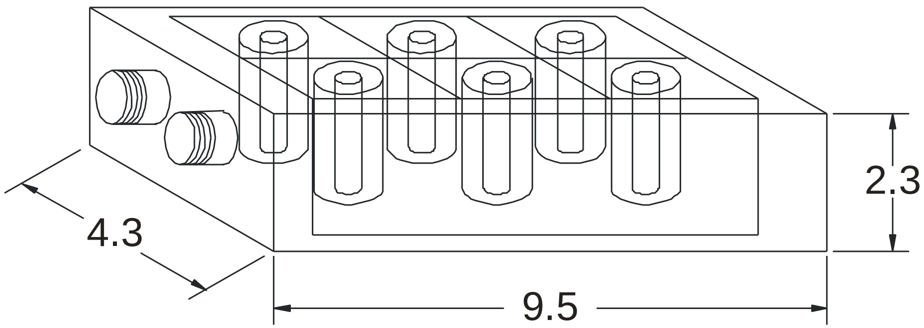
Cross-Coupled Filters

Current platform is a milled-out aluminium block – light weight and easy to machine. Each resonant cavity is formed by removing material with a milling machine.



Apperture Coupled Filter Platform



Cross-Coupled Filter Platform

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Filter Selection Process

1. Minimum isolation requirements

2. Maximum acceptable insertion loss (which determines selectivity)

3. Pass band width

4. Physical size constraints

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Required Ordering Information

Required Ordering Information

- Band pass – Pass Frequency / Insertion Loss
- Band Reject – Pass and Reject Frequencies / Notch Isolation
- Q-Circuit – Pass and Reject Frequencies / Notch Isolation

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Choosing the Right Product

FILTER PRODUCTS

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Combiners

Purpose of the Antenna Combining System

- Allows multiple transmitters to share a single antenna

Advantages

- Fewer antennas per site
- Optimize antenna location – more uniform coverage
- Reduce tower loading
- Reduce transmission line requirements
- Future expansion capabilities

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Combiners

Types of Antenna Combing Systems

- Filter cavity type (duplexers)
- Cavity – ferrite type (CT, TJ, RTC combiners)
- Hybrid – ferrite type (TC combiners)
- Expandable multicouplers (C-series multicouplers)

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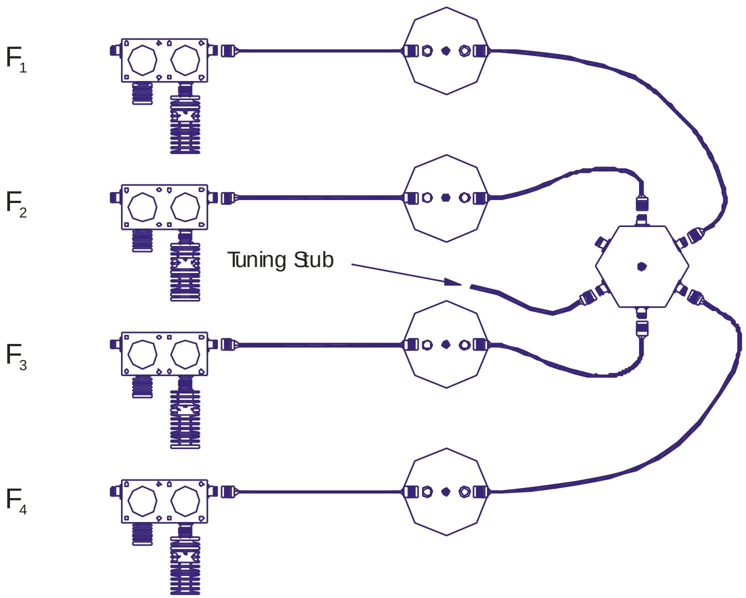
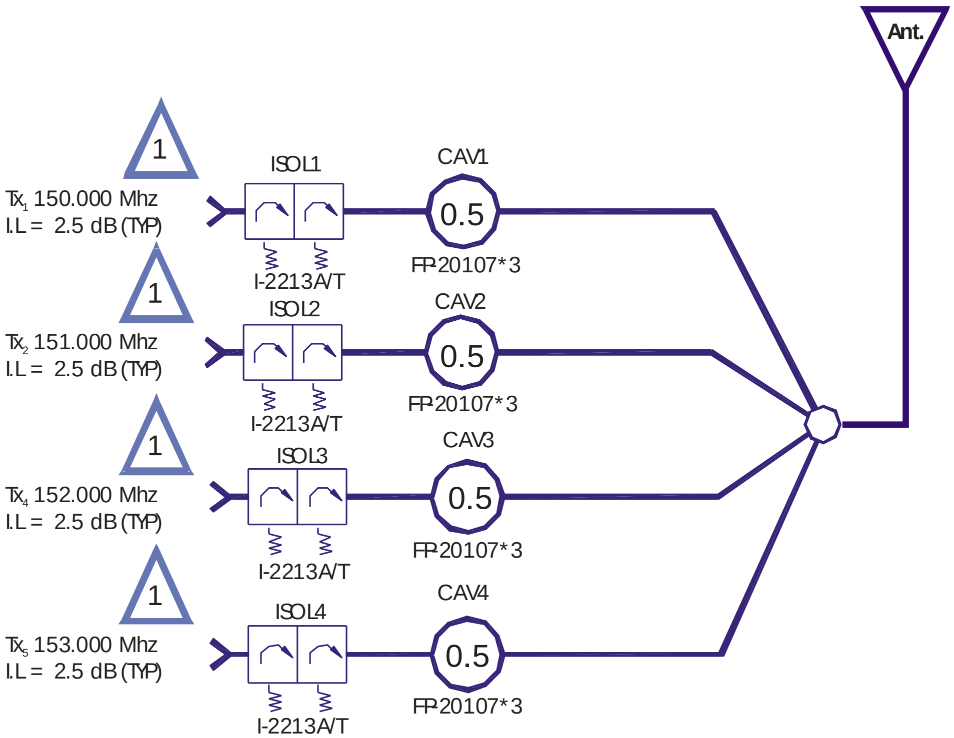
Cavity-Ferrite

Mechanical/Schematic



Mechanical Layout



Schematic Layout

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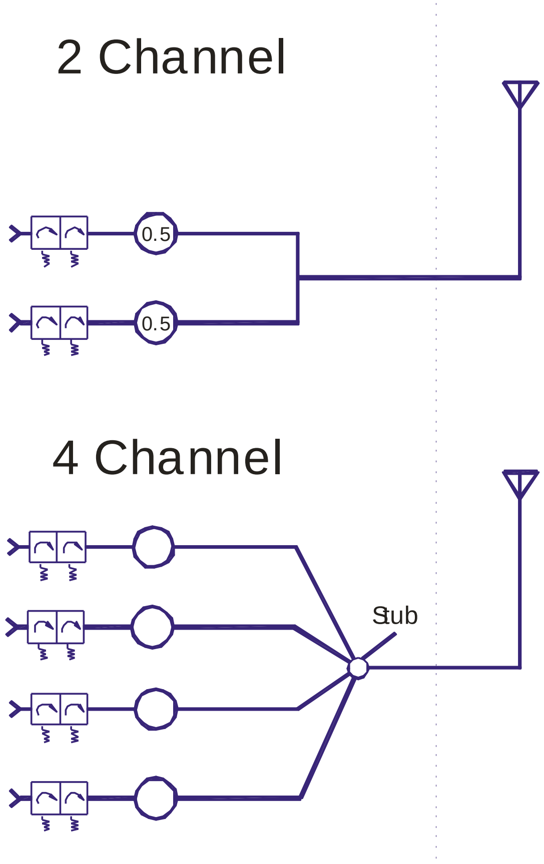
Cavity-Ferrite



Typical Tx-Tx Isolation = 70 dB
Typical Tx-Tx Spacing ~ 200 KHz
Typical Insertion Loss
2 Channel ~ 3.5 dB @ 200 KHz
4 Channel ~ 4.0 dB @ 200 KHz

Advantage
- Reasonable insertion loss
- Cleans up transmitter noise

Disadvantage
- Large size
- Expansion requires tuning

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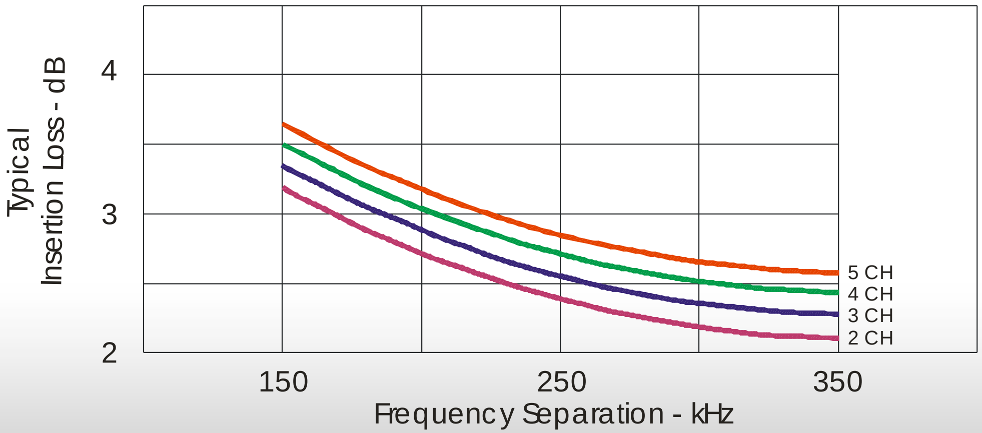
TJ Series Combiners

- Electrical Specifications – TJ-221*
- Frequency Range 132 – 174 MHz
- Frequency Separation See Curves
- Number of Channels 2 to 5
- Pass Band insertion Loss See Curves
- Isolation
- Tx - Tx 35 (single Isolator/70 (dual Isolator)
- Ant – Tx 25 (single Isolator/60 (dual Isolator)
- Maximum Input VSWR 1.25:1
-
- Maximum Input Power Watts 125/Channel
- Termination "N" Female
- Temperature Range -30°C to + 60°C
- Note: VSWR is referenced to 50 ohms



