RFI Systems Technical Training Seminar

A Member of Bird Technologies Group

TX RX SYSTEMS INC.

RFI

RFI Systems Technical Training Seminar

TODAY'S PRESENTERS:

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Agenda

Introduction to Multicoupling

- **The Components**
- **Basic Terminology**
- **Multicoupling**
- **Repeater Amplifiers**
- **Rx and Tx Desense**

RF Interference and Solutions

- **TX Carrier and Noise Desense**
- **How much filtering do I need?**
- **Where do mixes occur?**
- **Practical Testing for Intermods**

Multicoupling 101

Solutions . . .

Multicoupler Combiner Systems

Signal Boosters

Duplexers

Filters and Preselectors

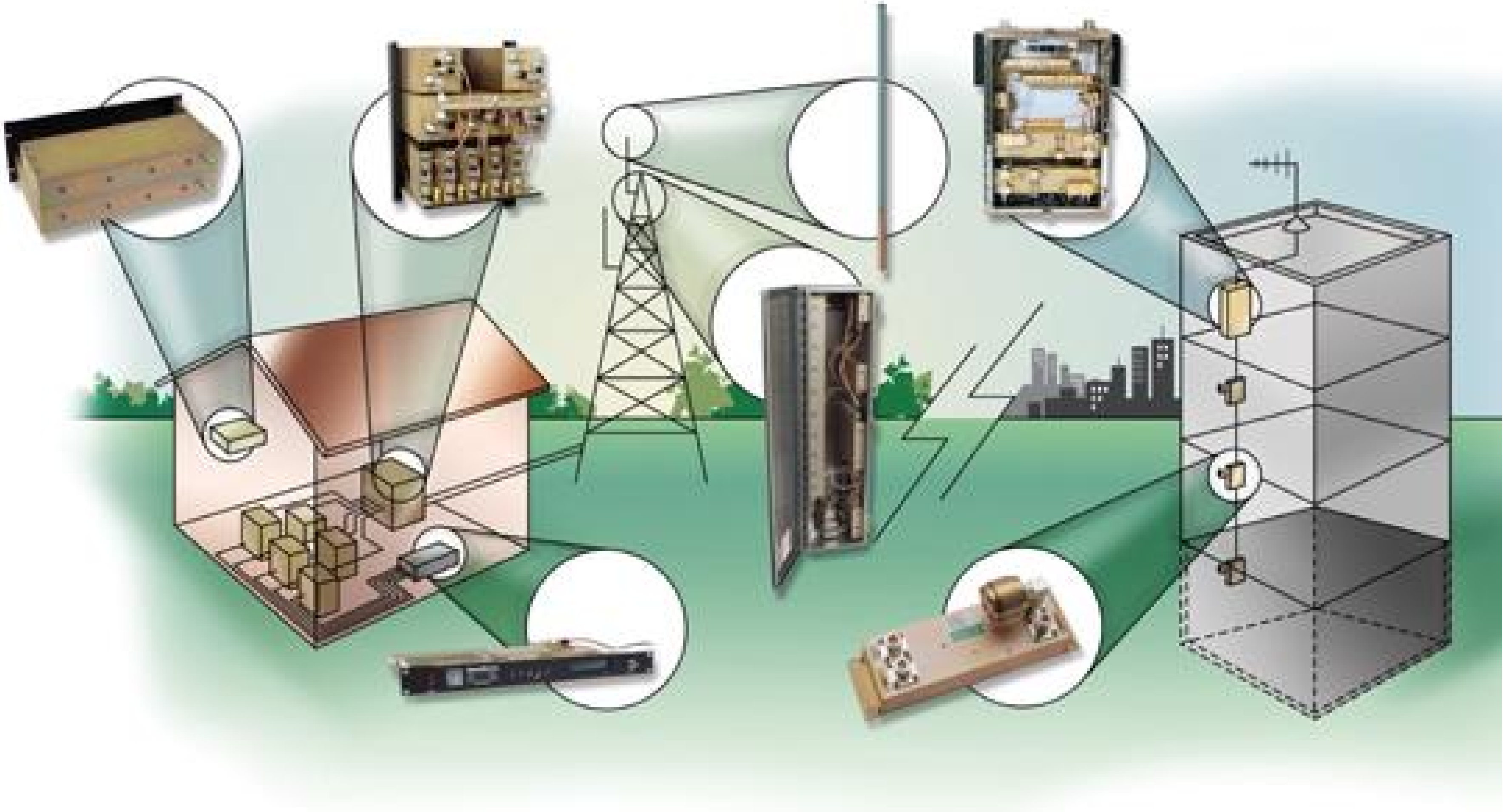
RF System Products

Antennas

Cable & Connectors

Lightning Protection

Energy Products

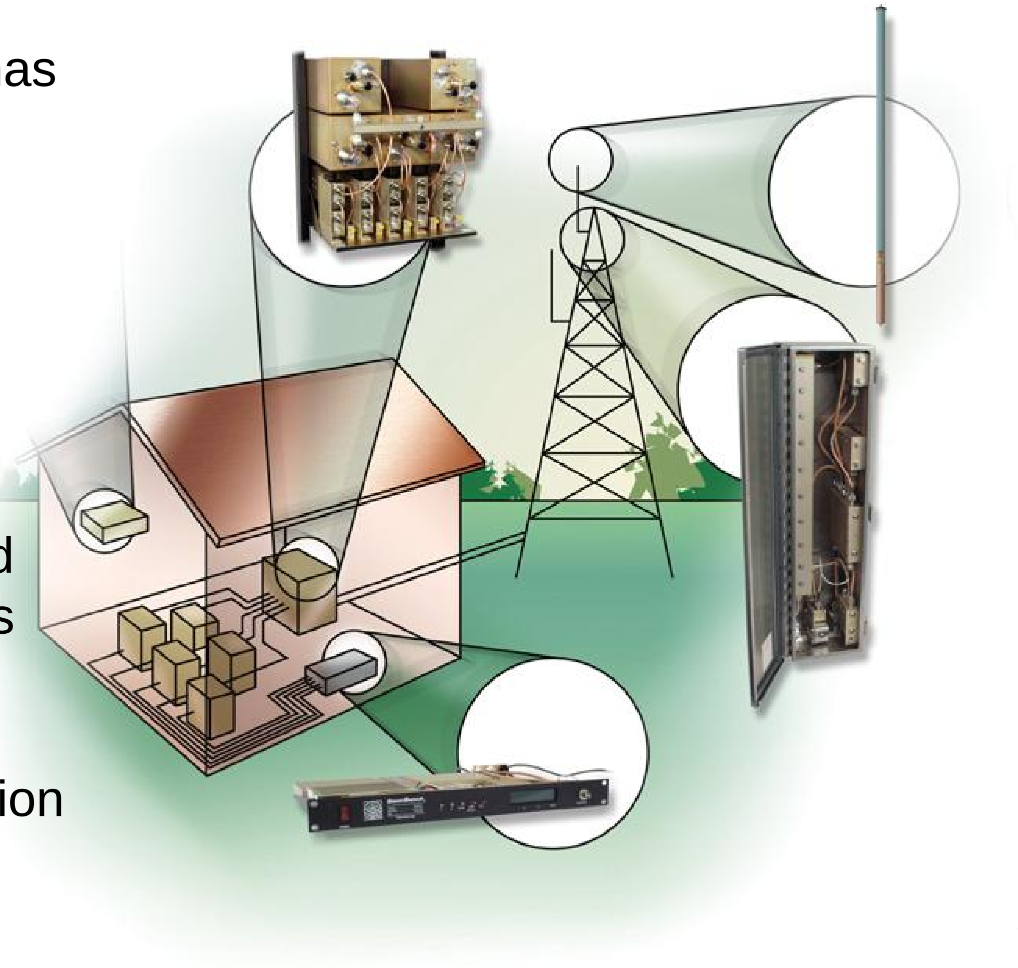


- **Maximize Antenna Site Potential**
- **Improve Coverage**
- **Solve Interference Problems**

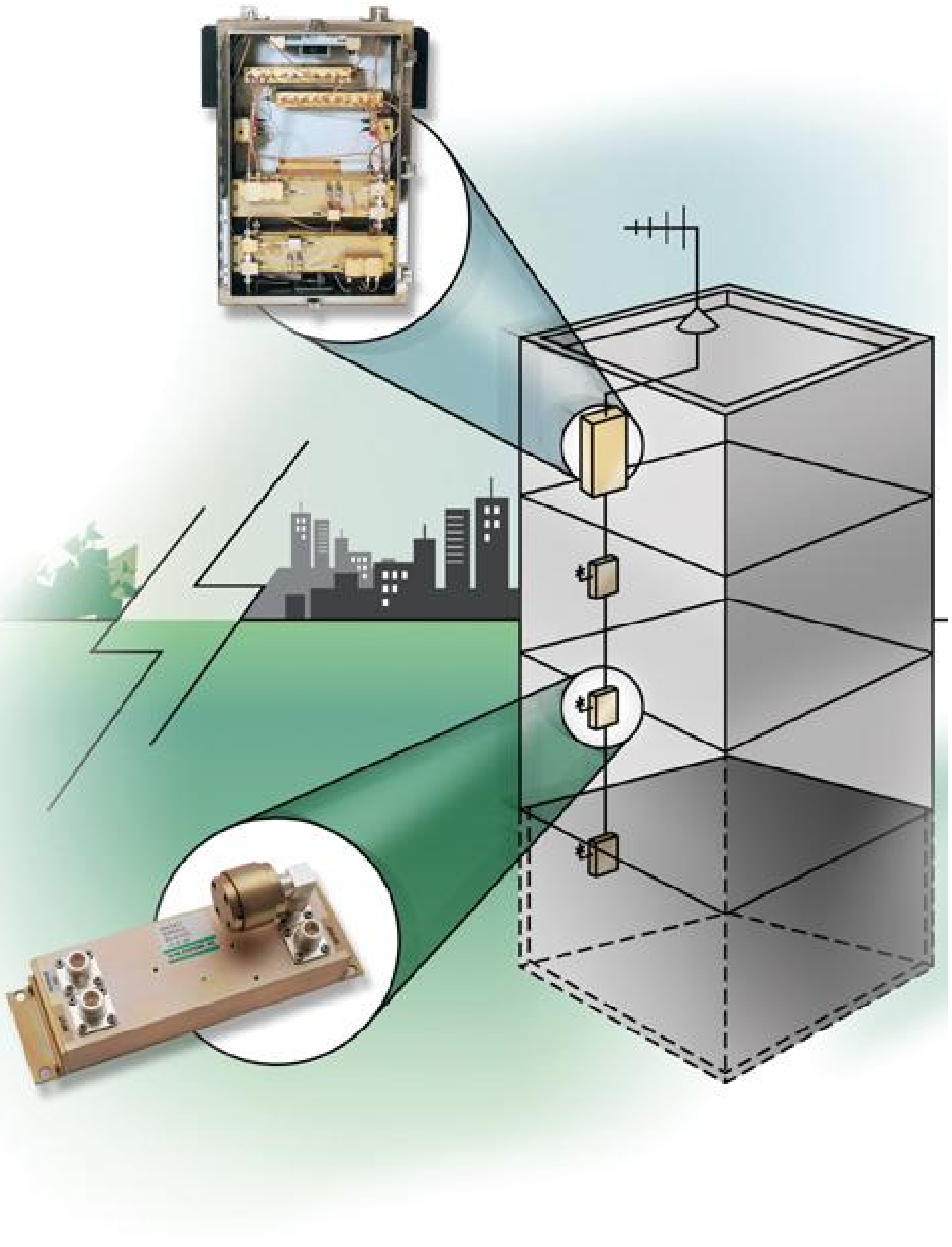
Maximize Antenna Site Potential

• High power broadband Antennas coupled with Transmitter Combiners facilitate combining multiple service bands onto one transmission line and antenna.

• Use of our high performance Preselectors with our broadband Compact Receiver Multicouplers and Crossband Couplers can easily accommodate multiple service bands on one transmission line and antenna.



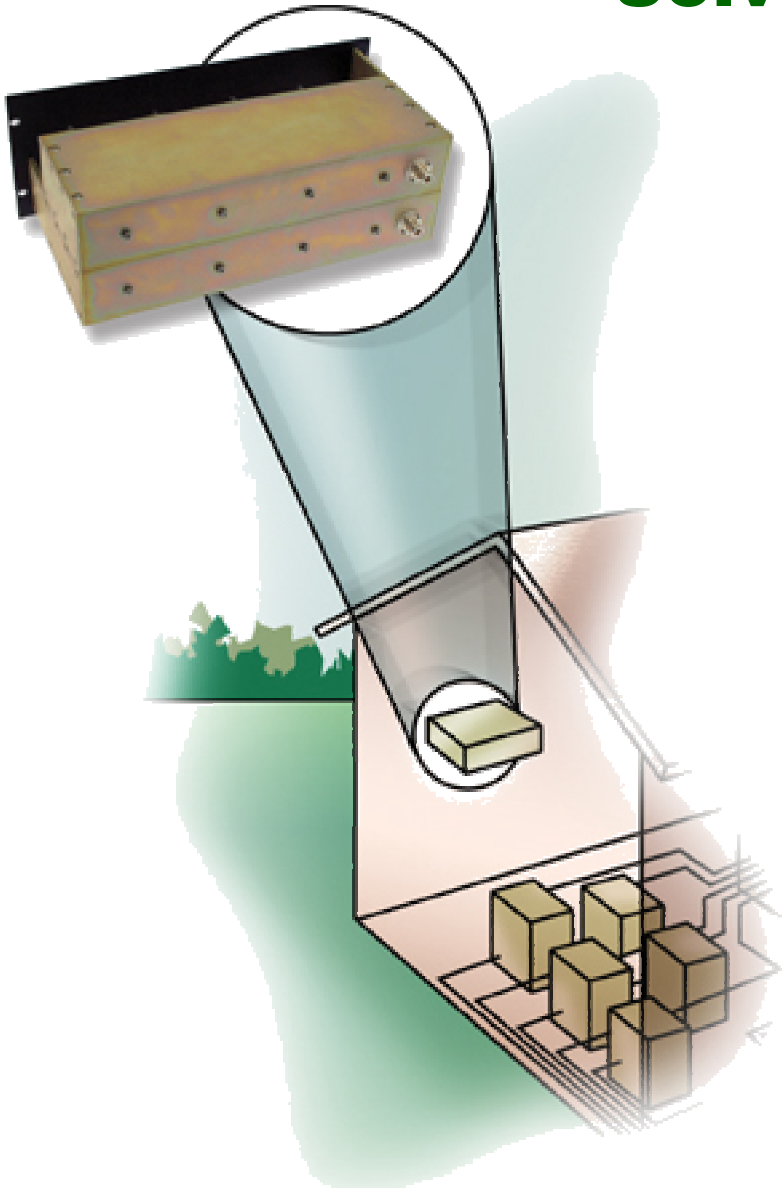
Improve Coverage



- Tower-Top Amplifiers improve receiver sensitivity

- Signal Boosters enable coverage into impenetrable areas - such as tunnels and underground parking.