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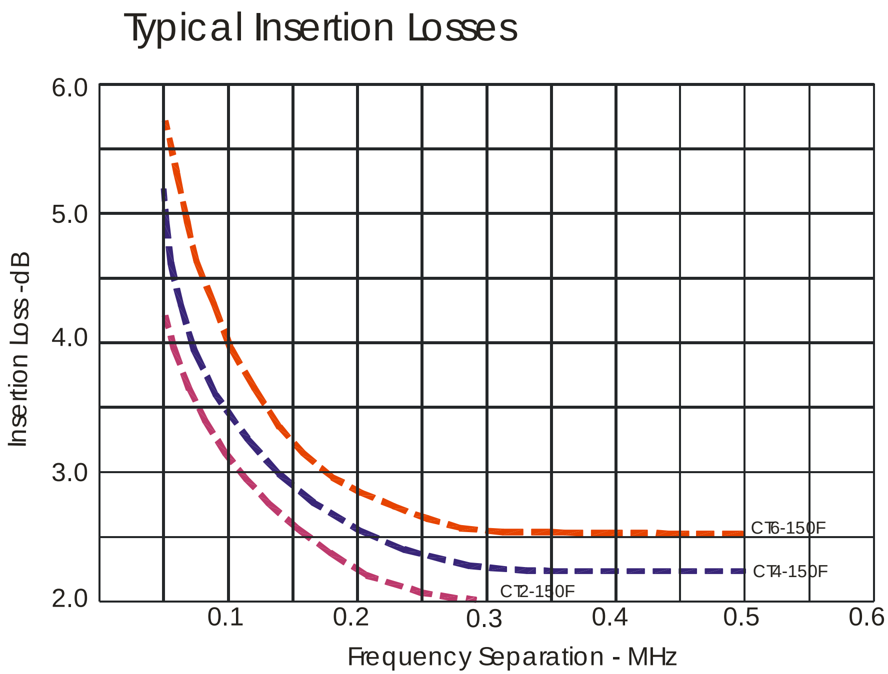
CT Series

- Electrical Specifications - CT*-150F
- Frequency Range 132 – 174 MHz
- Frequency Separation 0.06 – 4.0 MHz
- Number of Channels 2 – 8
- Pass Band Insertion Loss See Curves
- Isolation
- Tx – Tx 70 dB
- Antenna - Tx 60 dB
- Maximum Input VSWR 1.25:1
- Maximum Output VSWR 1.5:1
- Maximum Input Power Watts 125/channel
- Termination 'N' Female
- Temperature Range -30°C to + 60°C
- Note: VSWR is referenced to 50 ohms



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Summary of Cavity-Ferrite

In general we find:

- Most models available in 5 channel blocks
- Minimum typical spacing ~200 KHz
- Input (transmitter) power output limited to 125 – 150 Watts
- Insertion Loss at 1 MHz TX-TX spacing approximately 2.5. dB

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Hybrid Combiners

- Used for extremely close-spaced transmitter frequencies
- Inherently high insertion loss (approximately 4 dB for 2 channels)
- Compact physical size
- Cost effective

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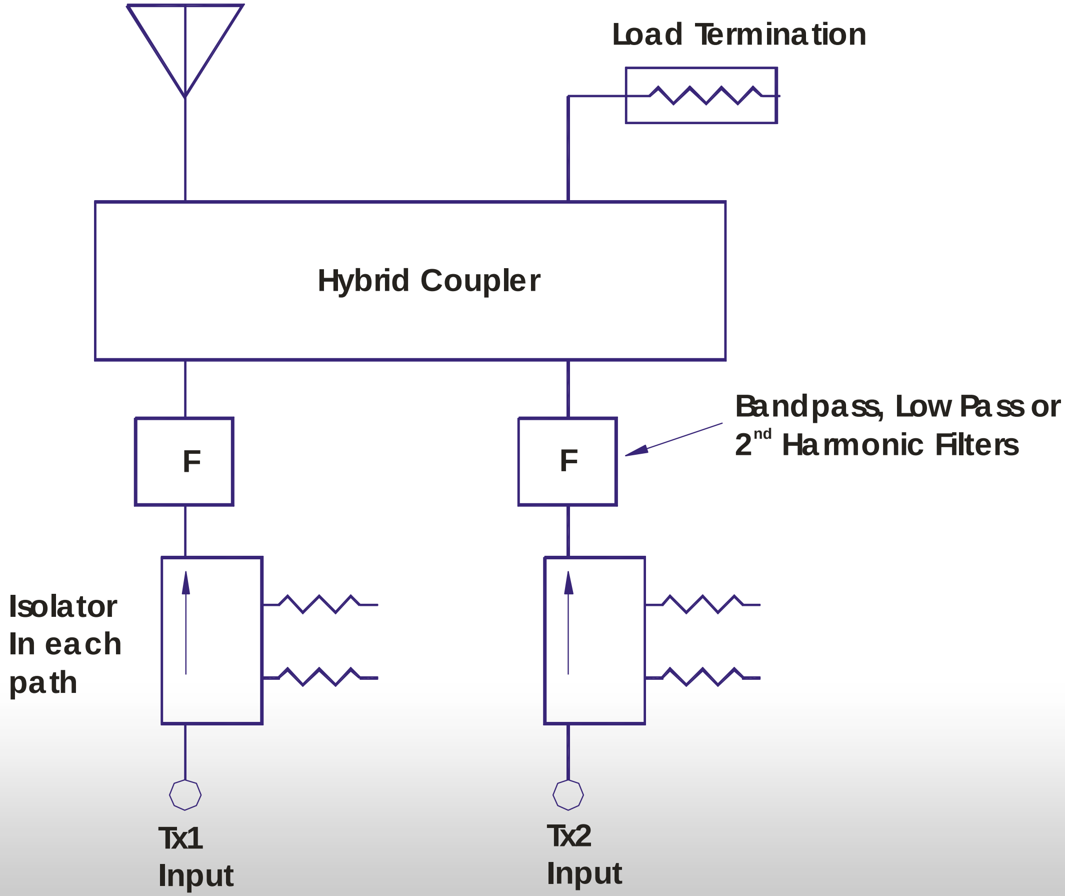
Hybrid Combiners

Typical hybrid coupled two-transmitter combiner block diagram. Isolation between input ports will be at least 80 dB



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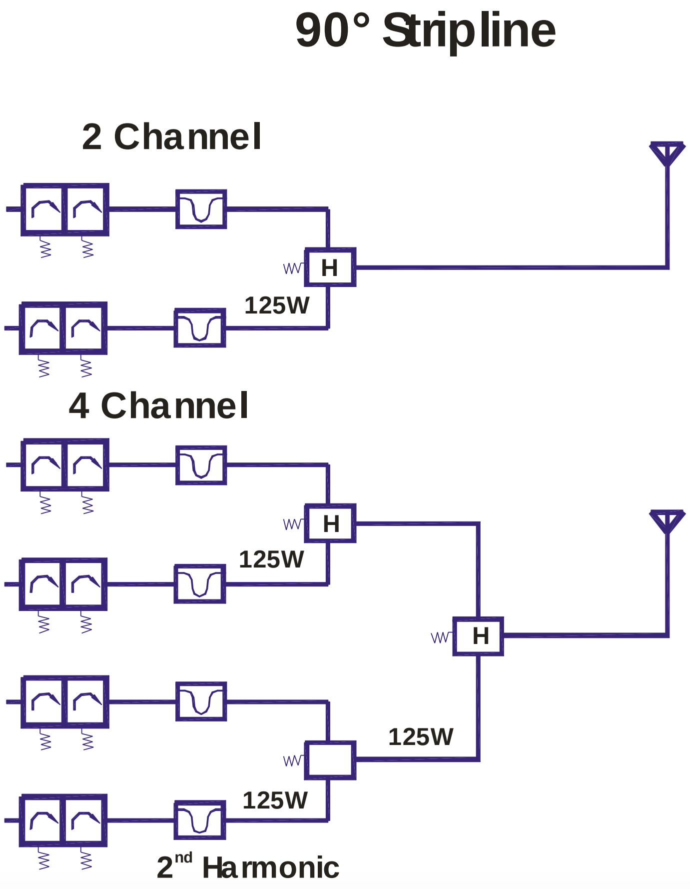
Hybrid-Ferrite Combiners



Typical Tx –Tx isolation = 80 dB

Typical insertion loss

2 channel = 4.2 dB

4 Channel = 7.4 dB

Advantage

- Work at very close spacings
- Small size (2 CH = 3.5” h tray)
- Cost effective

Disadvantage

- High insertion loss
- Lack of Tx noise suppression

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Unbalanced Hybrids

- Equalizes insertion loss of odd channel (3rd or 5th) to even numbered groups in order to create uniform talk-out coverage.
- Special coupler design imposes greater loss on the odd channel
- Several split ratios available to provide channel equalization within +/- .5dB

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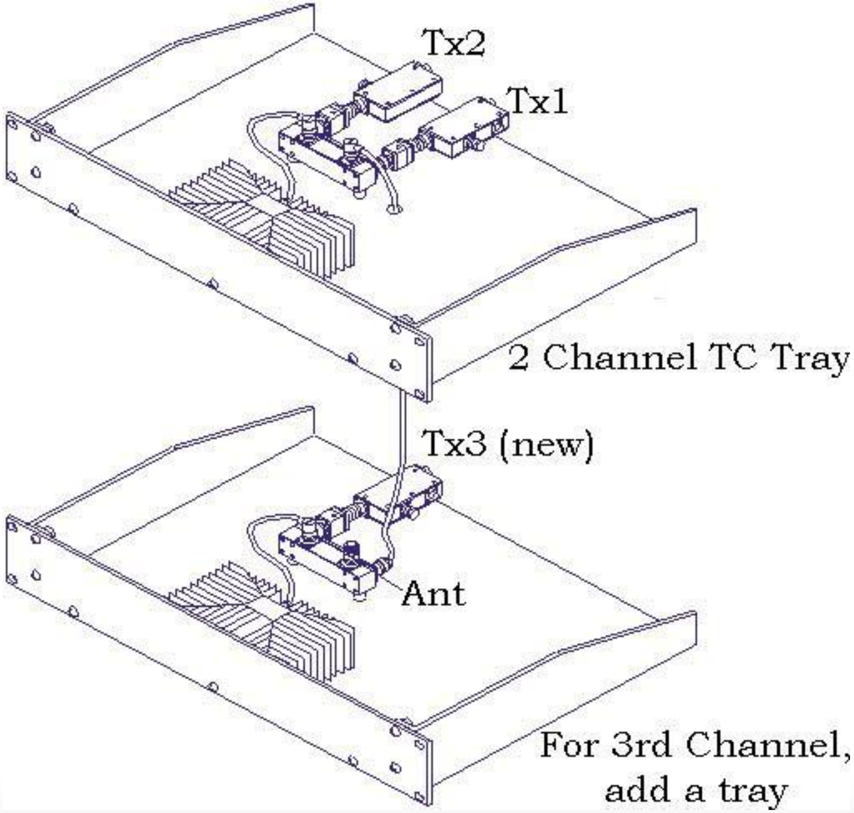
Hybrid Combiners

3 Channel Hybrid-Ferrite Combiner



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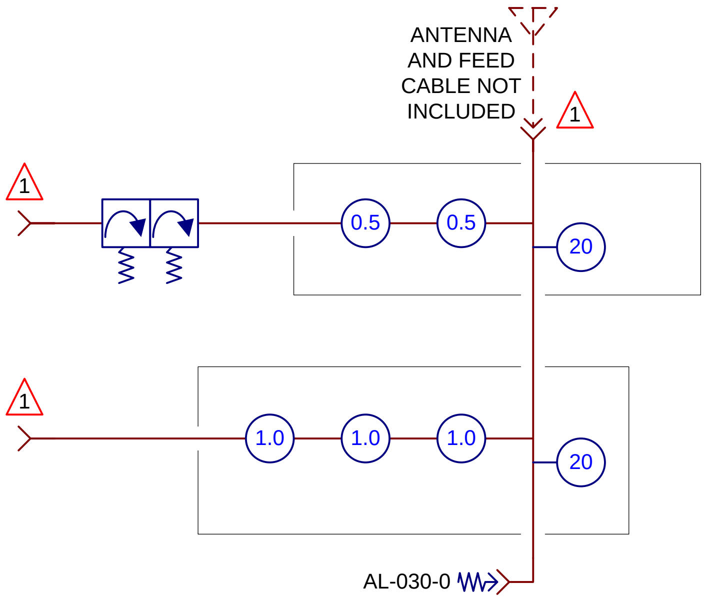
Expandable Multicouplers (C-Series)



Typical Tx-Tx Isolation = 70 dB
Typical Tx-Tx Spacing>500 Khz
Typical Insertion Loss
    on channel = 1.3 to 3.5 dB
    thruline = 0.2 to 0.3 dB

Advantage:

- Easy expansion
- Cleans up transmitter noise

Disadvantage

- Requires greater spacing
- Large size
- High cost

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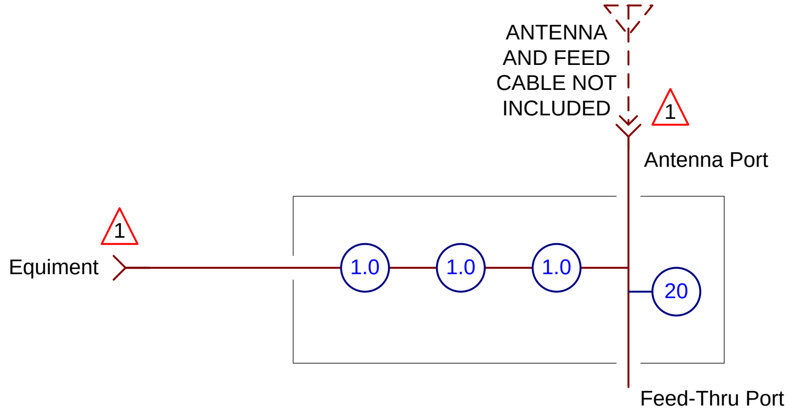
C-Series Multicoupler

C-series multicouplers may have 1,2, or 3 bandpass cavities which provide isolation between frequencies.

The reject cavity allows C-series units to be interconnected by a non-critical length cable.

C-series allows for easy expandability.



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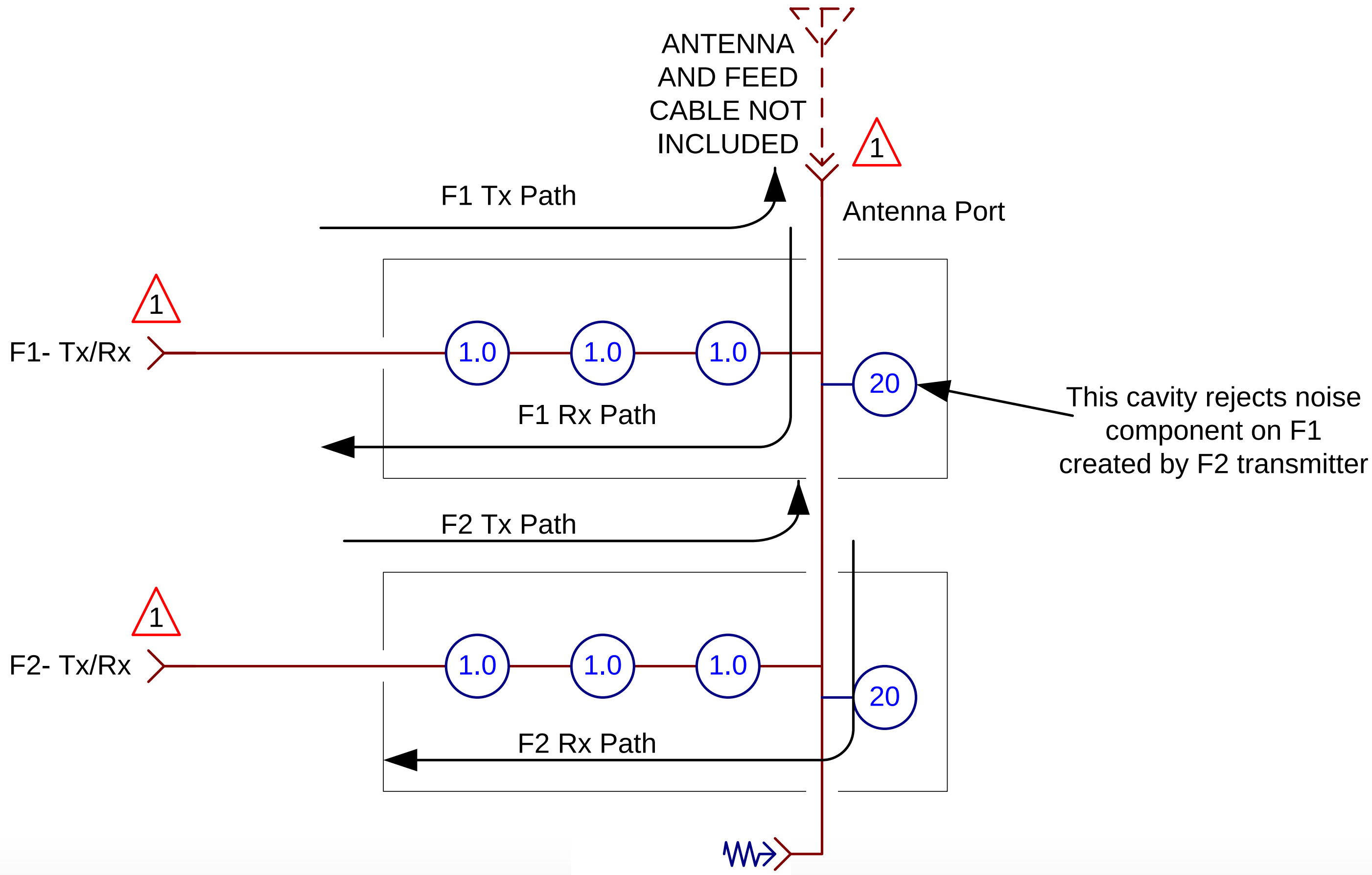
C-Series Multicoupler



The termination eliminates undesirable reflections

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Pass-Thru Expandable Multicoupler

- Existing C Series "Pass-Reject" Architecture
  - Used in multi-channel antenna combining systems, wider frequency spacing ~ 500 kHz
  - Easy support for frequency adds/deletes (non-critical cable length)
  - Uses bandpass (FP) and notch cavities (FR)
  - Less susceptible to bridging loss

- *New* C Series "Pass-Thru" Architecture
  - Used in multi-channel antenna combining systems, narrow frequency spacing ~ 100 kHz
  - Not as flexible in supporting frequency adds / deletes (critical length cable)
  - Uses one less cavity per leg relative to Pass-Reject architecture
  - More susceptible to bridging loss

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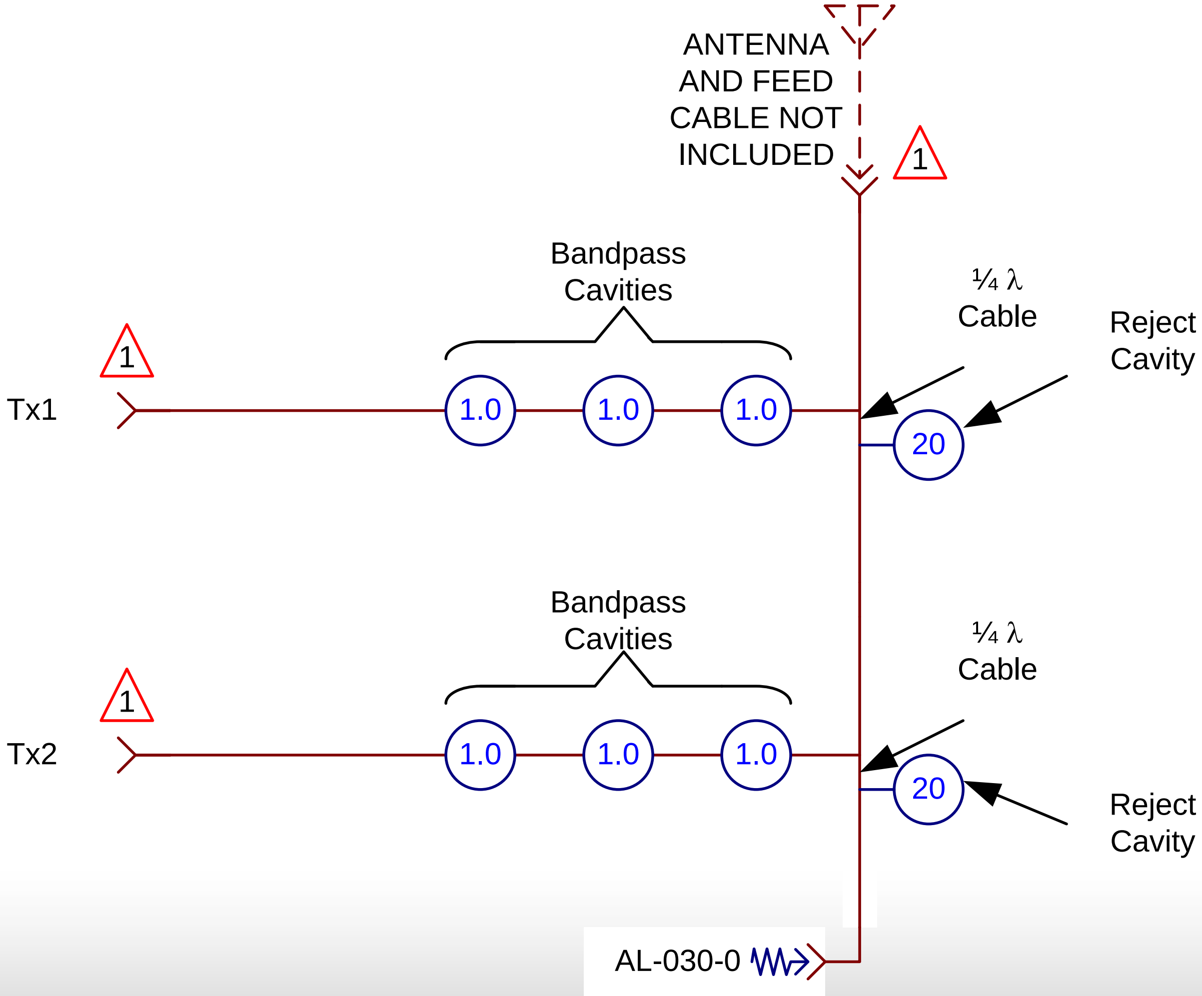
C-Series “Pass-Reject” Architecture