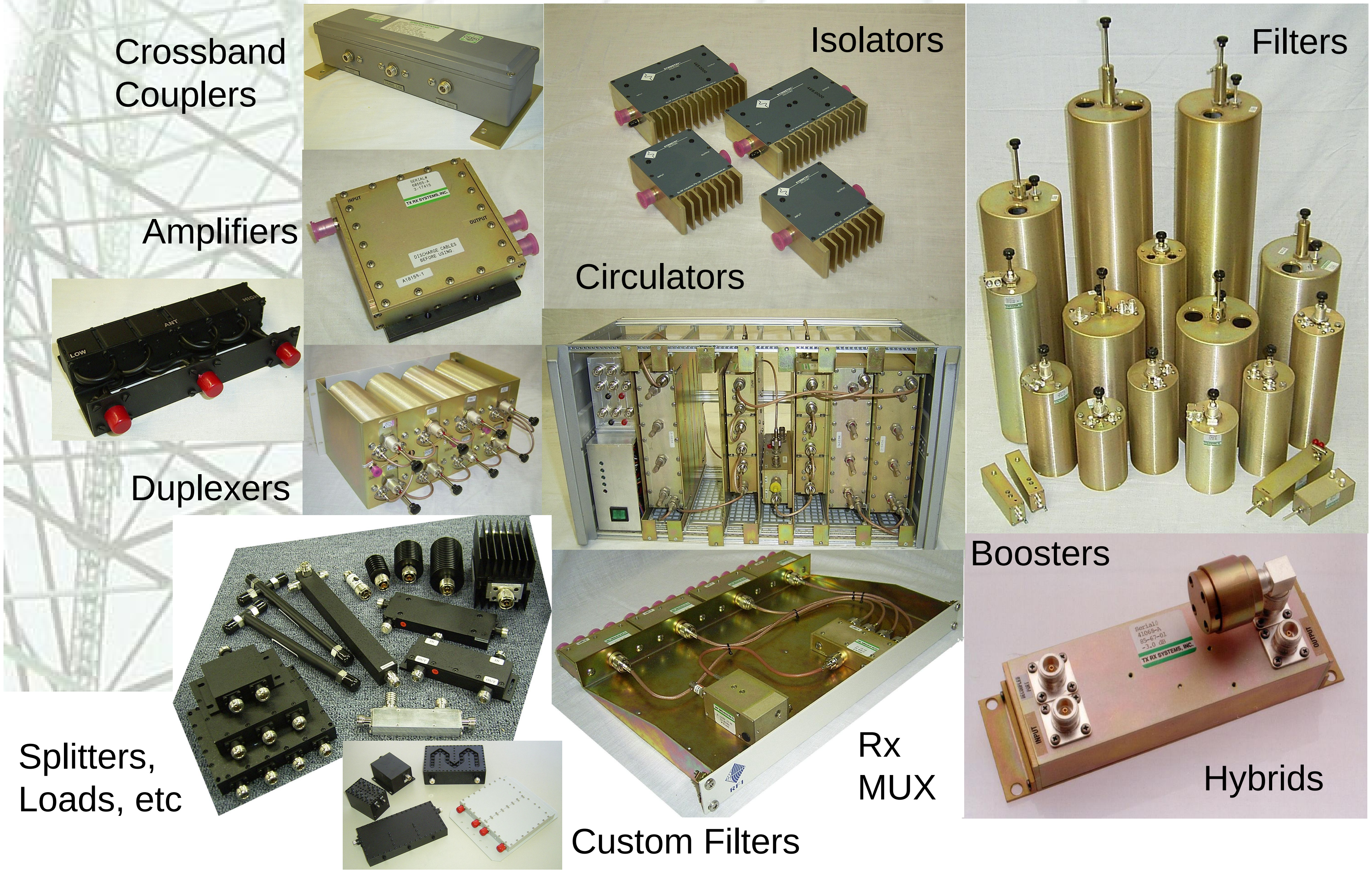
Solve Interference Problems



• Filters, Preselectors, Isolators and other products solve interference problems due to co-location of multiple service providers and highly congested tower sites.

• Excellent electrical performance coupled with superior construction, ensures reliability over a number of environments.

Components


Crossband Couplers
Amplifiers
Duplexers
Isolators
Circulators
Filters
Boosters
Hybrids
Splitters, Loads, etc
Custom Filters
Rx MUX

Basic Definitions

Insertion loss

– The loss that the desired signal experiences traveling through an RF filter at the center frequency

Attenuation

– The loss (isolation) non-desired frequencies experience through an RF component outside the filters 3 dB passband

Response

– General characteristics of frequency Vs. attenuation

Return Loss (VSWR)

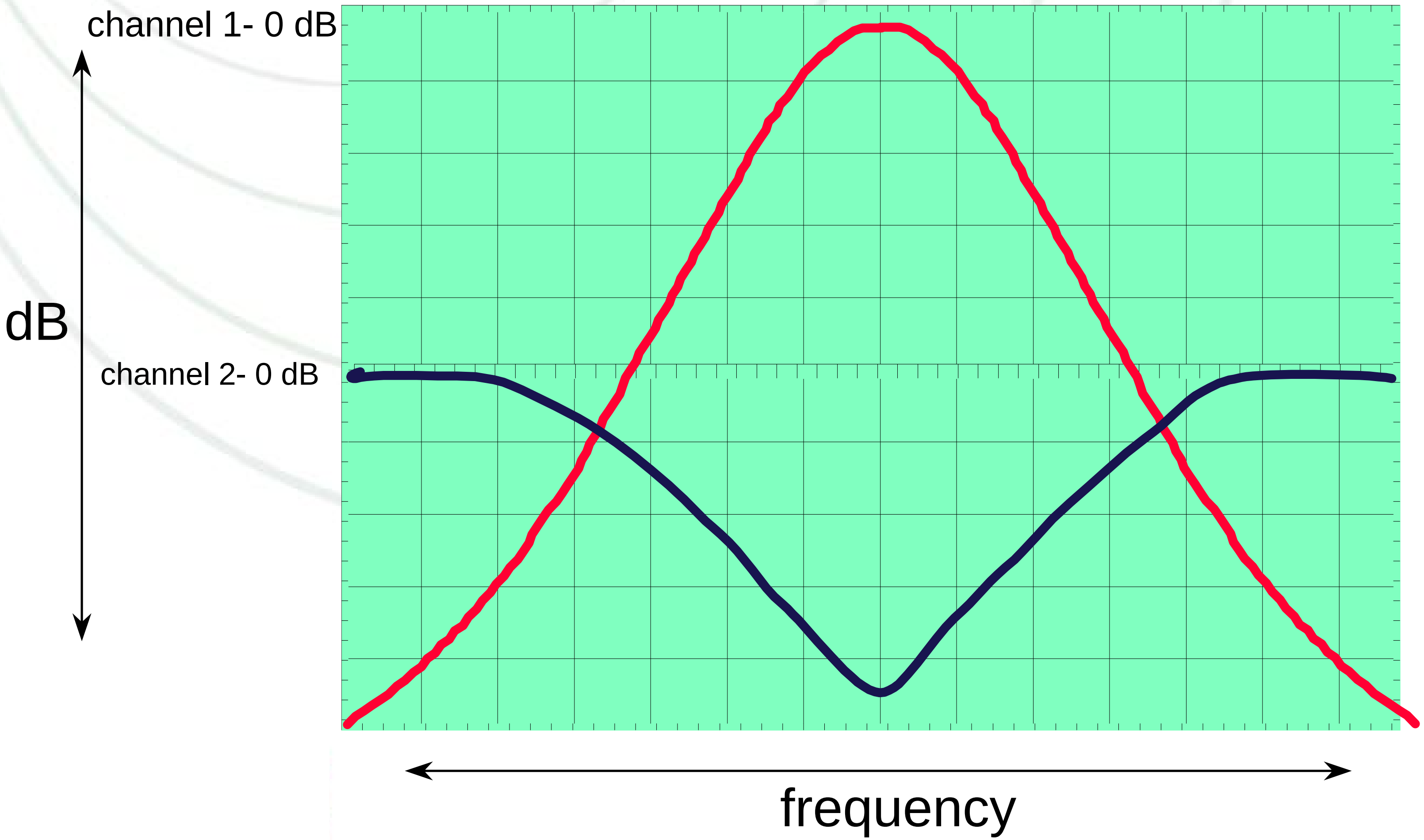
– Defines the degree of impedance match seen looking into a device. This is based on a nominal impedance of 50 ohms.

- – RL = 10 log P_i / P_r
- – if Incident power (Pi) = 100 watts
- – and Reflected power (Pr) = 10 watts
- – and log (100 / 10) = 1
- – then RL = 10 * 1 = 10 dB

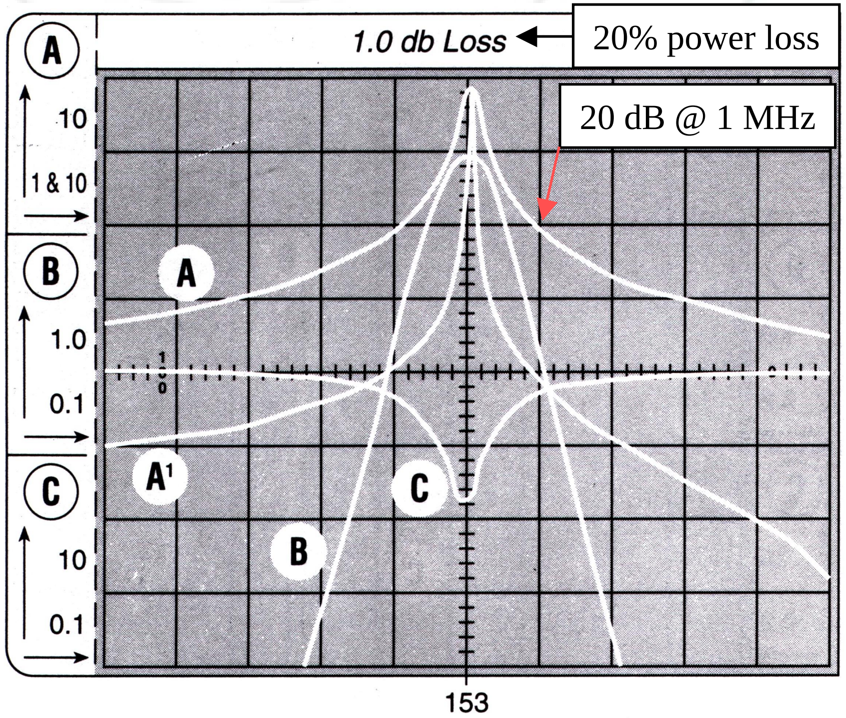
Bandpass Filters

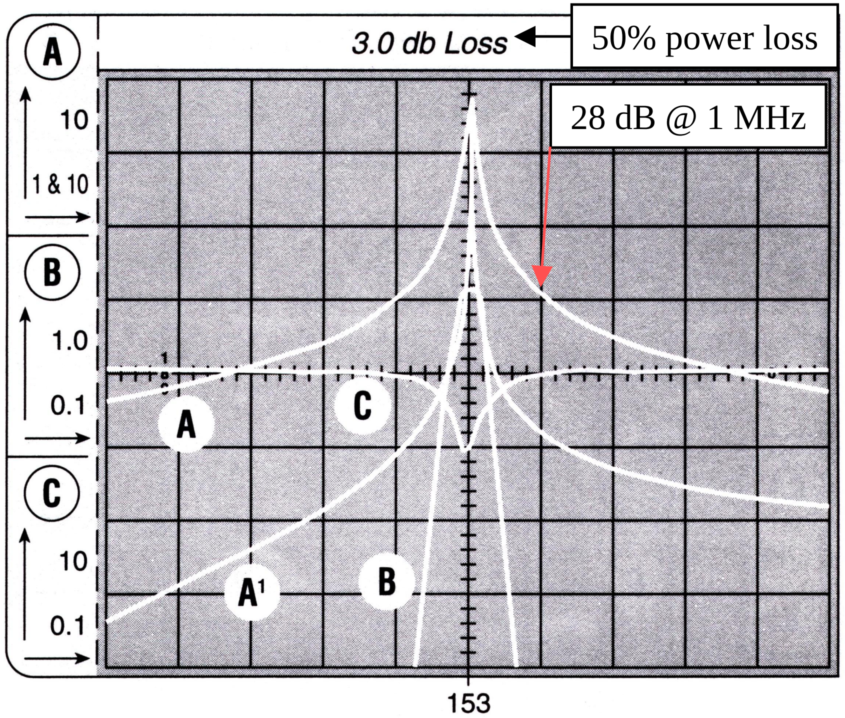
- Most commonly used filter type
- Excellent general purpose filter
- Near symmetrical response (roll-off) outside center frequency
- High power handling capability
  - function of insertion loss (field coupling)
- “Relatively” narrow bandwidth (150 kHz)
  - as determined by 20 dB return loss
- Multiple units in series make wide-window filters (preselectors)

Bandpass Response



Bandpass Cavities





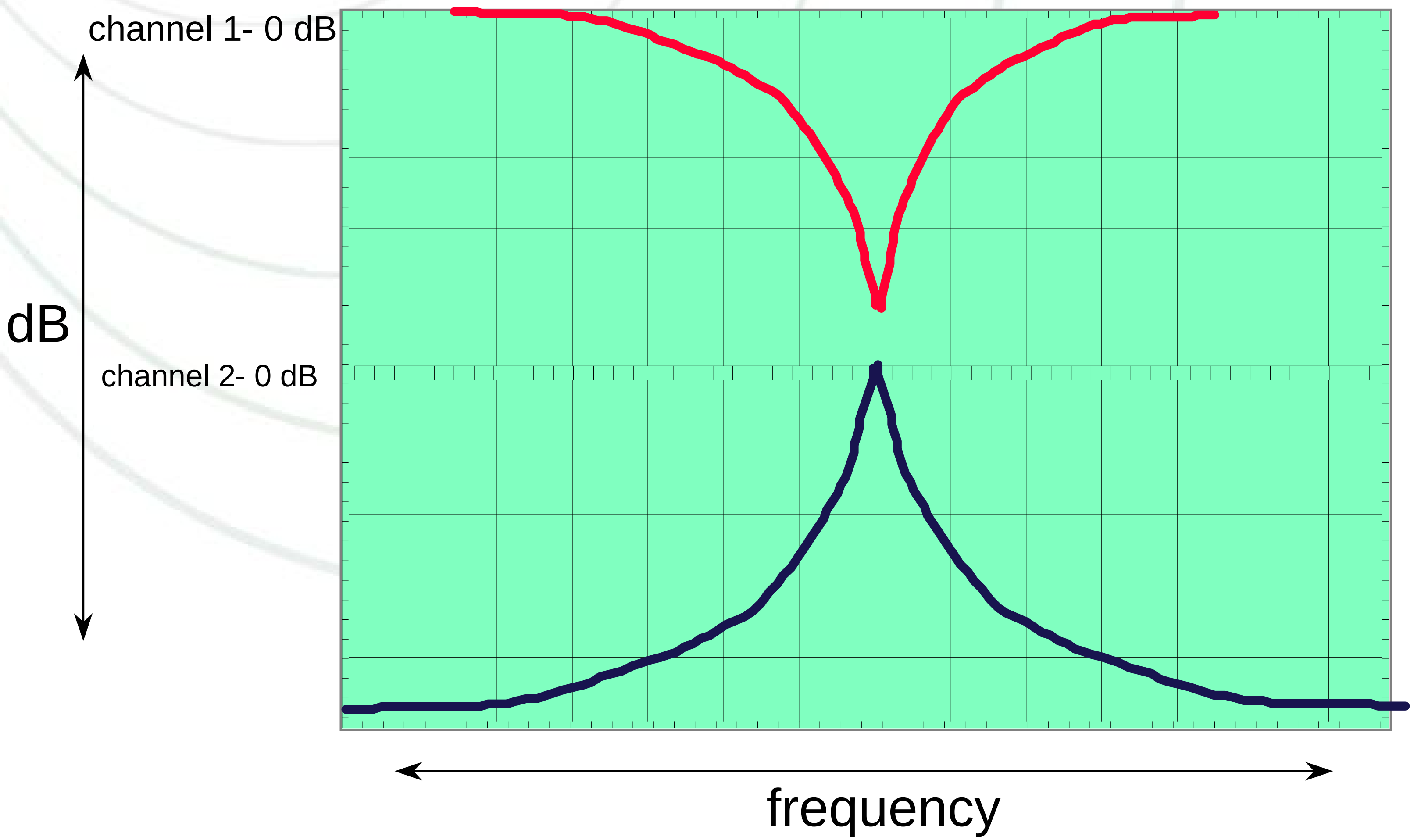
- A = broadband isolation
- B = expanded passband
- C = return loss (VSWR)