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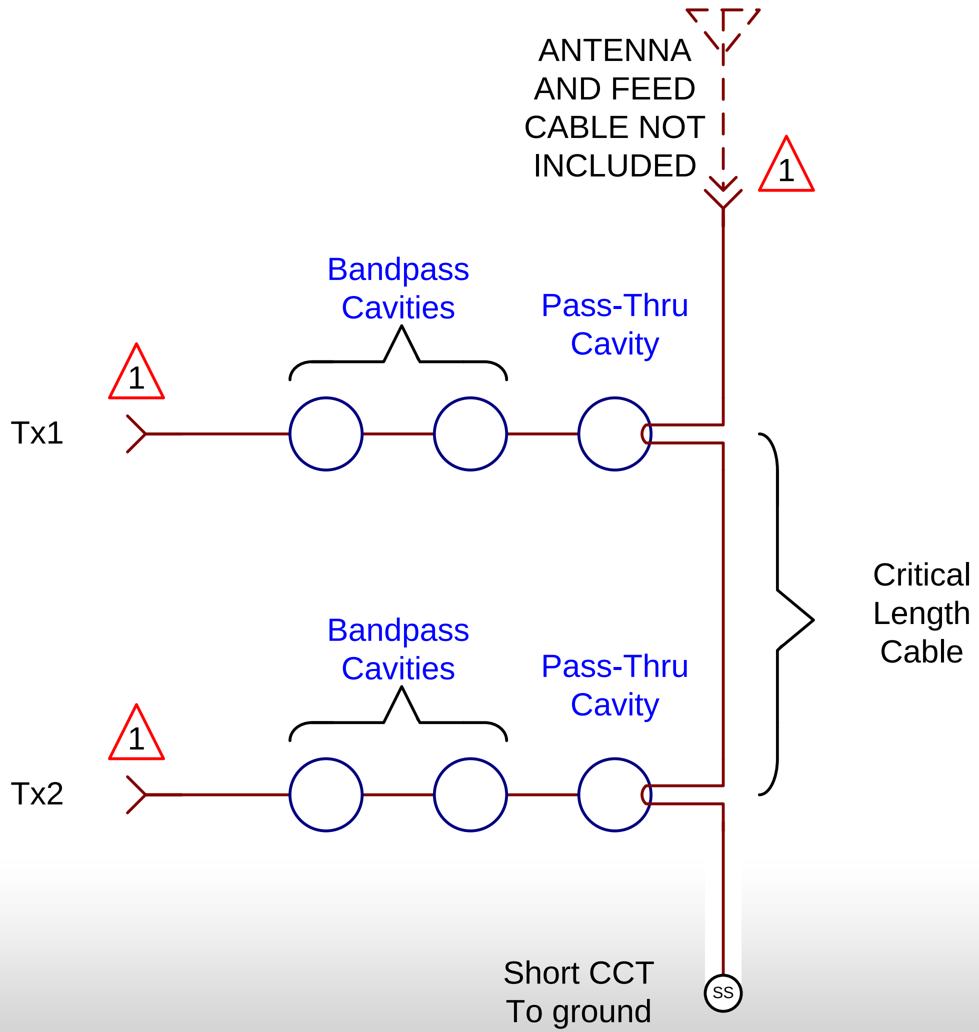
C-Series "Pass-Thru" Architecture



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Combiner Selection

- Frequency spacing, Tx-Tx
- Isolation requirements
- Power input limitations
- Insertion loss per channel
- Physical size requirements

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Receiver Multicouplers

Purpose

Multicouplers allow many receivers to share a single antenna without imposing a net splitting loss

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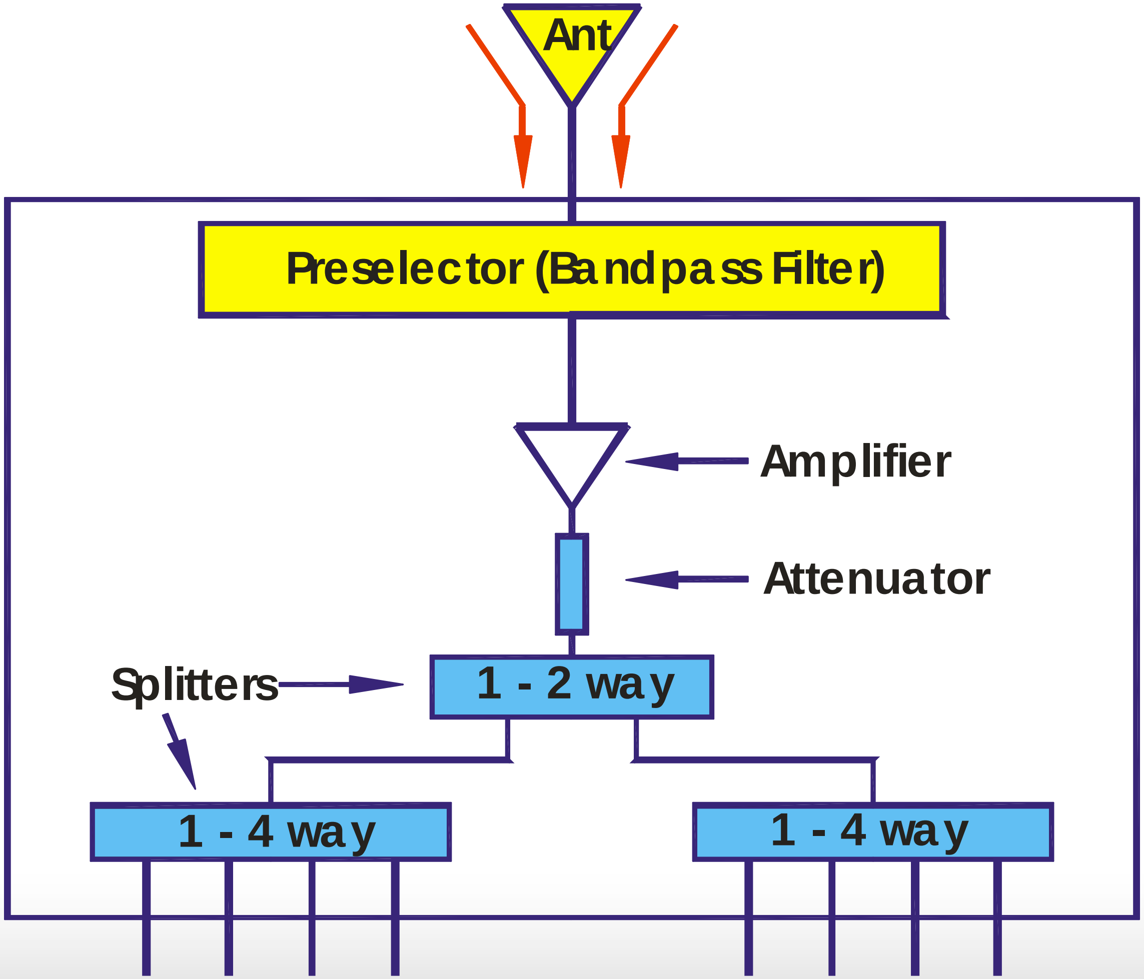
Receiver Multicouplers: Basic Block Diagram



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Receiver Multicouplers

Receiver Multicoupler

Typical Rx-Rx Isolation = 25 dB
Typical system gain = 0 to 4 dB
No limitation on spacing

- Noise figure ~ 2 dB for VHF
- Noise figure ~ 0.8 dB for UHF and above
- 3rd order intercept ~ +40 dBm

Preselector choice is critical

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System Applications of Receiver Multicouplers

Excessive gain in receive systems can cause:

- Rx desense due to *effective* decreased isolation from transmitters
- IM distortion products from received frequencies

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Receiver Multicoupler Selection Process

1. Base Tray vs. Tower Top Amplifier

2. Preselector (Bandwidth and Insertion Loss)

3. Amplifier selection: GaAsFET or Bipolar

4. Number of Channels and future expansion possibilities

5. Power Supply

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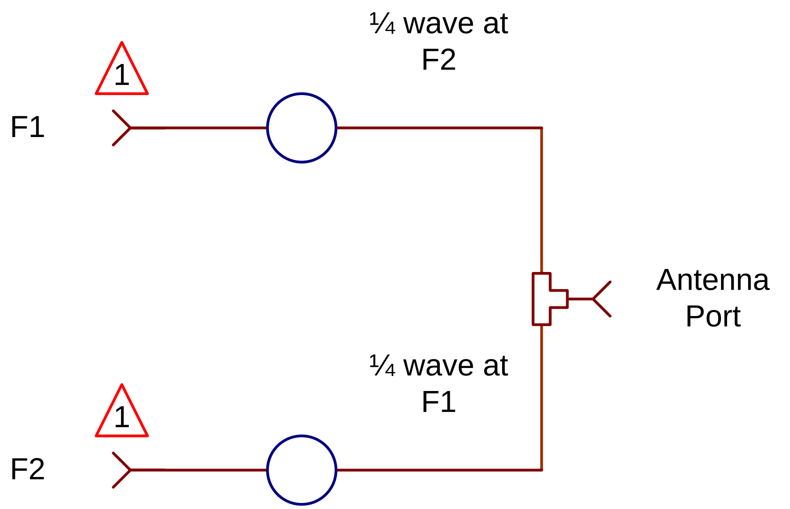
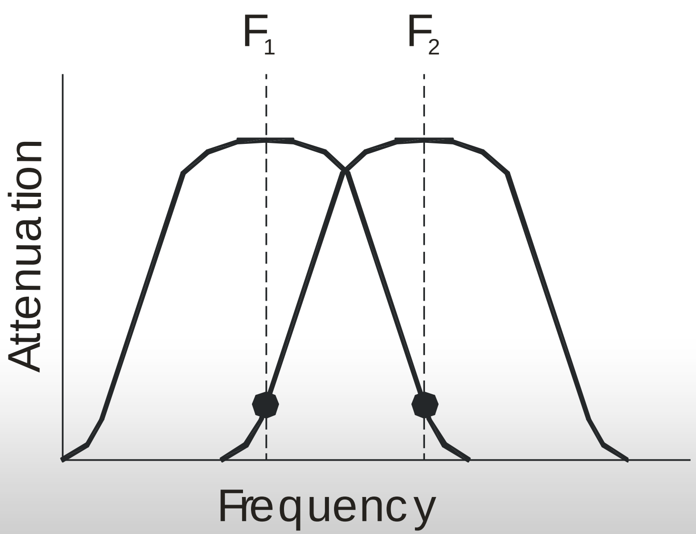
Duplexers

- Three port device which is used to combine two signals onto one antenna
- Typical Tx-Rx isolation 80-95 dB





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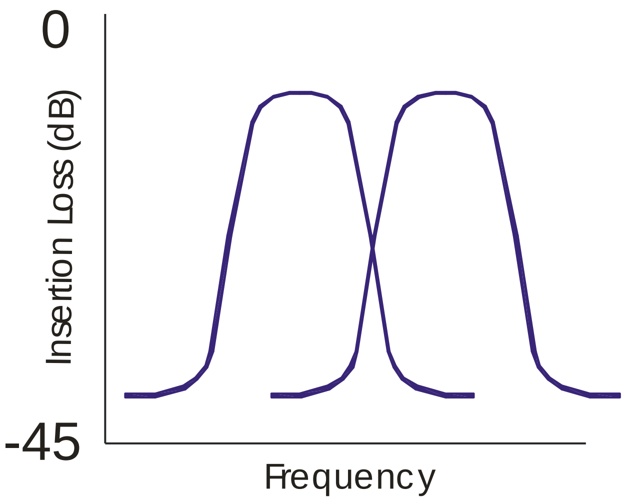
Bandpass Co-Axial Cavity Duplexers

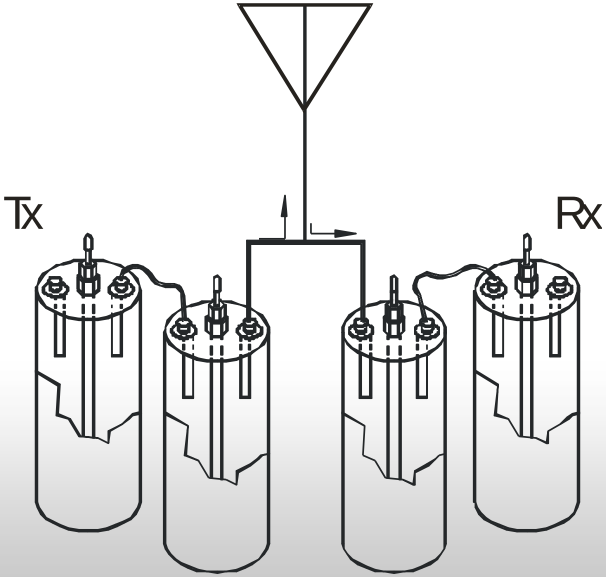
Applications:

Relatively wide T/R separation

and broad pass band regions

– often used for combined 800 MHz trunking system





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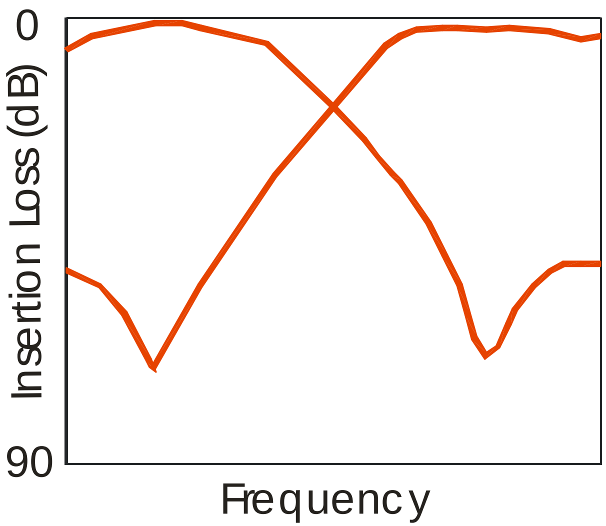
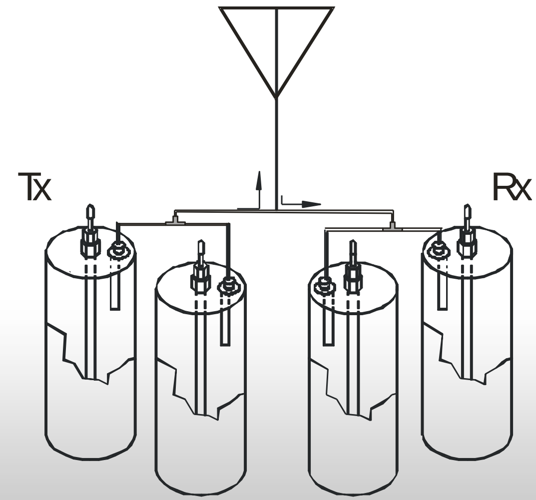
Reject Co-Axial Cavity Duplexers

Applications:

Low band (30-50 MHz). High “Q” helical resonators, can provide 90dB selectivity at frequency spacing down to 300 KHz in a relatively compact cabinet.

Mobile duplexers for VHF, UHF and 800 MHZ. Low “Q” resonators provide T/R separations down to 4.5 MHz in extremely small packages.





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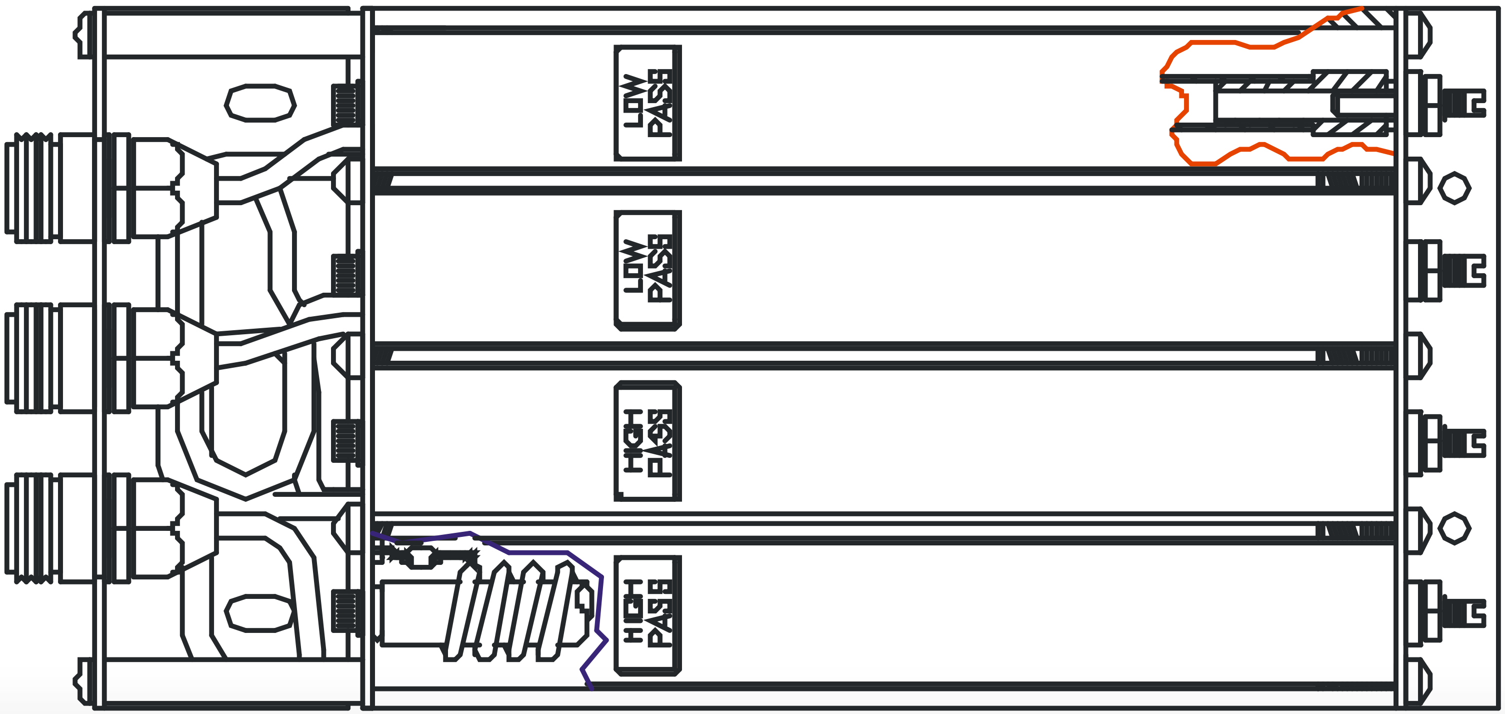
Mobile Duplexer

Construction of Resonators (used in Band reject Type Duplexer)



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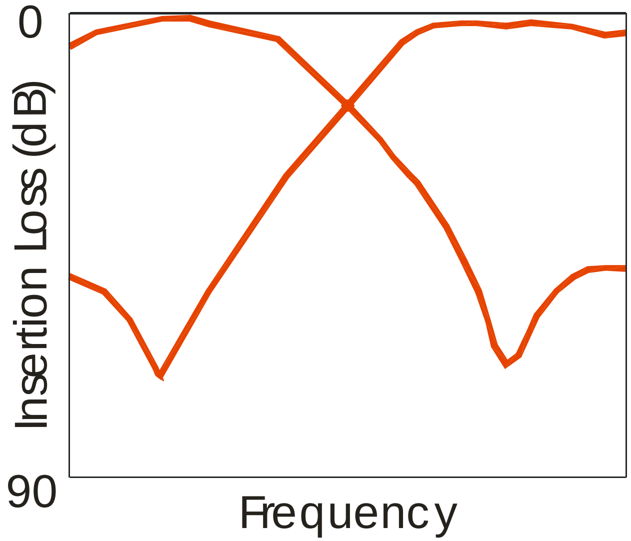
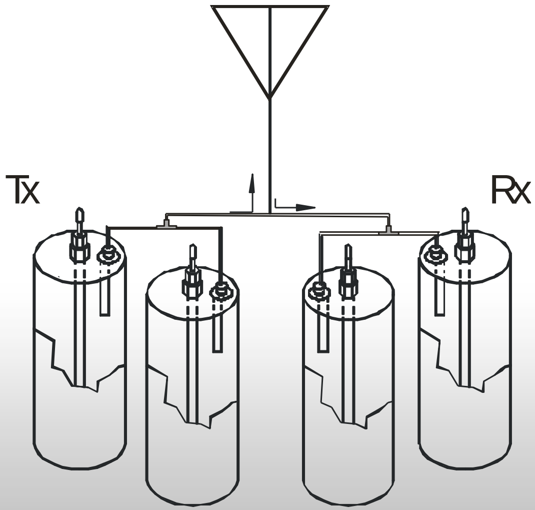
Q-Circuit Cavity Duplexers

Applications:

Closer T/R spacing than band reject allows, with a slight increase in insertion loss. Also, an advantage at crowded sites: provides a passband characteristic as well as a broad isolation notch.