- Most desirable response
- But Higher loss

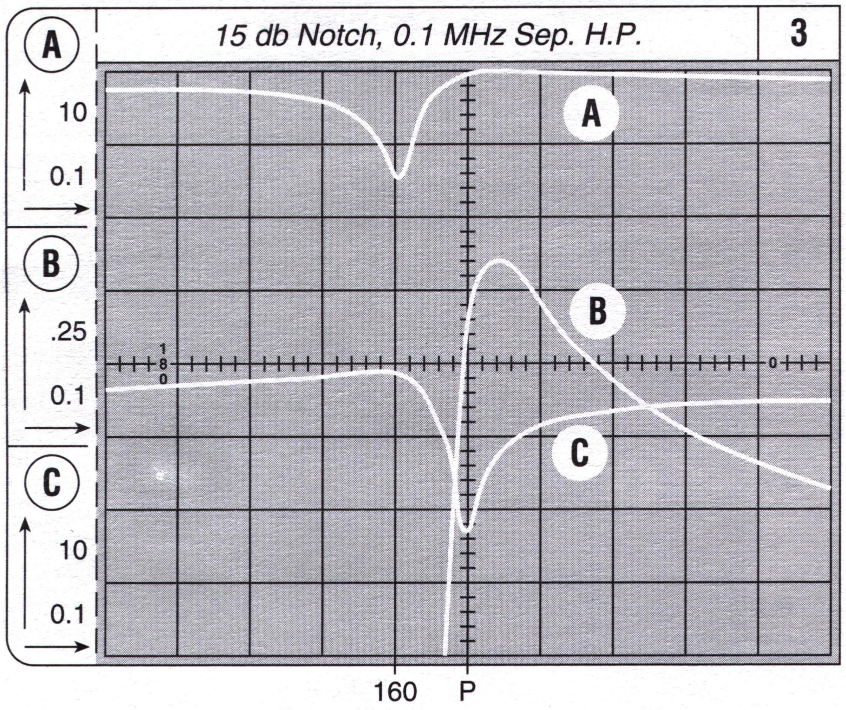
Notch Filters

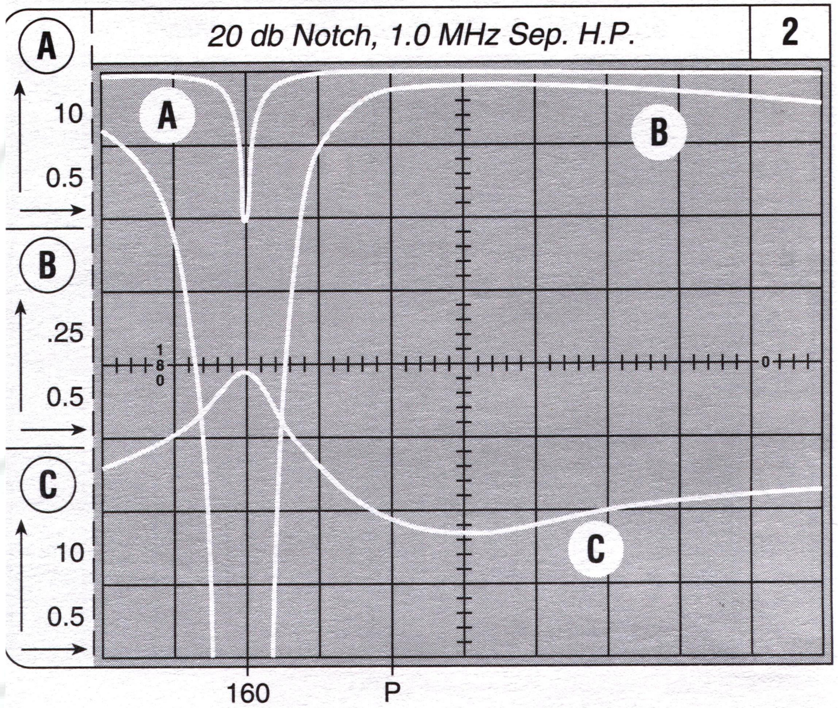
- Application specific filter
- More effective isolation than bandpass or pseudo-bandpass at close separations
- Near symmetrical passband response outside notch frequency
- High power handling capability
  - function of insertion loss
- “Relatively” narrow notch bandwidth
  - only effective over small frequency range

Notch Response



Series Notch Cavities





- A = broadband isolation
- B = expanded passband
- C = return loss (VSWR)

- Notch can be tuned very close to pass frequency
- Only rejects one frequency
- Very low loss

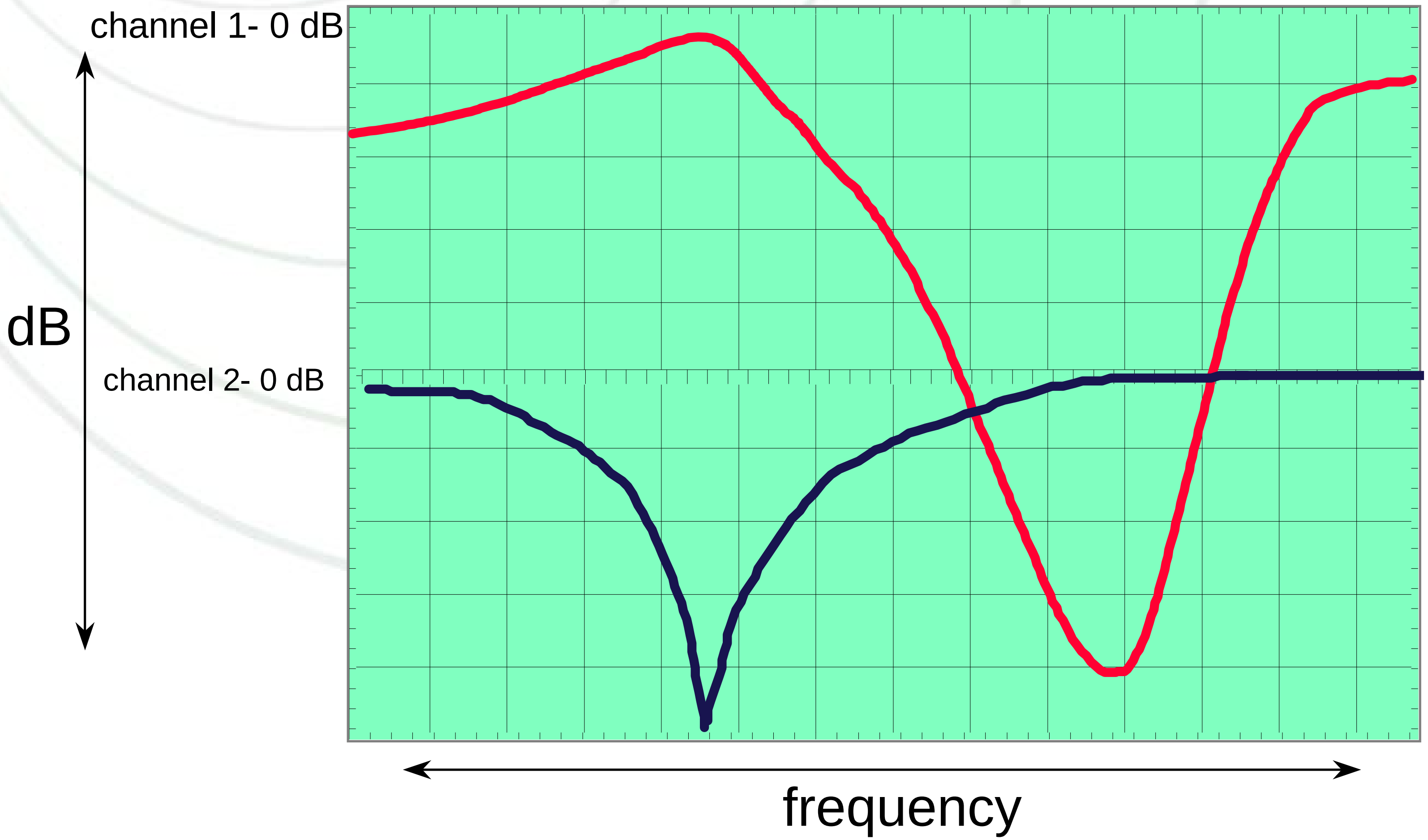
Pseudo-Bandpass (Vari-Notch)

- Application specific filter
- Response characteristic of both bandpass and notch filters
- More effective than bandpass in providing isolation at a specific frequency
- Not as effective as bandpass at providing broadband isolation

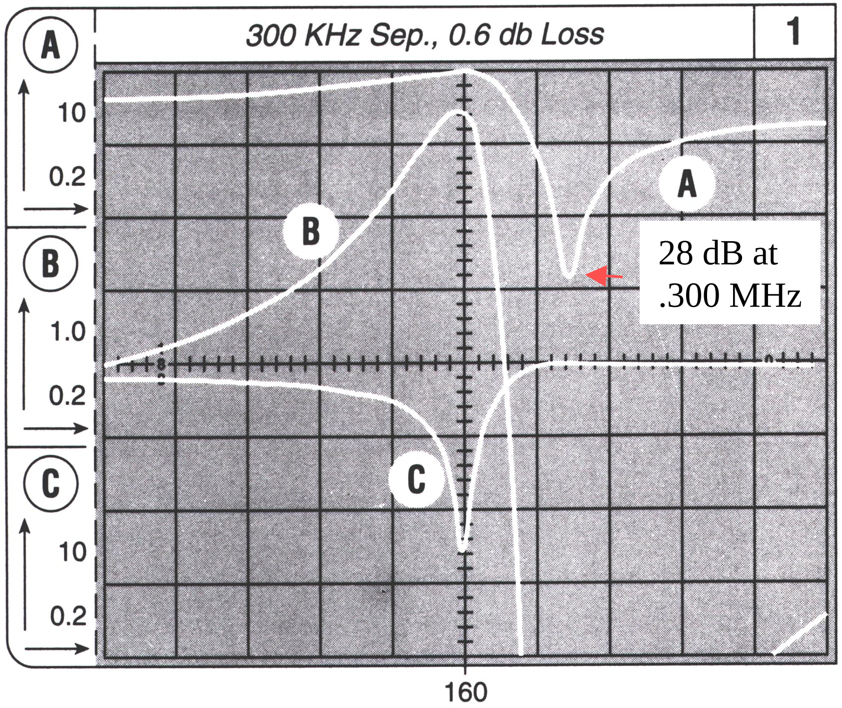
Pseudo-Bandpass (Vari-Notch)

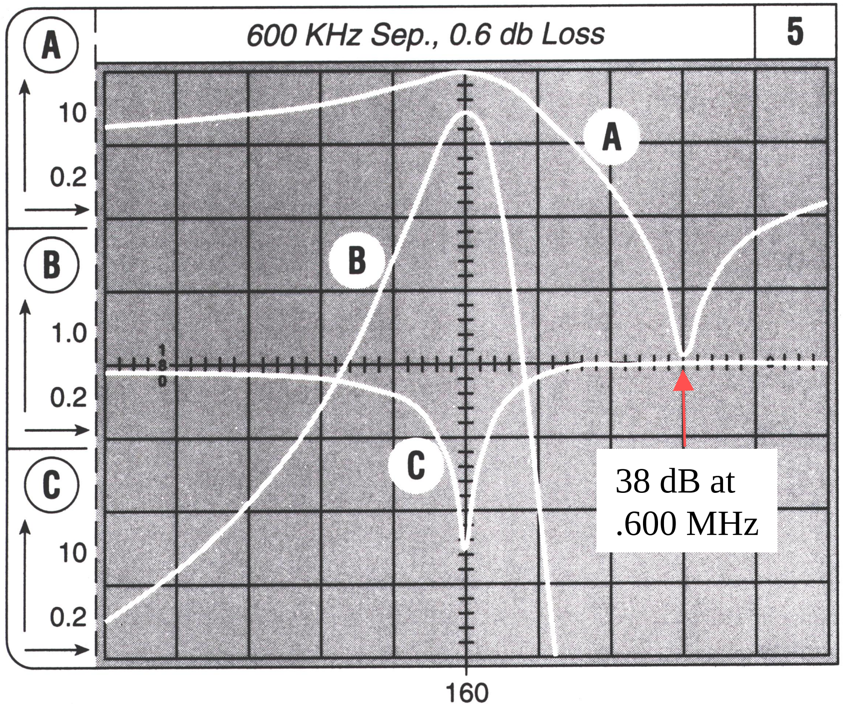
- More effective than notch filter in providing broadband isolation
- Not as effective as notch filter to provide isolation at close frequency separations
- High power handling capability
  - function of insertion loss (field coupling)

Pseudo-Bandpass (Vari-Notch) Response



Pseudo Bandpass (Vari-Notch) Cavities





- A = broadband isolation
- B = expanded passband
- C = return loss (VSWR)