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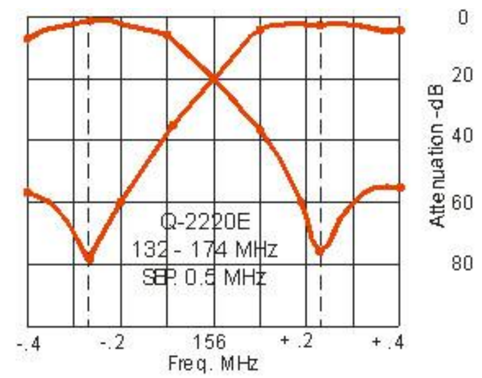
Q-Circuit Res-Lok Duplexers

	Q-1220E	Q-2220E	Q-3220E	Q-4220E
Electrical Specifications				
Frequency Range MHz	66-88	132-174	406-512	806-960
Frequency Separation	0.2 min	0.5 min	0.8 min	45 min
Insertion Loss dB (Tx/Rx to Ant.)	1.8 max	1.5 max	0.8 max	1.0 max
Isolation dB (Tx noise suppression at Rx, Rx isolation at Tx)	65 min	70 min	75 min	80 min
Maximum input VSWR		1.5:1 (ref. to 50 Ohms)		
Input Power Watts	350 max	350 max	350 max	150 max

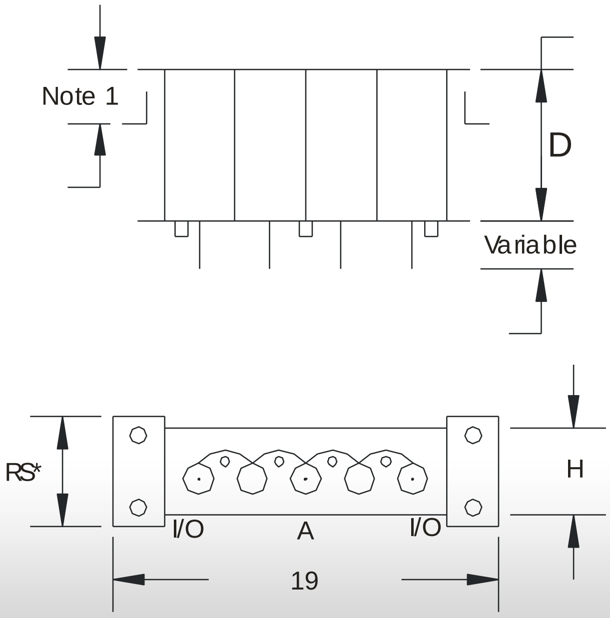


Dimensions (Inches)

MODEL	H	RS*	D
Q-1220E	4.17	5.25	48.3
Q-2220E	4.17	5.25	24.2
Q-3220E	4.17	5.25	10.3
Q-4220E	4.17	5.25	5.5

RS* - Vertical Rack Space Required

Note 1: Mounting brackets are adjustable FR to RR



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Duplexer Selection Process

1. Minimum isolation required
2. T/R frequency separation
3. Max acceptable insertion loss
4. Pass band width – Single vs. Multiple frequency
5. Off frequency rejection
6. Physical size constraint
7. Cost effectiveness

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Ferrite Isolators, Circulators, and RF Loads

How They Work and Why They're Needed

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Isolators

Purpose

To prevent the creation of transmitter generated intermodulation (IM)
An isolator allows RF to pass in only one direction – from transmitter to antenna

Causes of reflected power:

Open circuit: damaged transmission line or disconnected cable

Shorted antenna

Detuned filter – cavity drift

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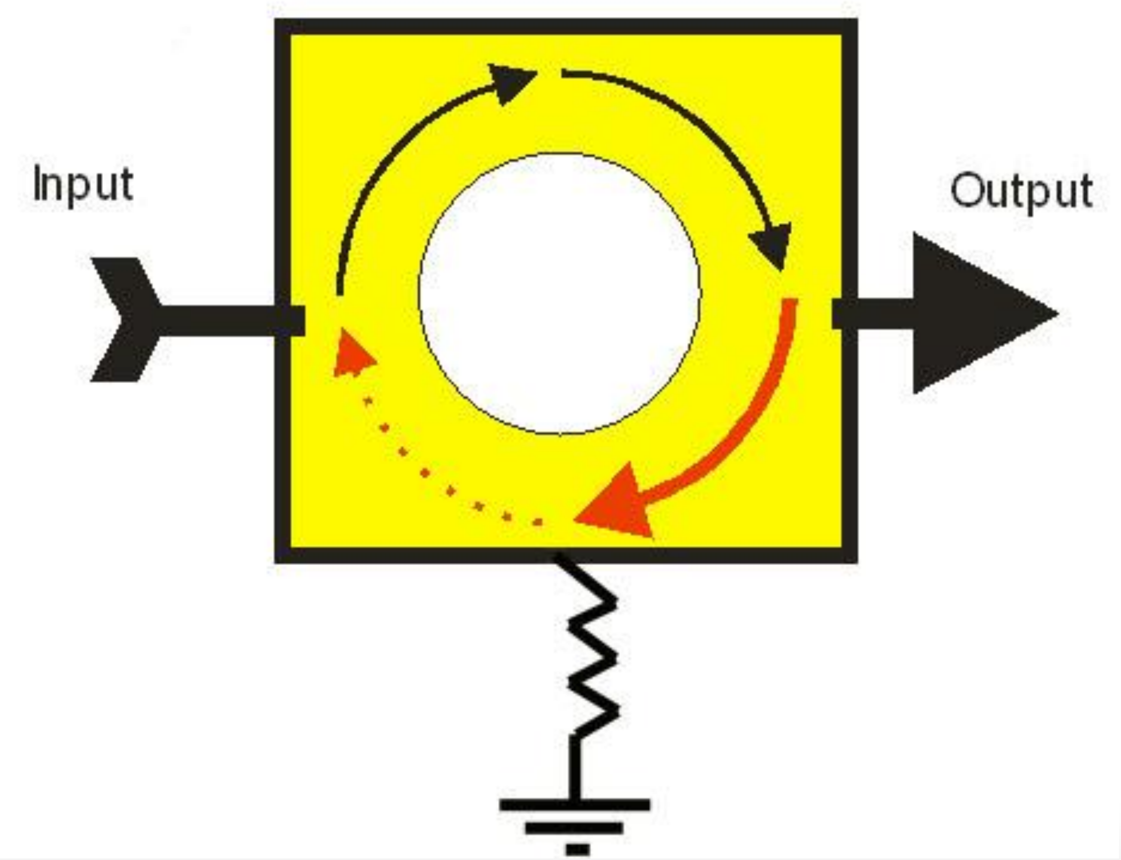
Block Diagram: Single Junction Isolator



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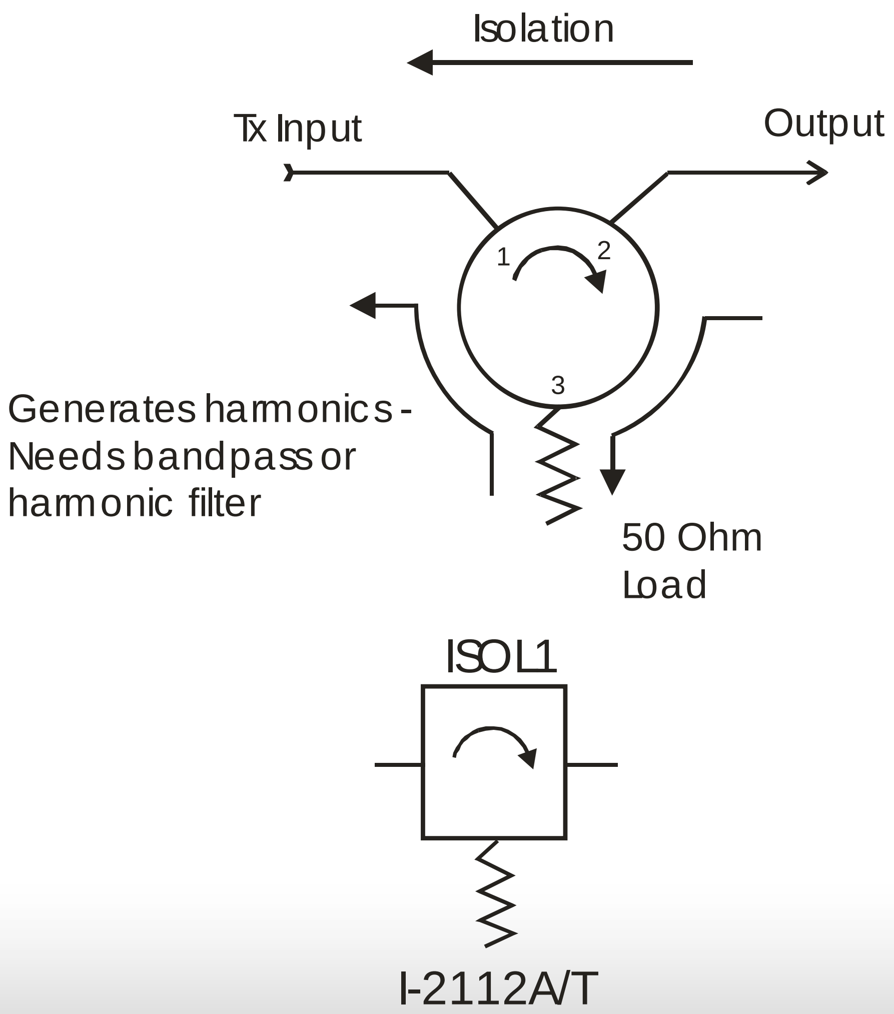
Isolators

- When all ports are matched into 50 Ohms R.F. energy travels in a favoured direction but suffers 20 to 40 dB attenuation in the reverse direction.

- The degree of isolation depends on the accuracy of the 50 Ohm load on the third port. Any reflections circulate back to Port 1 and reduces the isolation from Port 2 to 1



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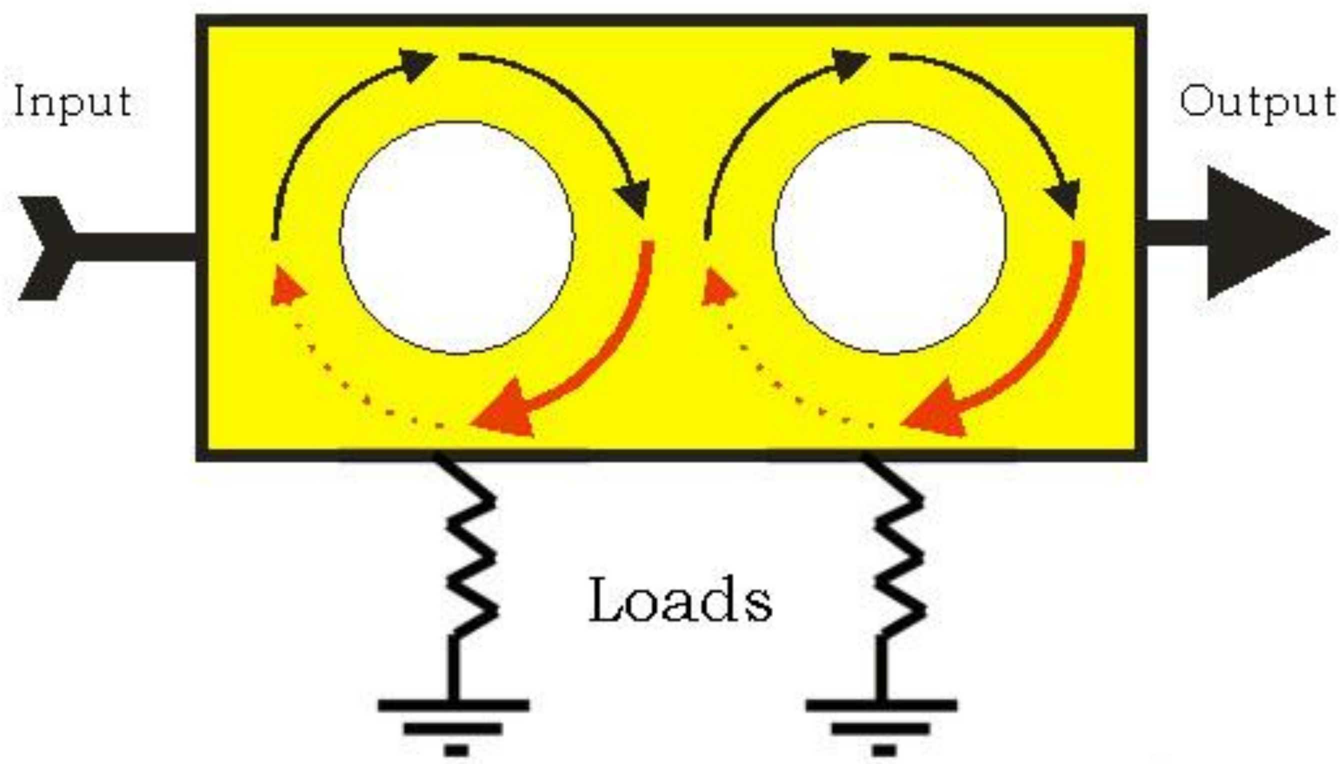
Block Diagram: Dual Junction Isolator



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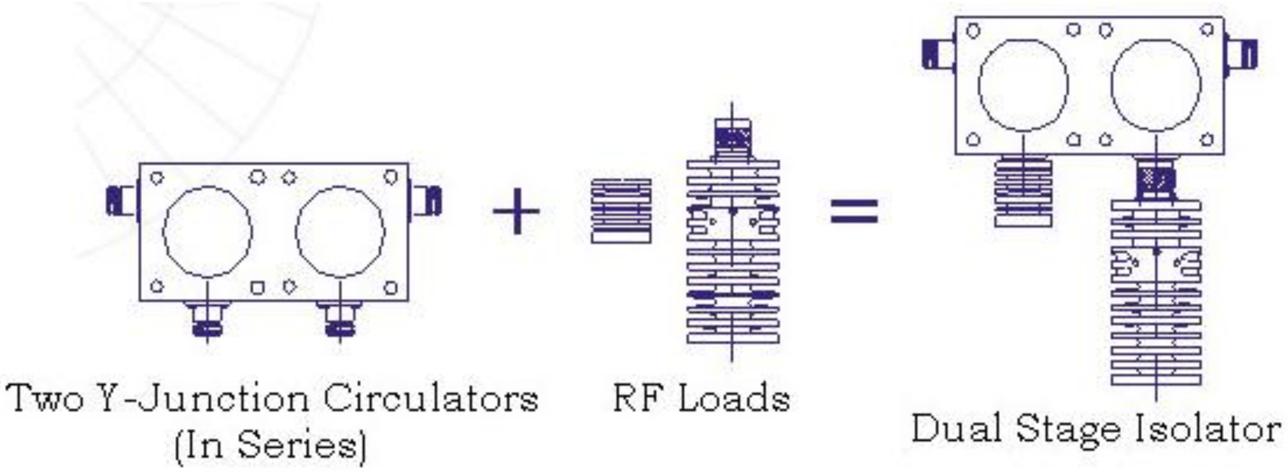
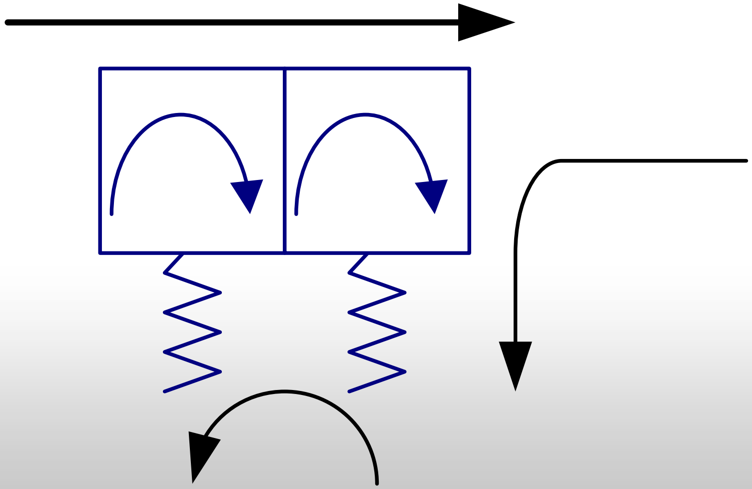
Circulator/Isolator



Transmitted RF Power minus the
Dual Stage Isolator's Insertion Loss



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Isolator Selection Considerations

1. Isolation required, single or dual stage
2. Power rating
3. Forward insertion loss
4. Load power rating – load on single stage isolator or output load on dual stage isolator does not need to be rated at full transmitter power output due to insertion loss of isolator, filter (s), and transmission line

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Sources of RF Interference

1. Common types of receiver interference
   1. Transmitter sideband noise
   2. Transmitter spurious outputs
   3. Transmitter carrier overload
   4. Intermodulation
      - Caused by two or more signals mixing at a nonlinear point in the circuit

2. Usual sources of interference
   1. Your own transmitter
   2. Nearby transmitters
   3. Environmental noise: power transformers, car ignitions et. al.

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Effects of RX Interference

- TX sideband noise
  - Broadband white noise increases receive “system noise figure” reducing sensitivity

- Carrier overload (receivers)
  - Saturates amplifier / mixer circuits thereby lowering gain and reducing sensitivity

- Intermodulation (power amps, LNA’s, joints)
  - Large IM spikes can cause desense
  - Causes unwanted channels to be “heard”

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Intermodulation

Relative non-linearity of mixing points

- PASSIVE – slightly to moderately non-linear; antenna elements, connectors, guy wires, towers
- ACTIVE – moderately to excessively non-linear
  - Class A amplifier (moderate)
    - multicouplers, signal boosters
  - Class C amplifier (excessive)
    - Transmitter power amplifiers
    - Receiver mixers

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RF Interference

Examples of IM Frequency Relationships

EXAMPLE 1 – 3rd order IM

A = 150 MHz
B = 151 MHz
2A – 1B = 149 MHz
2B – 1A = 152 MHz

To determine the order, add the coefficients on the intermodulation equation

EXAMPLE 2 – 5th order IM

3A – 2B
3B - 2A
3A – 1B – 1C

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Intermodulation Power Levels

- IM power level is a function of
  - The degree of mixing point non-linearity
  - The power level of the signals involved in the mix
  - The order of the IM product

- Class C power amps about 10% efficient
  - Two equal power signals at 100 watts each will produce third order intermodulation power of 10 watts (+40 dBm)

- Welded antenna joints about .00000001% mixing efficiency (passive):
  - Two equal power signals at 100 watts each (+50 dBm) mixing in an uncorroded electrical joint will produce third order intermodulation power of -50 dBm

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IM: Initial Analysis

- Computer Program to predict potential IM hits given on-site transmit and receive frequencies
- IM power level estimation
- Practical antenna selection and placement to address passive intermodulation issue

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RF Interference Solutions

TX Noise

- Filters in transmit channel

Carrier overload (receiver)

- Filters in receive channel
- Reduce gain in RX pre-amplifier (multicoupled systems)

For both cases, additional antenna isolation will be effective. Applies to systems with individual TX and RX antennas.

Intermodulation – TX power amplifier (s)

- Filters in transmit channel
- Isolators in TX channel
- Split problem transmitter combinations on to separate antennas
- Additional antenna isolation, applies to systems with at least two transmit antennas
- Change frequencies

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RF Interference

Summary of Available Tools

- Isolation requirements program based on radio specific duplex operating curves
- Intermodulation prediction program
- Filters
- Isolators
- Multiple Antennas – channel rearrangement
- Frequency changes

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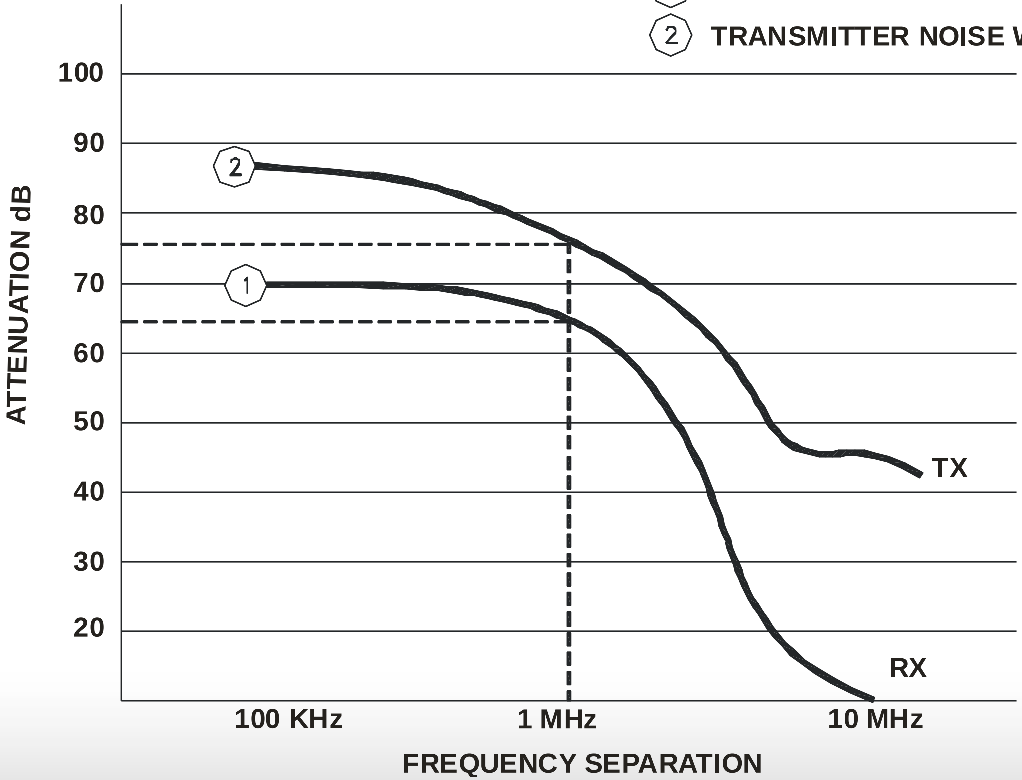
RF Interference

DUPLEX OPERATION CURVES
FOR 138 - 174 MHz MASTER II

THESE CURVES SHOW THE ATTENUATION REQUIRED TO PREVENT GREATER THAN 1 dB REDUCTION IN A 12 dB SINAD RATIO DUE TO:

1. DESENSITIZATION OF RECEIVER ER-64-A
2. TRANSMITTER NOISE WITH NB MODULATION



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NEW FILTER PRODUCTS

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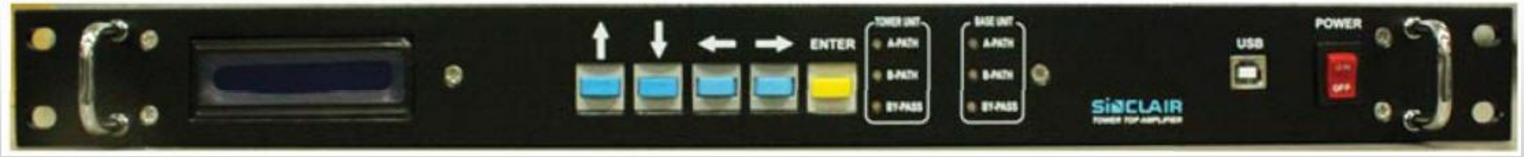
Second Generation TTA

TTM4(AA-W/EE)D(BB)G1B

- • Redundant quadrature coupled amplifiers in both the top and the base
  • Auto switching to the backup amplifier on fault detection
  • Preselectors in the top portions with an optional preselector in the base
  • Ethernet connection allows for remote control and monitoring
  • Communications between top and base done through RF feed line. No separate cable required.