- Close in rejection
- Some bandpass characteristics
- relatively low loss

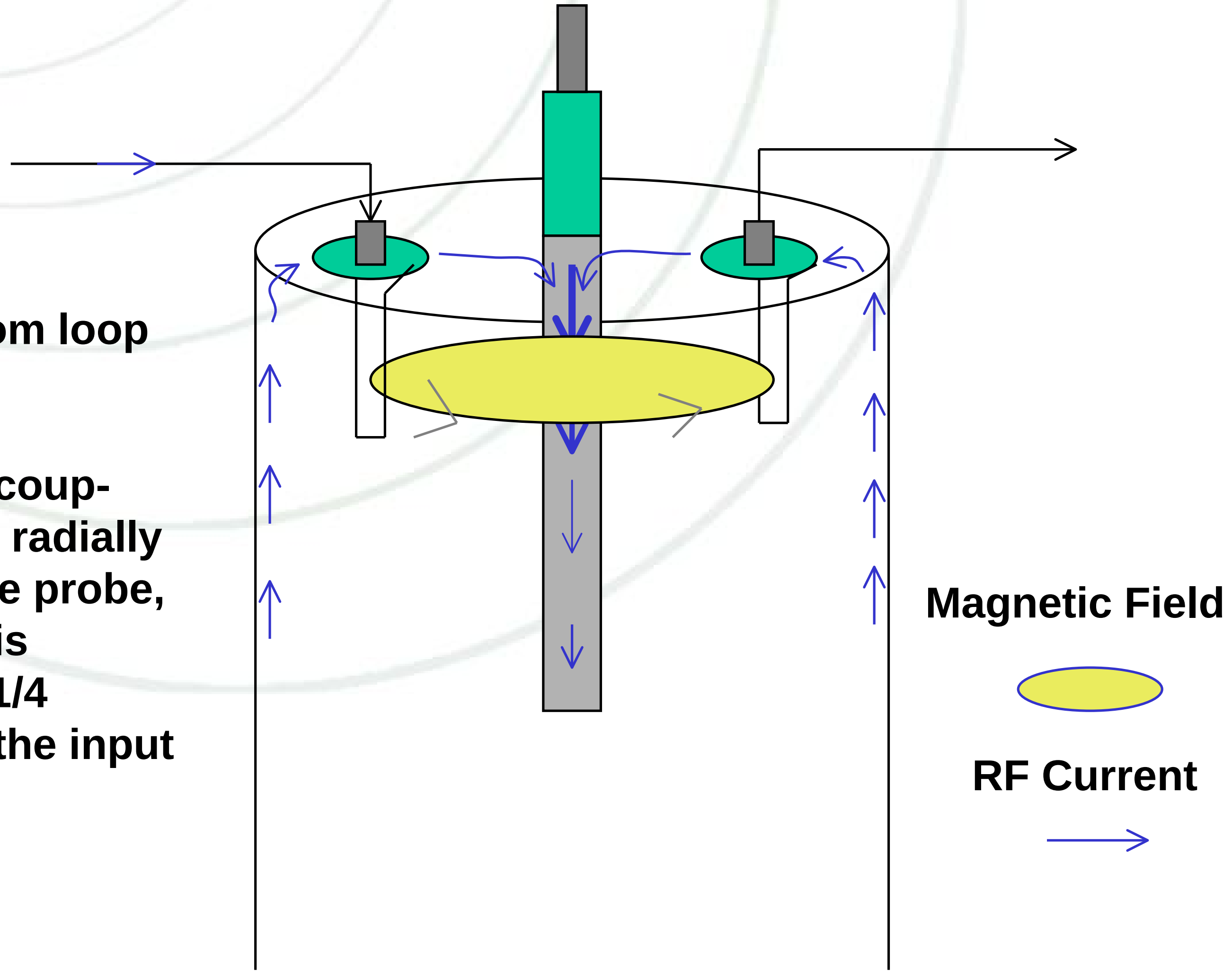
Filter Theory

- Cavity Development
- Fields
- Coupling
- Q Factor

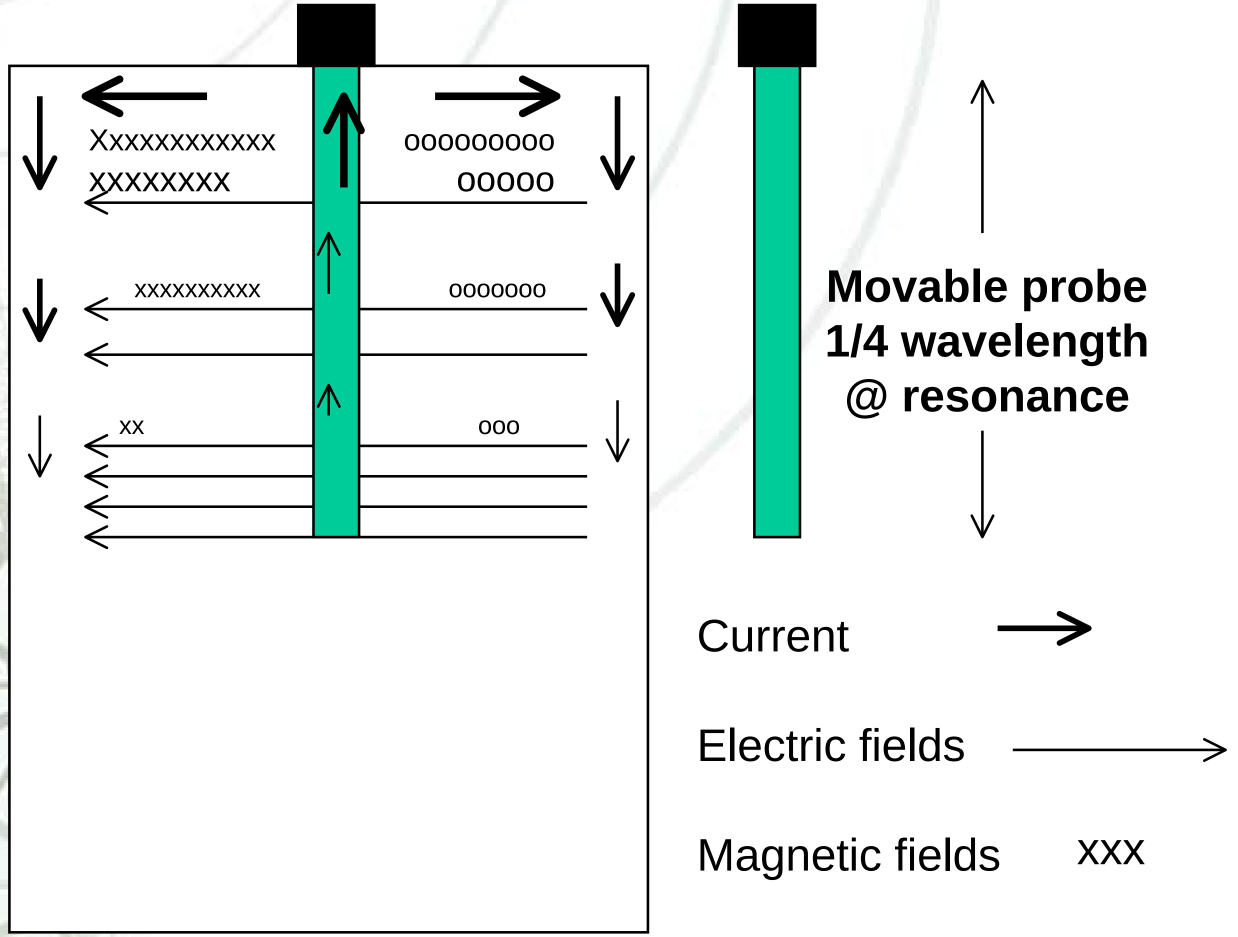
Filter Theory - Cavities

•Coupling to/from loop is magnetic.

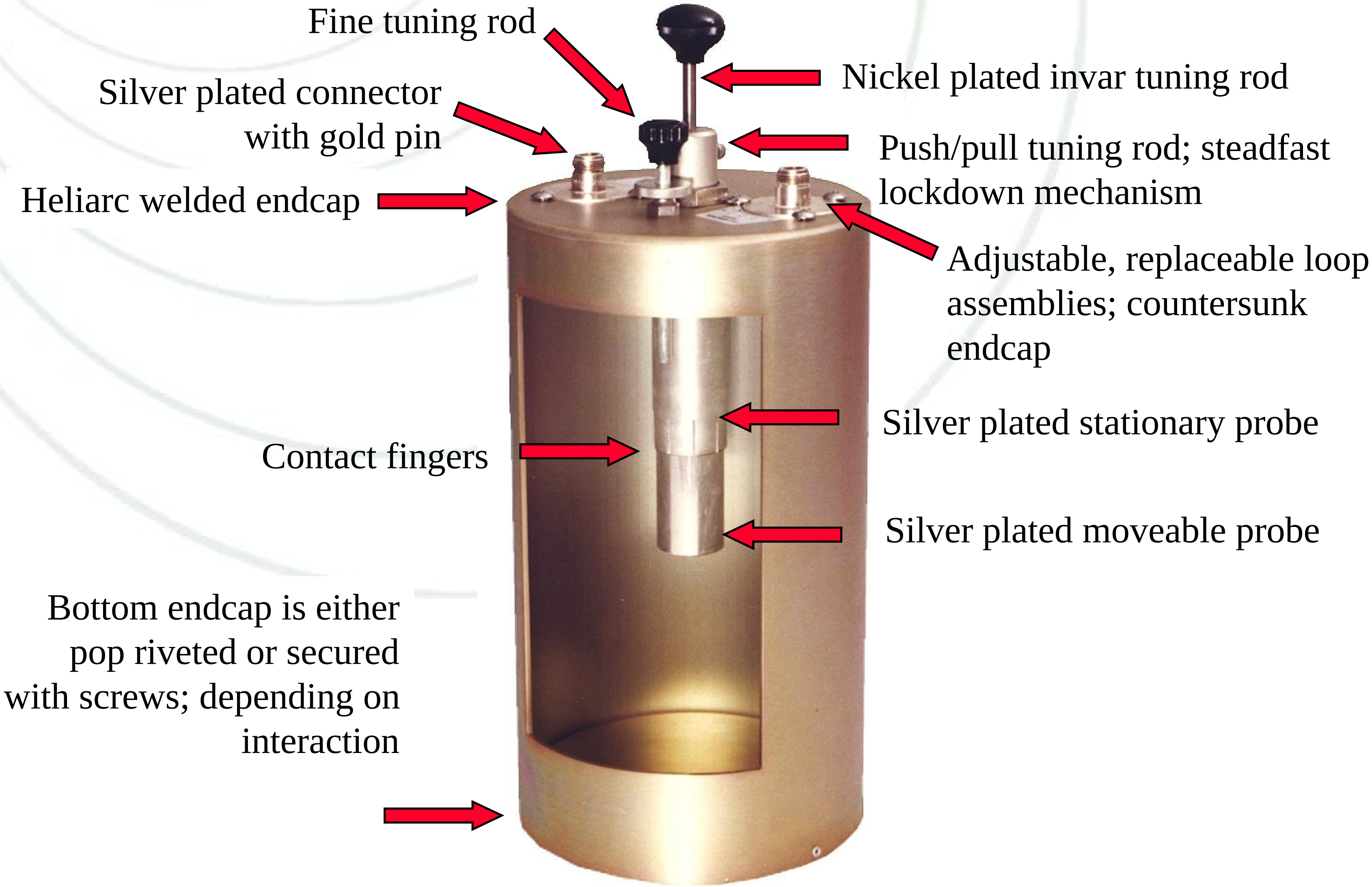
•For maximum coupling the loop is radially aligned with the probe, and the probe is approximately 1/4 wavelength at the input frequency.



Filter Theory - Cavities



Cavity Construction



Cavity Construction

Silver plating

- Maximizes long term conductivity

Gold connector pins

- Minimizes noise and intermod

Probe fingers

- Maximizes contact area between stationary and moveable probes

Heliarc welded endcap

- Maximizes ‘Q’ (cavity efficiency)

Steadfast lockdown mechanism

- Will not change frequency when locked down

Ferrite Isolator Basics

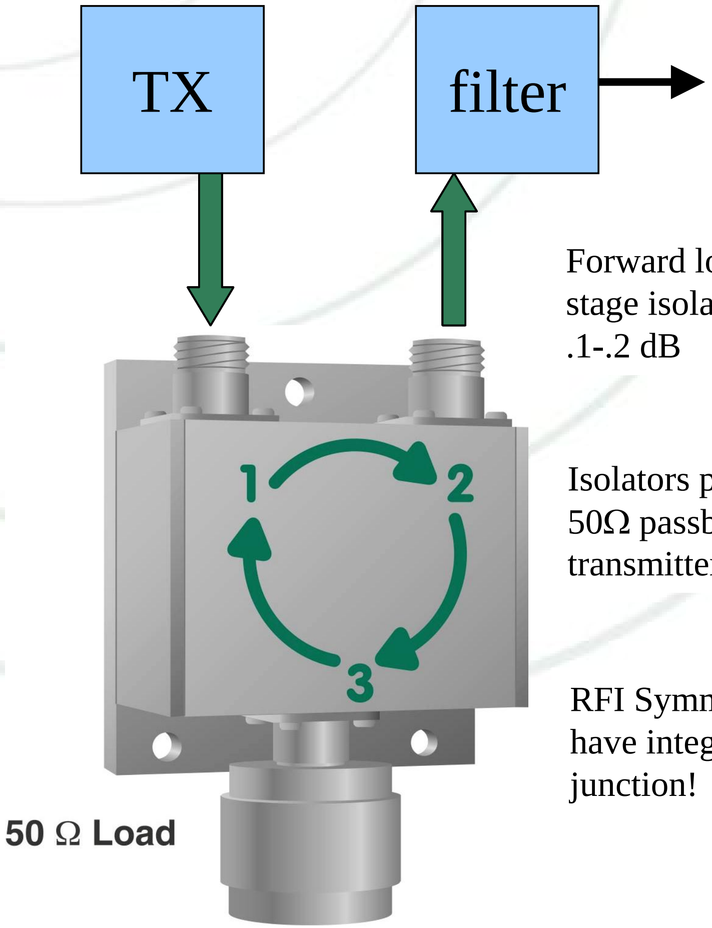
Ferrite Circulators provide directional routing of RF signals

A Ferrite Isolator is a Circulator with one port terminated with a load to absorb the routed signal

Ideally suited to Reverse Power protection for Tx PA Amps or other active circuits

May also be utilised for routing of simplex signals

Forward Direction



To antenna system

Forward loss of a single stage isolator is typically .1-.2 dB

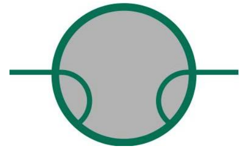
Isolators provide a broad 50Ω passband for the transmitter

RFI Symmetry Isolators have integral LPFs on each junction!

RF entering port 1 has a low loss path to port 2

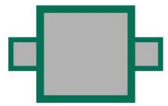
Filters required on output

Bandpass



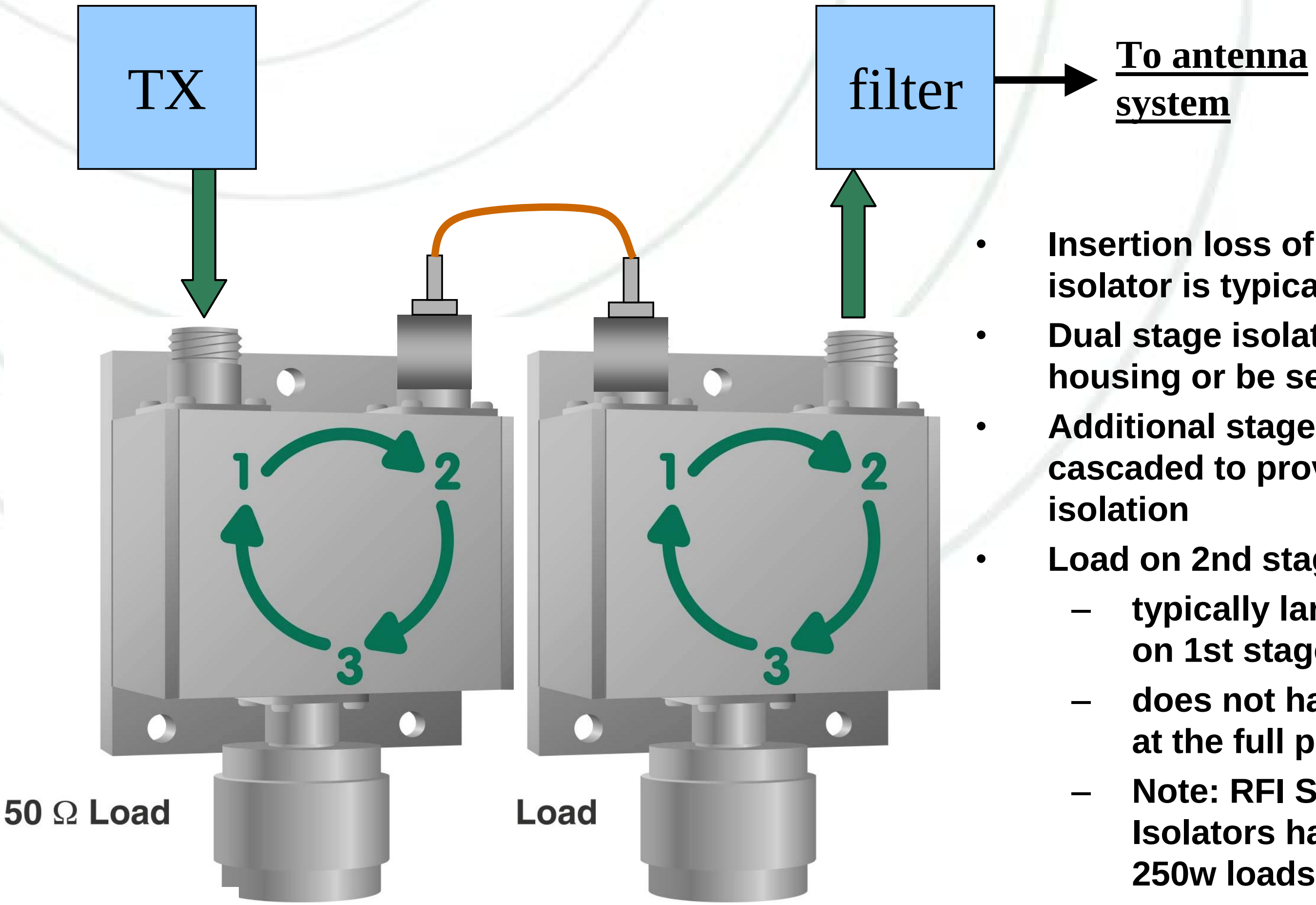
Low Pass

2nd Harmonic Filters



Typical Second Harmonic generated by Isolator is 62 dB below 125 Watts or -11 dBm

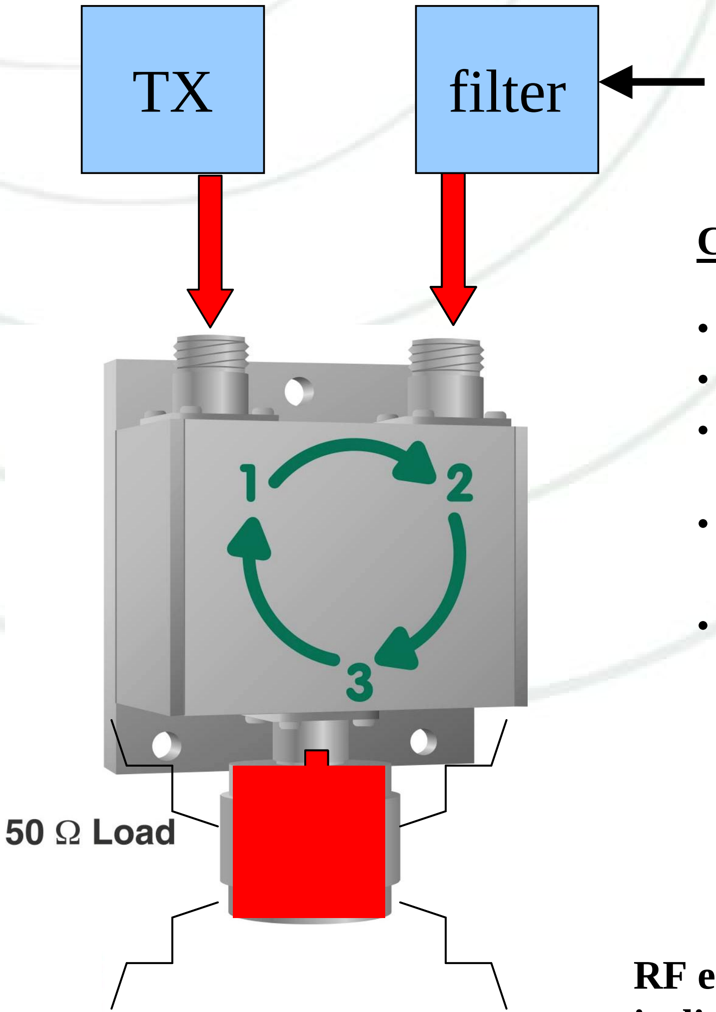
Forward Direction - Dual Stage



- Insertion loss of a dual stage isolator is typically .2-.4 dB
- Dual stage isolators can share a housing or be separate
- Additional stages may be cascaded to provide additional isolation
- Load on 2nd stage:
  - typically larger than load on 1st stage (not shown)
  - does not have to be rated at the full power of the TX*
  - Note: RFI Symmetry Isolators have integral 250w loads

*reflected power does not reach full power of transmitter due to insertion loss of isolator, filter, transmission line, etc.

Reverse Direction



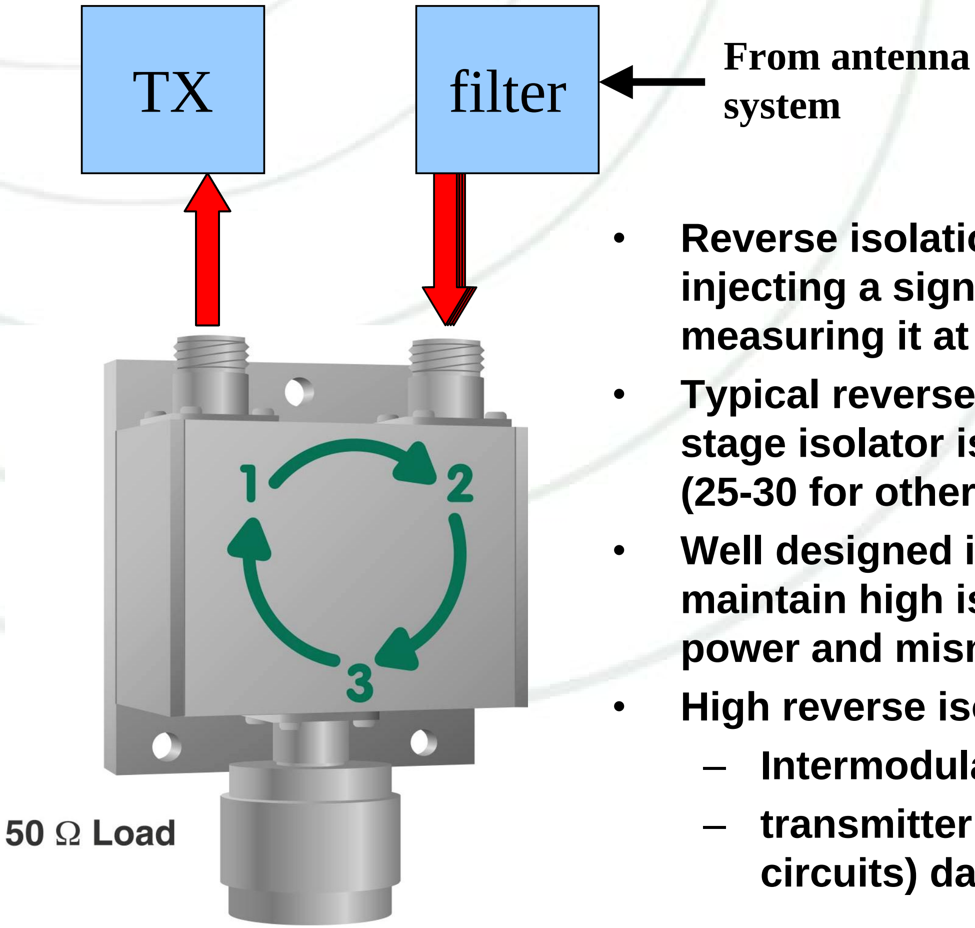
<u>From antenna system</u>

<u>Causes of Reflected Power</u>

- Shorted/Faulty antenna
- Lack of "directivity"
- Coupling (Lack of Isolation) between Tx antennas
- detuned filter
  - cavity drift
- open circuit
  - disconnected cable
  - damaged transmission line

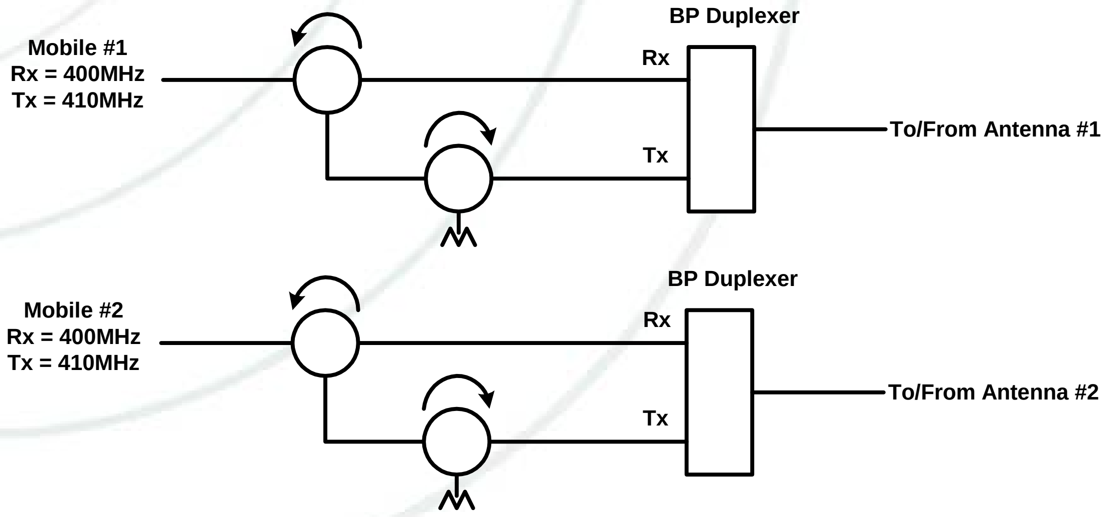
RF entering port 2 flows to port 3 and is dissipated as heat in the load

Reverse Isolation



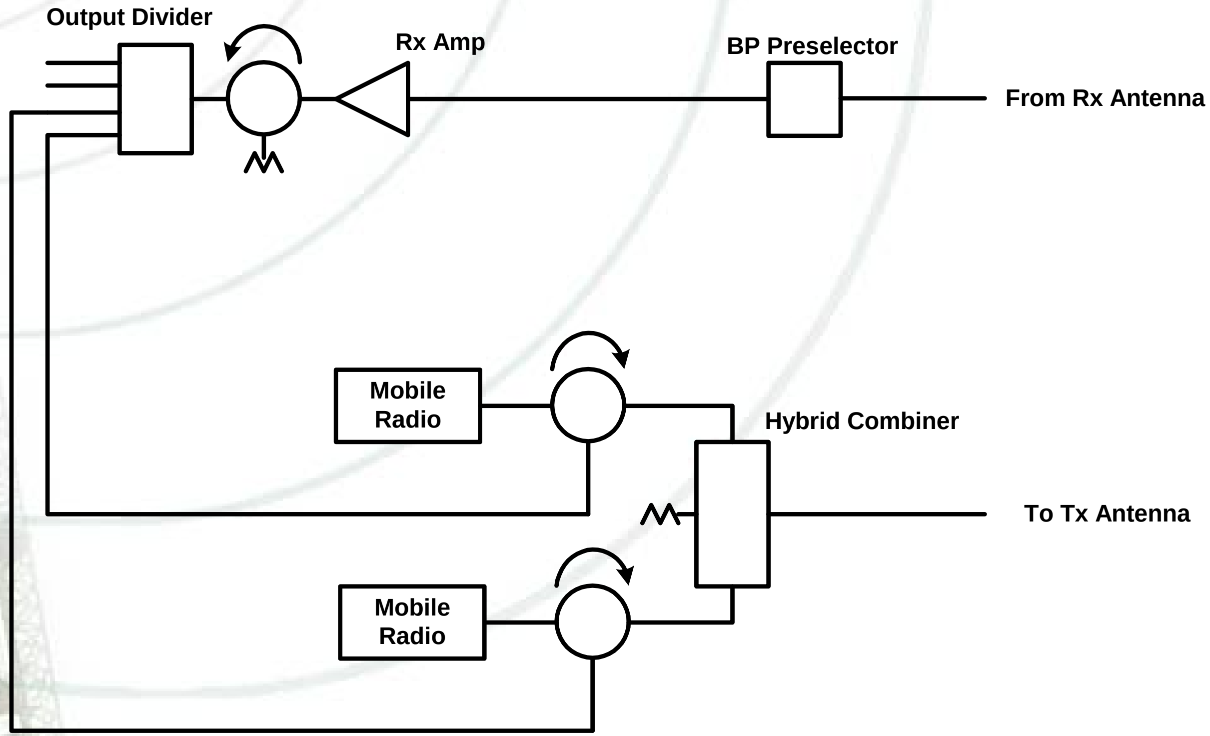
- Reverse isolation is measured by injecting a signal into port 2 and measuring it at port 1
- Typical reverse isolation for a single stage isolator is up to 45dB for RFI (25-30 for others).
- Well designed isolators will maintain high isolation under full power and mismatch conditions
- High reverse isolation minimizes:
  - Intermodulation generation
  - transmitter (or other active circuits) damage

Ferrite Isolator/Circulator Examples



In a close-proximity dual mobile (or trigger link) installation, the combined Isolator/Circulator configuration allows in-band mobile #1's Tx signals to be isolated from mobile #2's Tx/Rx port.

Ferrite Isolator/Circulator Examples



Circulator selectively routes Tx and Rx signal paths from mobile.

Isolator prevents low level Tx signals from entering Rx Amp output port – therefore preventing IM generation.

Multicoupler Systems

Multicoupler Systems

- Allow multiple transmitters and/or receivers to share a common antenna system
- Isolation must be adequate to allow simultaneous operation of all frequencies (the level of isolation required is a function of power levels and frequency separation)
- Can consist of several antenna systems (multiple TX & RX antennas) on high-density sites, or where specific isolations cannot be easily or cost-effectively achieved in multicoupling alone.

Typical Terminology

Multicoupler

- Transmit & Receive multicoupler system on one or several antennas
- Receive multicoupler system including those with Tower Top Amplifiers (TTA)

Combiner

- Transmit multicoupler with ferrite isolators

Advantages

Maximize tower utilization

- Reduces tower loading by minimizing the number of antennas & coaxial cable
- Expandable systems avoid need for tower climb to add additional antennas
- Premium antenna location can be utilized by many users (ie the top antenna spots are enjoyed by all)

Advantages

Minimize interference risk

- Proper multicoupler system is designed to avoid all transmitter noise, receiver desense, and intermod problems
- Bandpass filters used commonly in multicoupler systems to provide carrier suppression against other transmitters, and noise suppression to avoid causing problems for other receivers

System Design Issues

Antennas

- Avoid placing multiple transmitters on the receive antenna whenever possible
- Building tops typically mean horizontal antenna spacing, additional isolation must therefore be provided by the multicoupler system
- Run intermod study to determine frequency computability and number of antennas required
- Antennas should be high quality (low IM) with adequate power handling capability

System Design Issues

Multicoupler

- Should be designed for ALL frequencies; taking into account expansion requirements
  - Minimum TX-RX frequency spacing is NOT the same as the standard spacing. (e.g. 5 MHz at UHF)
- Close proximity frequencies should be taken into consideration
  - Good idea to check out site with spectrum analyzer and filter BEFORE committing to the site
- Tower top amps should be used with caution to ensure sufficient isolation is provided.