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Compact Hybrid Couplers

Frequency Band	Frequency Range	Sub bands	Band Width	Splits	Model Number
VHF	130-180 MHz	130-160 MHz	30 MHz	70%/30%	HH2141C-1-1
				80%/20%	HH2141C-1-2
		150-180 MHz	30 MHz	70%/30%	HH2141C-2-1
				80%/20%	HH2141C-2-2
UHF	350-512 MHz	350-415 MHz	65 MHz	70%/30%	HH3141C-1-1
				80%/20%	HH3141C-1-2
		405-470 MHz	65 MHz	70%/30%	HH3141C-2-1
				80%/20%	HH3141C-2-2
		459-512 MHz	53 MHz	70%/30%	HH3141C-3-1
				80%/20%	HH3141C-3-2
700/800	746-960 MHz	746-869 MHz	123 MHz	70%/30%	HH4141C-1-1
				80%/20%	HH4141C-1-2
		806-960 MHz	154 MHz	70%/30%	HH4141C-2-1
				80%/20%	HH4141C-2-2

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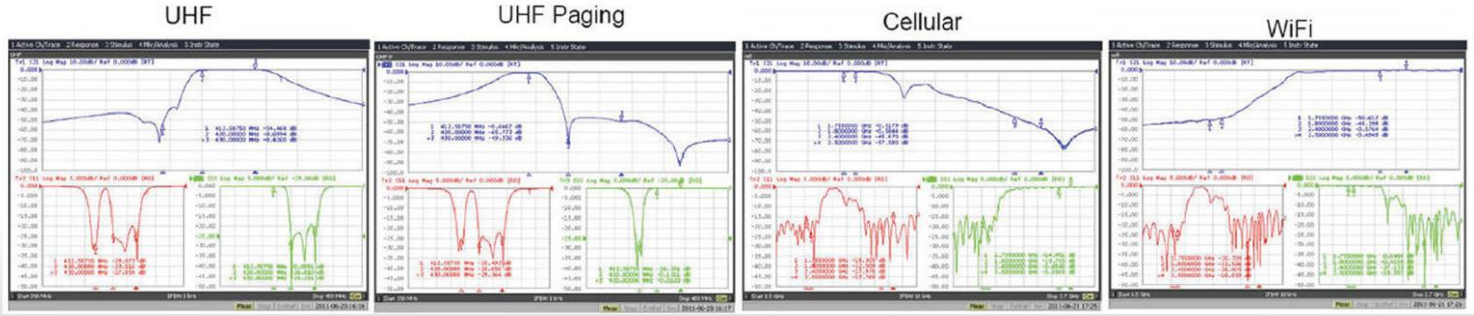
Multiband Combiner

SMBC-4-UCW-W-X-Y-Z

- Compact, High Isolation
- Four input ports, one output port
- W=1 for UHF Paging frequency 412.5875 MHz
- X=1 for 420-430 MHz
- Y=1 for 1750-1800 MHz
- Z=1 for 2400-2500 MHz



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Lumped Element Filters

FPxxxRxxx-(C)

- Suitable for close frequency band signal isolation
- Designed for panel surface mount
- Compact construction with one N-male connector and one N-female connector
- 100 watts power handling capability
- Various band configurations available.

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Crossband Couplers

FX2400NF

Electrical Specifications		
VSWR (max)		1.5:1
Isolation (typ)	dB	40
Connectors		N female
Frequency Band (Low Pass)	MHz	138 to 174
Frequency band (High Pass)	MHz	746 to 960
Pass band insertion loss (Low pass)	dB	0.4
Pass band insertion loss (High pass)	dB	0.4
Power handling (Low pass)	W	200
Power handling (High pass)	W	200
Input/ Output Impedance	Ω	50

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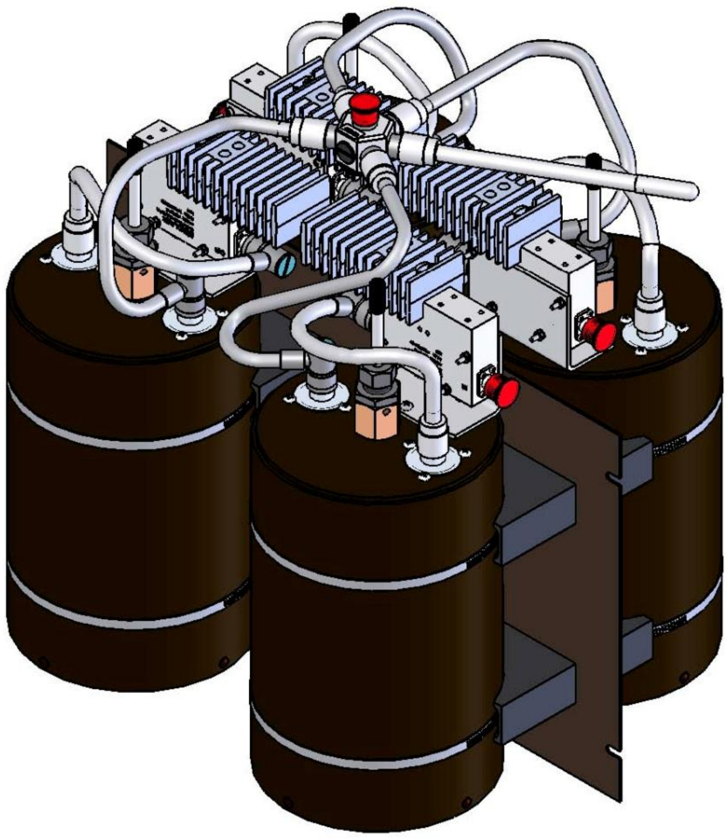
Cavity-Ferrite Tx combiner, 7” cavities, 406-512 MHz

TJ3x1y-R-z

- Low loss broad band dual stage isolators
- Allows for minimum Tx-Tx spacings of 200 KHz
- Expandable for more channels
- Uses high 'Q' 1/4 wave bandpass cavity filters
- Panel mount



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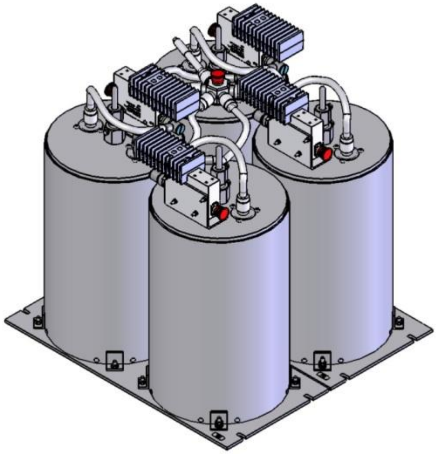
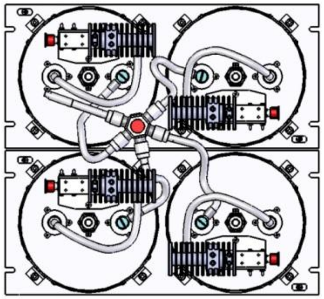
Cavity-Ferrite Tx combiner, 8.5” cavities, 406-512 MHz

TN321x-R-y

- Minimum Tx-Tx separation of 0.1 MHz
- Low loss broad band dual stage isolators
- Uses high 'Q' 1/4 wave bandpass cavity filters that are horizontally mounted
- Expandable for more channels





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Compact hybrid ferrite, 2 or 4 channel, single or dual stage isolator, 350-512 MHz

TCC3x3y-z

- Connect 2 or 4 60 Watt transmitters to one antenna
- Single or dual stage isolator versions available
- 1 Rack unit high compact housing

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VHF Compact & UHF Cross- Coupled Preselectors

- High selectivity, high performance design
- Very compact, low profile VHF preselector for 130-150 MHz & 150-174 MHz
- UHF preselectors for 380-420 MHz & 450-512 MHz
- UHF design uses advanced 6 & 8 section cross-coupled filter technology to provide extremely high selectivity

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VHF & UHF Rx Multicouplers With Advanced Features

- Available 8 to 32 channel receiver multicoupler deck in 8-port increments occupies 1 R.U.

- Front panel BNC female sampler prior to LNA

- Front panel electronic 0-15 dB BCD selectable attenuator in 1 dB steps

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VHF & UHF Rx Multicouplers With Advanced Features

Model	Description
RM200-008V1B	VHF Receiver multicoupler with Advanced Features, 8-port, BNC, 132-174 MHz
RM200-008VQ10B	VHF receiver multicoupler, advanced features, 8-port, BNC, 132-174 MHz
RM200-008VQ10B-2	VHF receiver multicoupler, advanced features, 8-port, BNC, 132-174 MHz
RM200-008VQ11B	VHF receiver multicoupler, advanced features, 8-port, BNC, 132-174 MHz
RM200-008VQ11B-2	VHF receiver multicoupler, advanced features, 8-port, BNC, 132-174 MHz
RM200-016V1B	VHF Receiver multicoupler with Advanced Features, 16-port, BNC, 132-174 MHz
RM200-024V1B	VHF Receiver multicoupler with Advanced Features, 24-port, BNC, 132-174 MHz
RM200-032V1B	VHF Receiver multicoupler with Advanced Features, 32-port, BNC, 132-174 MHz

Model	Description
RM300-008V1B	8 port, variable attenuator, fault monitor, 350-512 MHz
RM300-008VQ10B	UHF receiver multicoupler, advanced features, 8-port, BNC, 380-512 MHz
RM300-008VQ10B-2	UHF receiver multicoupler, advanced features, 8-port, BNC, 380-512 MHz
RM300-008VQ11B	UHF receiver multicoupler, advanced features, 8-port, BNC, 380-512 MHz
RM300-008VQ11B-2	UHF receiver multicoupler, advanced features, 8-port, BNC, 380-512 MHz
RM300-016V1B	16 port, variable attenuator, fault monitor, 350-512 MHz
RM300-024V1B	24 port, variable attenuator, fault monitor, 350-512 MHz
RM300-032V1B	32 port, variable attenuator, fault monitor, 350-512 MHz

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