System Design Issues

<u>VHF systems</u>

- – Often challenging band plan
- – Potential for extremely close TX-RX spacings
  - Most multicoupler systems are custom designs
- – Lower frequency means separation must be greater between antennas
  - 10-15m tip-to-bottom to get 55 dB
- – Lower frequency means greater cavity efficiency
  - 6" bandpass cavity set at 1.0 dB insertion loss will provide 20 dB isolation at 1.0 MHz

System Design Issues

UHF systems

- Paired services mean standard spacings (usually)
- Watch for close minimum spacings
  - e.g. 461 TX and 459 RX
- Higher frequency means separation can be less between antennas
  - 6-7m tip-to-bottom to get 55 dB
- Higher frequency means lower cavity efficiency
  - 6” bandpass cavity set at 1.0 dB insertion loss will provide 12 dB isolation at 1.0 MHz

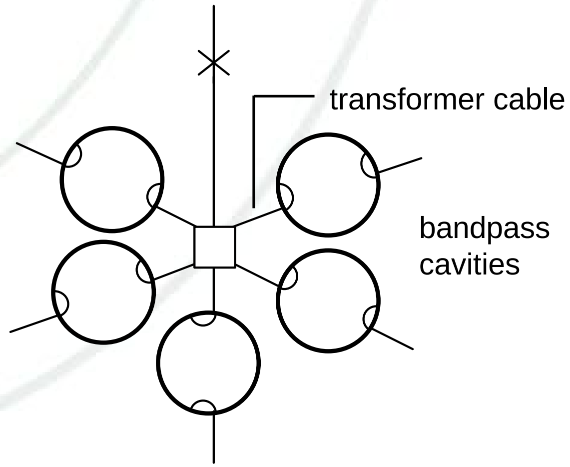
System Design Issues

800/900 MHz systems

- Paired services mean standard spacings
- Watch for cell sites and other services
  - In Australia this is now causing issues (CDMA density in particular)
- Higher frequency means separation can be less between antennas
  - 2-3m tip-to-bottom to get 55 dB
- Use of 3/4 wavelength cavities required
  - 6" bandpass cavity set at 1.0 dB insertion loss will provide 11 dB isolation at 1.0 MHz

Star Junction Multicoupler Issues

- **Common junction requires close proximity of all cavities; problem increases with frequency as cables become shorter.**
- **Expansion may require changing of all transformer cables and re-tuning of multicoupler**
- **Junction transformer cables required; odd multiple of a quarter wave at <u>mean of all frequencies.</u>**
- **Such averaging limits combiner bandwidth to approx 40MHz – ie such as 400-440MHz (even less as reasonable Return Loss values!)**

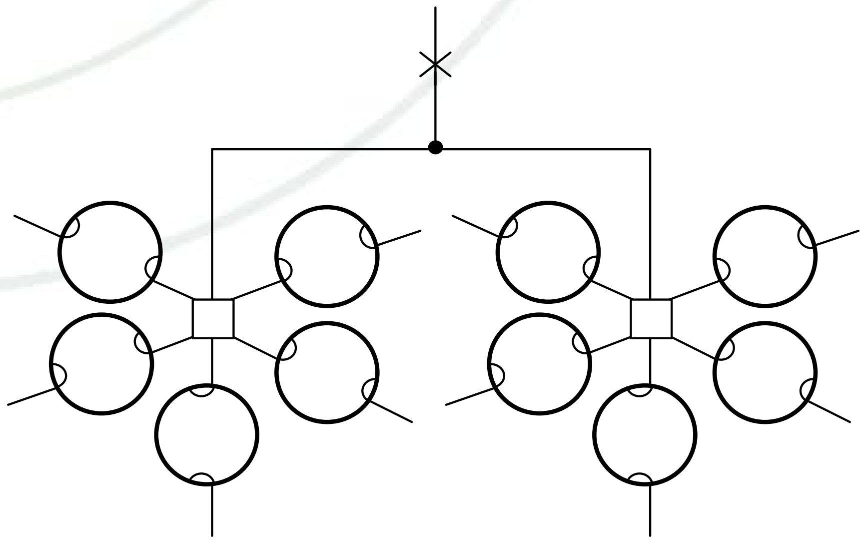


RFI <u>does</u> manufacture and <u>will</u> supply Star Junction Combiners

Star Junction Multicoupler Issues

The Problem?

Significant increases in number of channels requires multiple stars, therefore increasing the number of joints, insertion losses, mechanical mounting difficulties, and the risk of intermod.

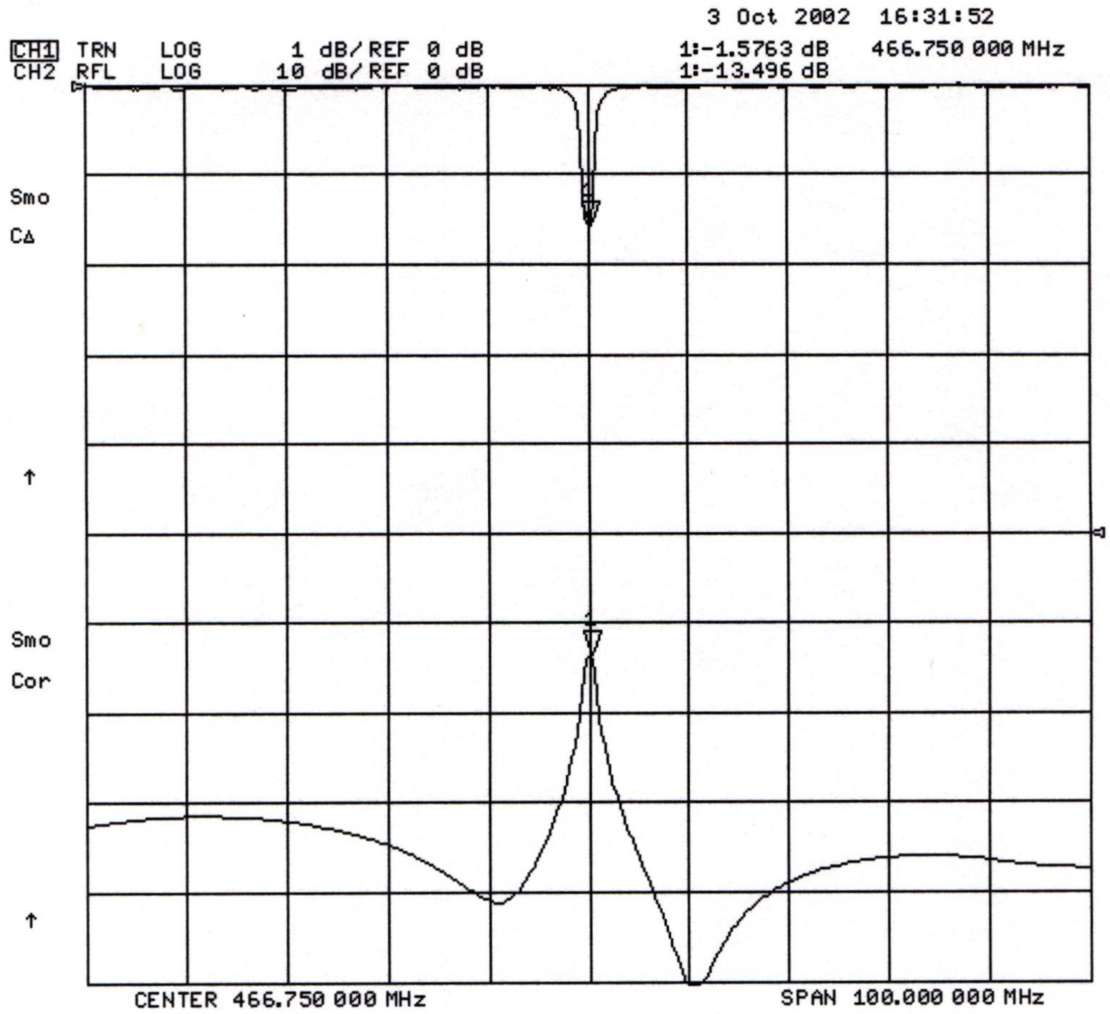


RFI <u>does</u> manufacture and <u>will</u> supply Star Junction Combiners
But why would you want one?

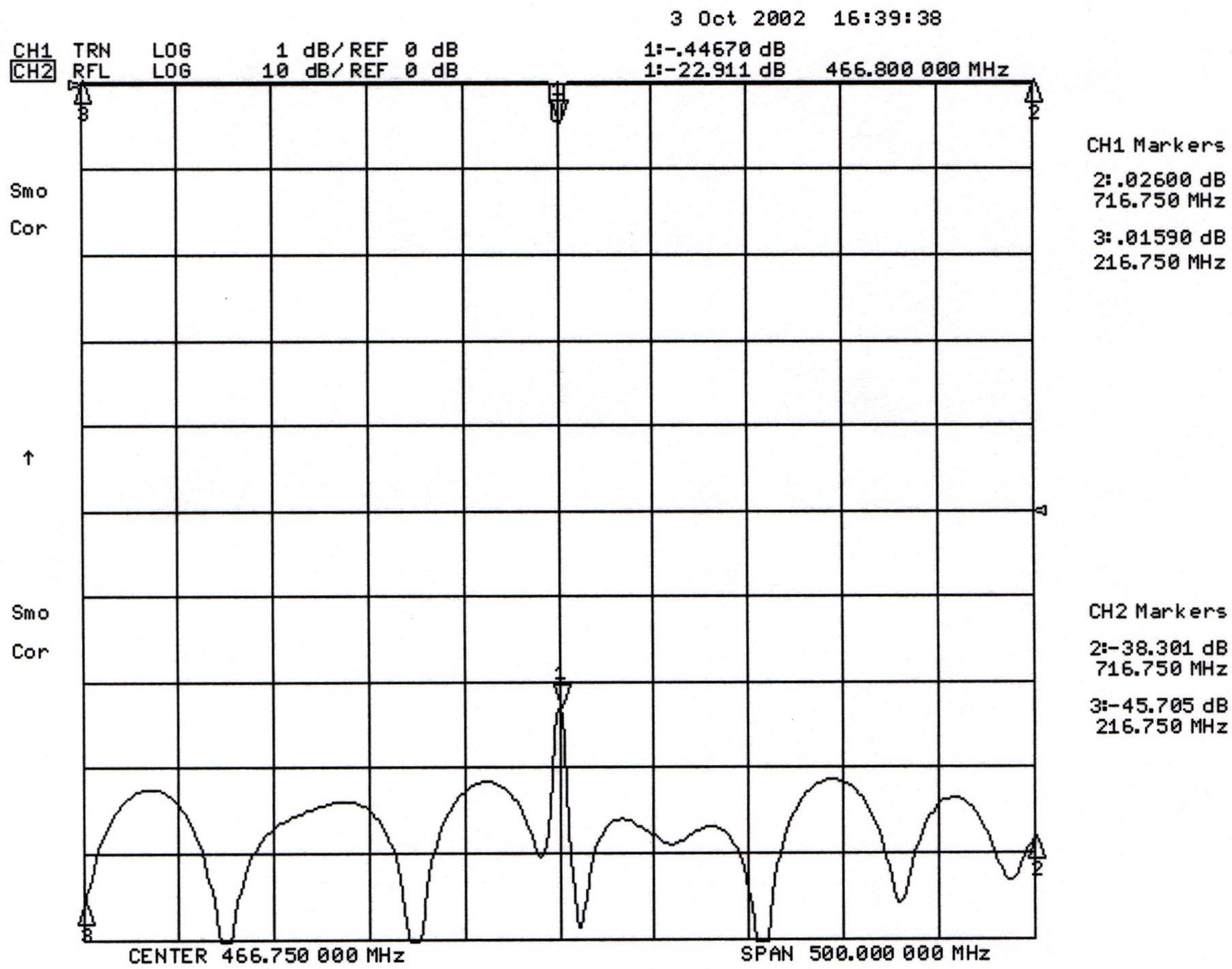
T-Pass to the Rescue

- Extremely broadband capability
  - 66-88 MHz
  - 88-108 MHz
  - 108-150 MHz
  - 132-174 MHz
  - 168-250 MHz
  - 220-300 MHz
  - 300-400 MHz
  - 400-550 MHz
  - 740-1000 MHz
- Multiple bands (ie VHF/UHF/800MHz) CAN be placed onto the one combiner – ideal for radiating cable or crossband coupler-based antenna networks.
- “Series” combining allows many channels to be combined to one antenna

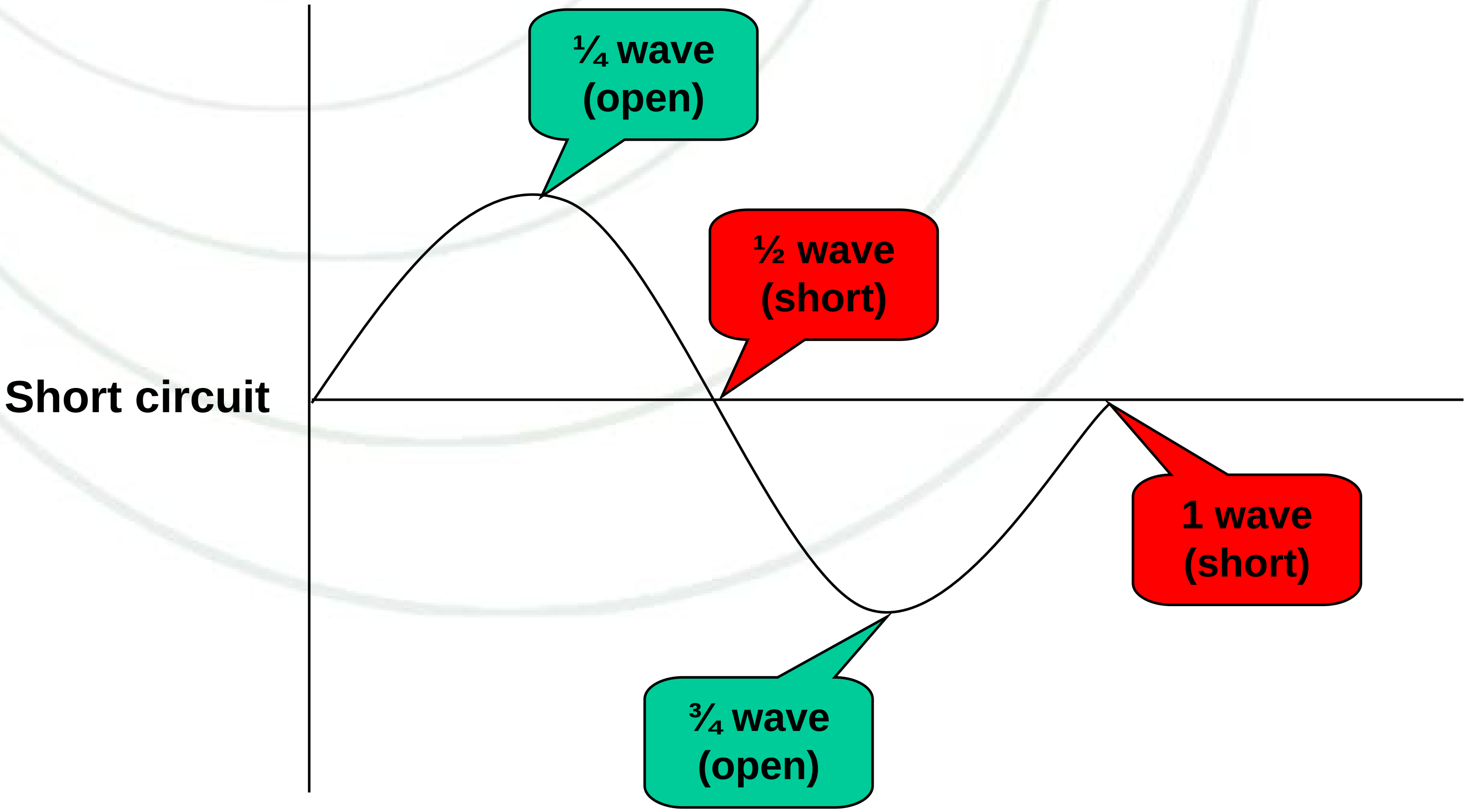
T-Pass at 100 MHz Span



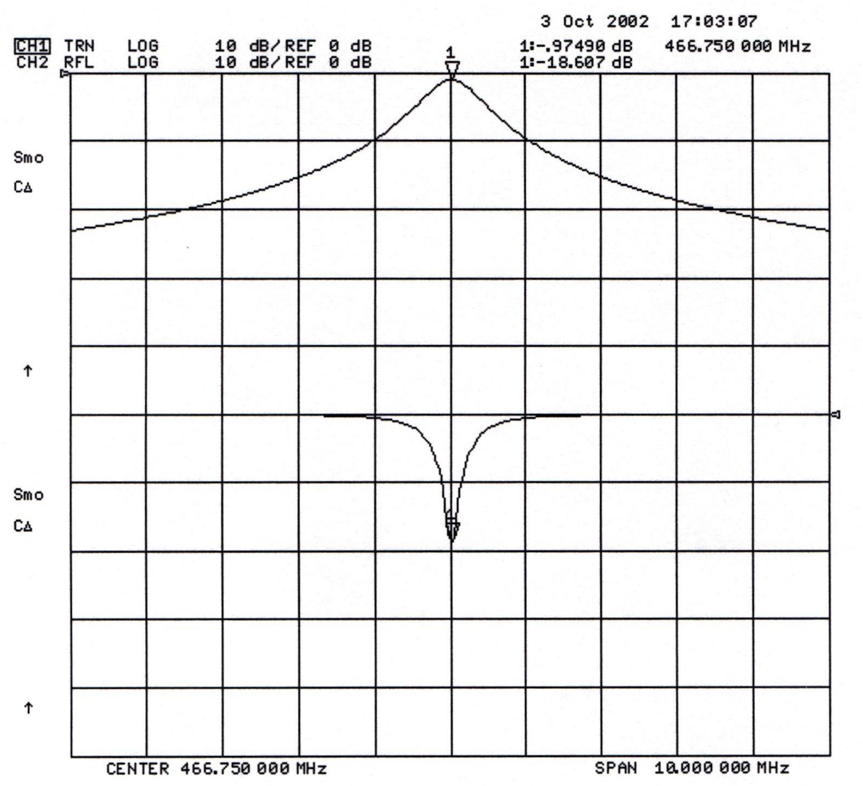
T-Pass at 500 MHz Span

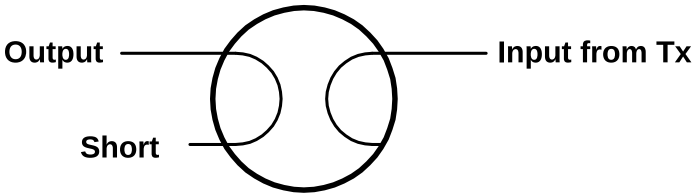


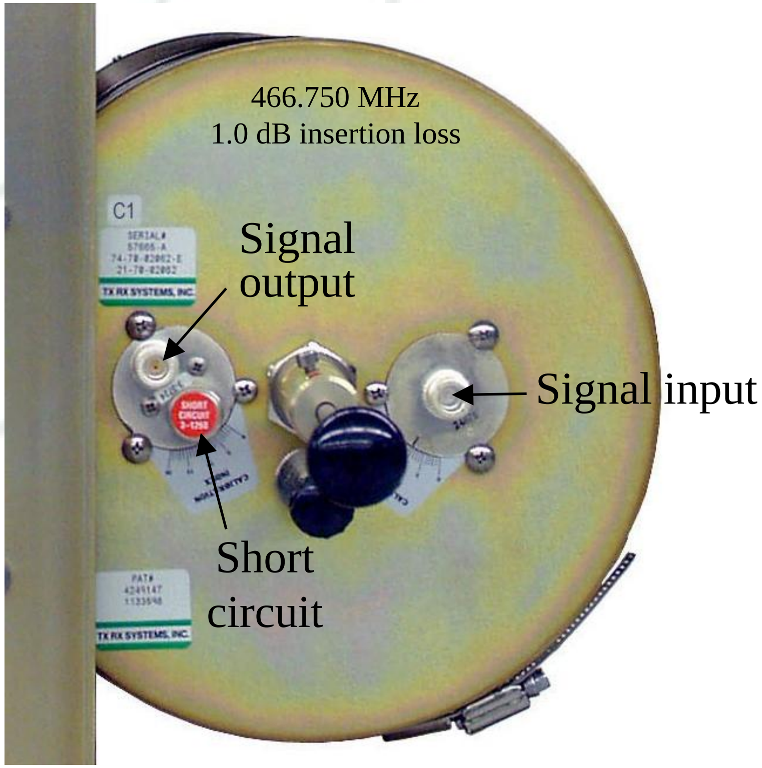
Multiple ½ wave T-Pass Cabling



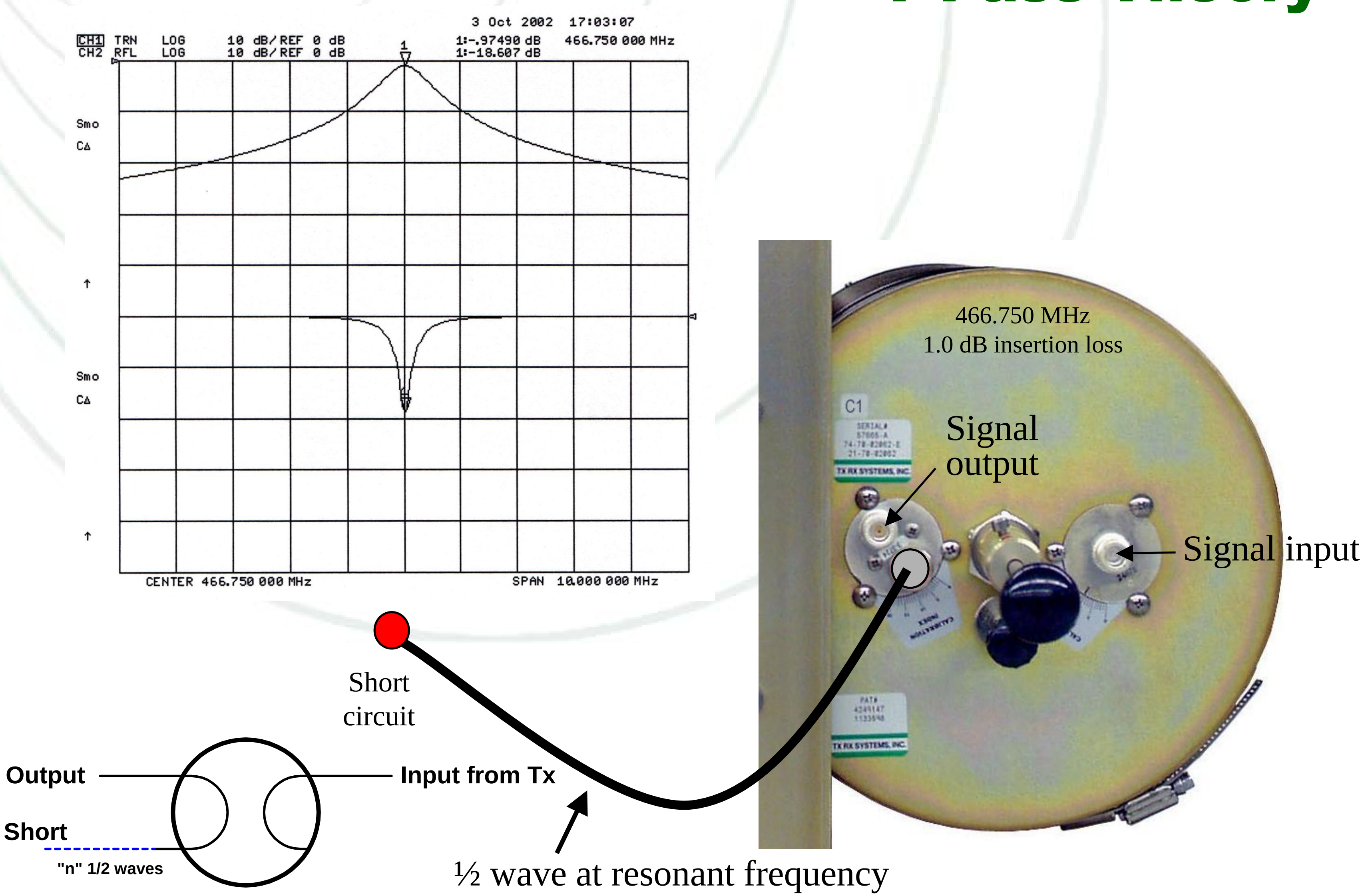
T-Pass Theory



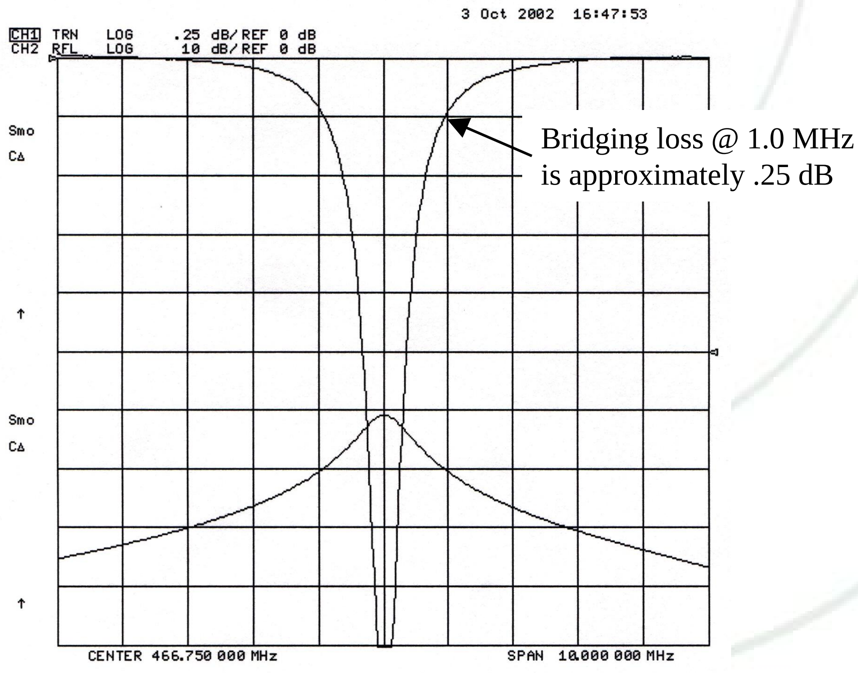


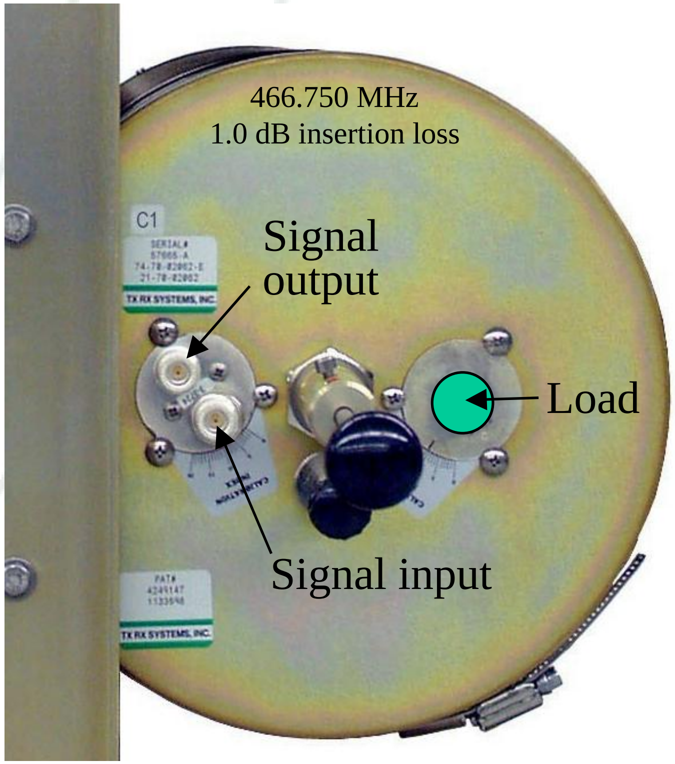


T-Pass Theory



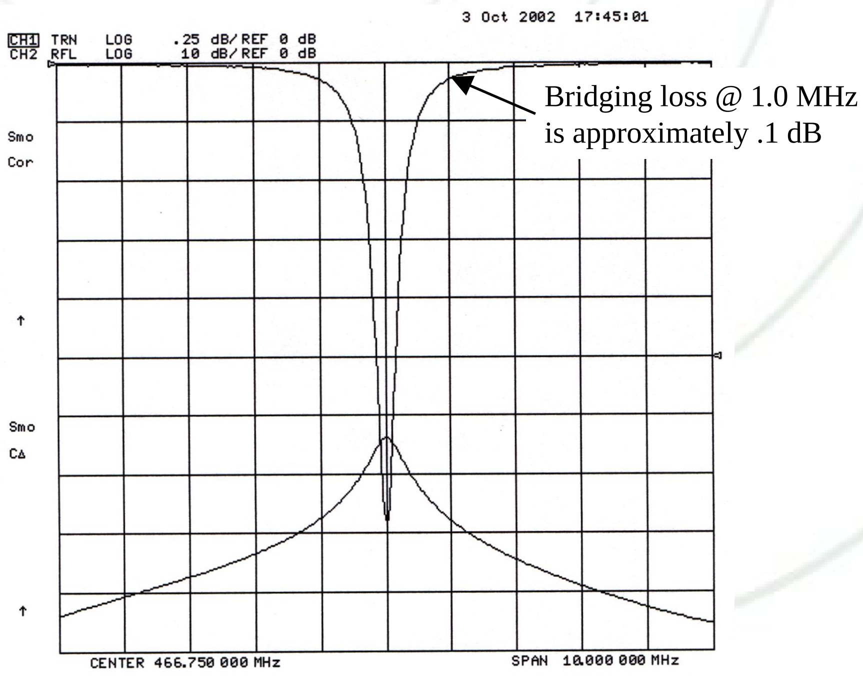
Bridging Loss

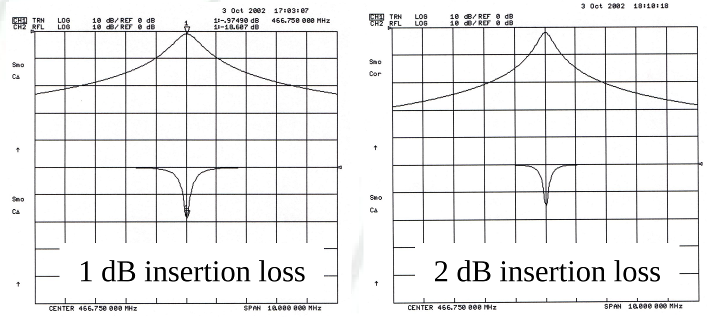


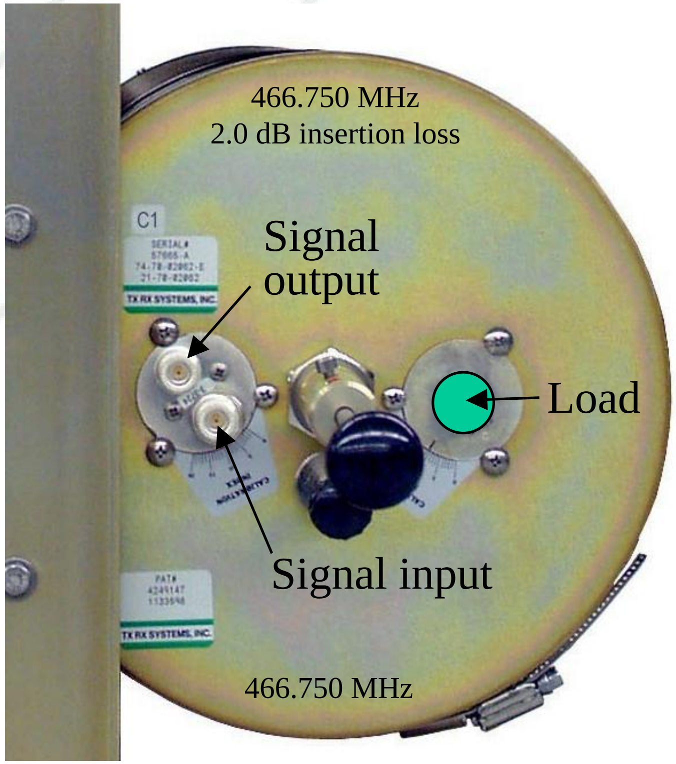


- Every cavity combiner has bridging loss
- Cavity selectivity determines bridging loss
- Input to output is 50 ohms for every frequency except resonant frequency

Bridging Loss

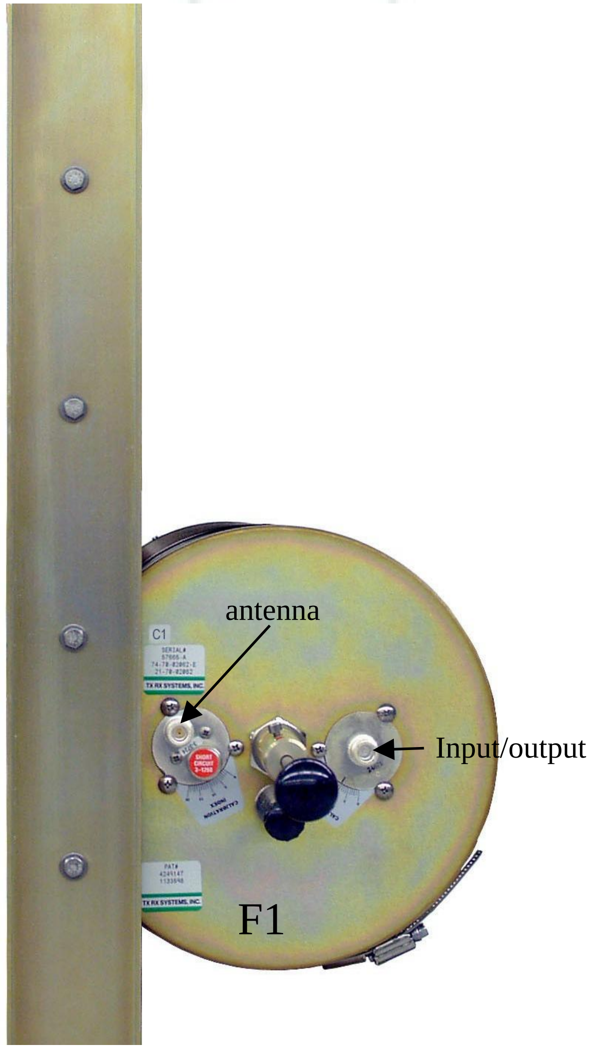




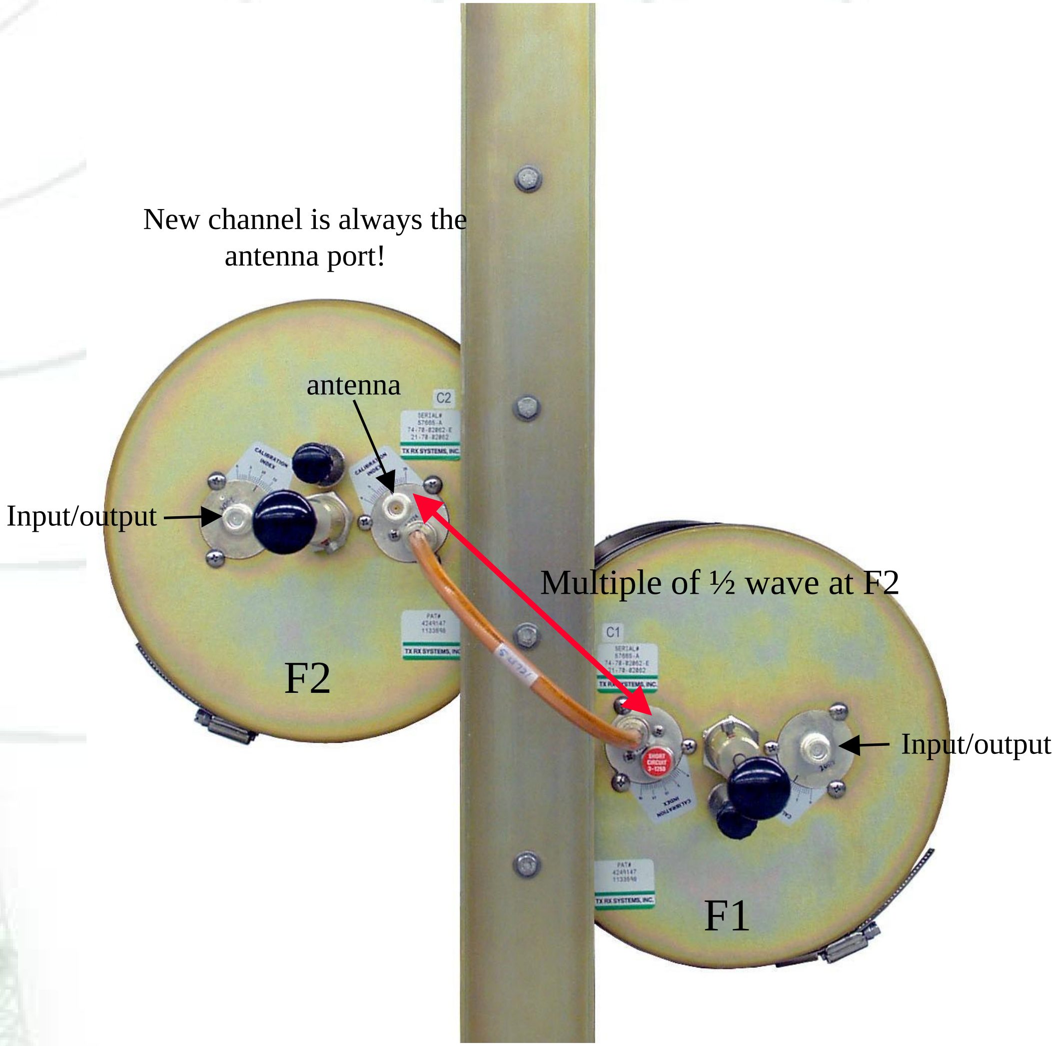


- **Bridging loss decreases as selectivity increases**
- **Can be achieved with higher cavity insertion loss or larger cavity**

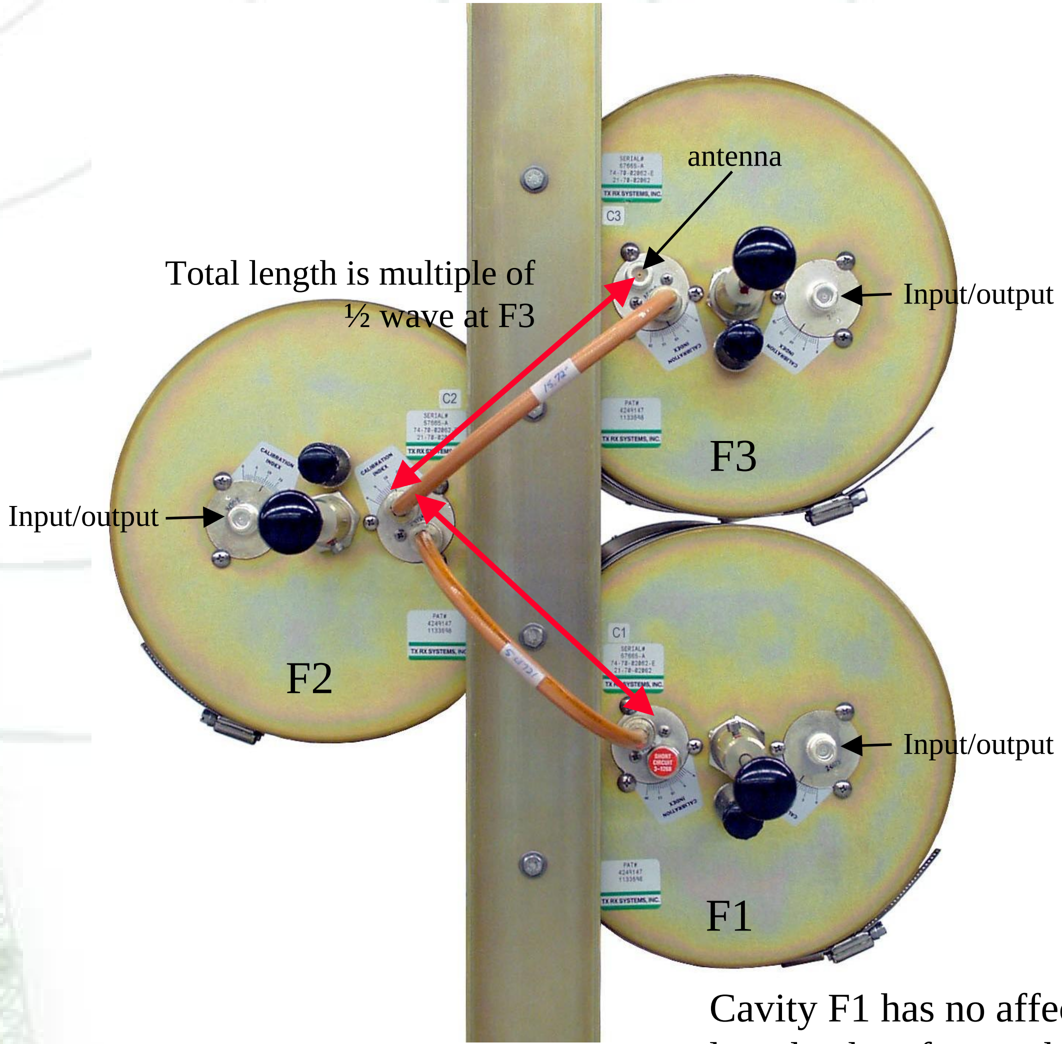
Ease of Expansion



Ease of Expansion



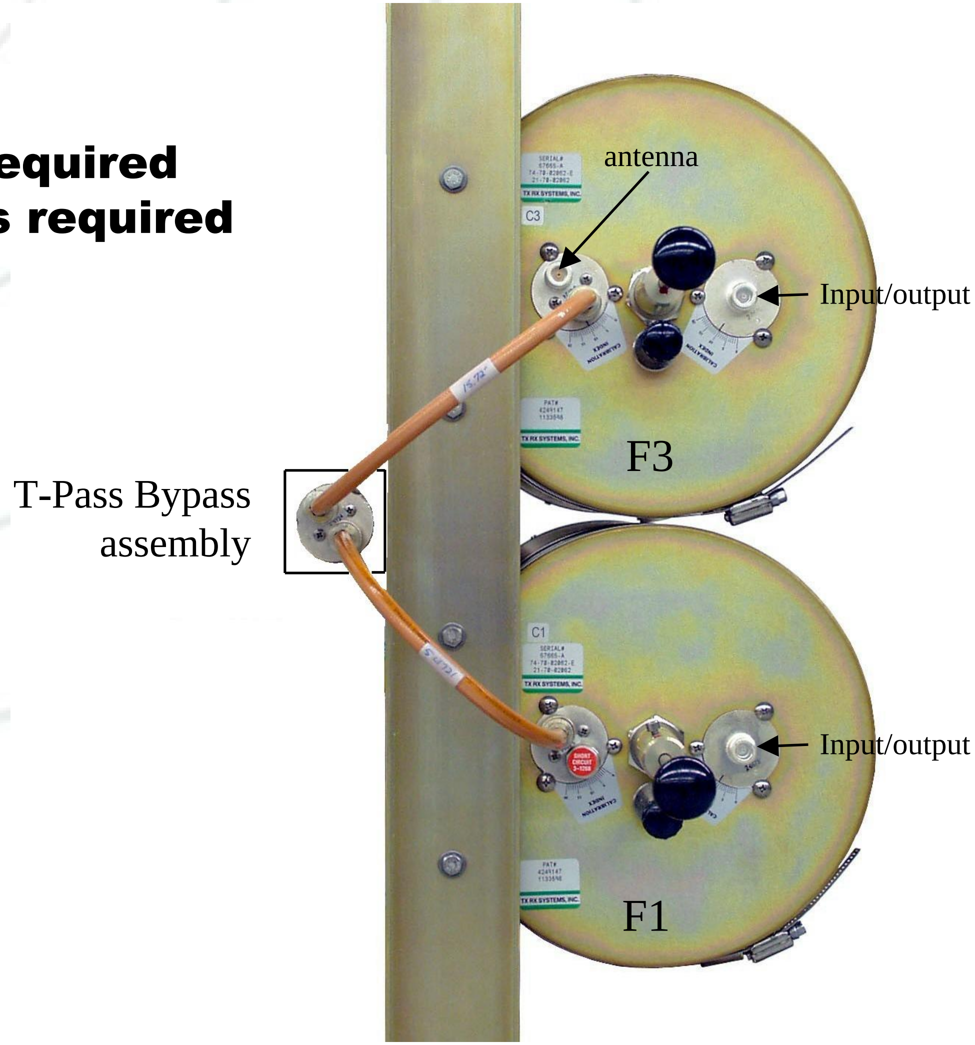
Ease of Expansion



Cavity F1 has no affect on cable lengths therefore making a handy spare channel

T-Pass Bypass Procedure

- No cable changes are required
- No mechanical changes required

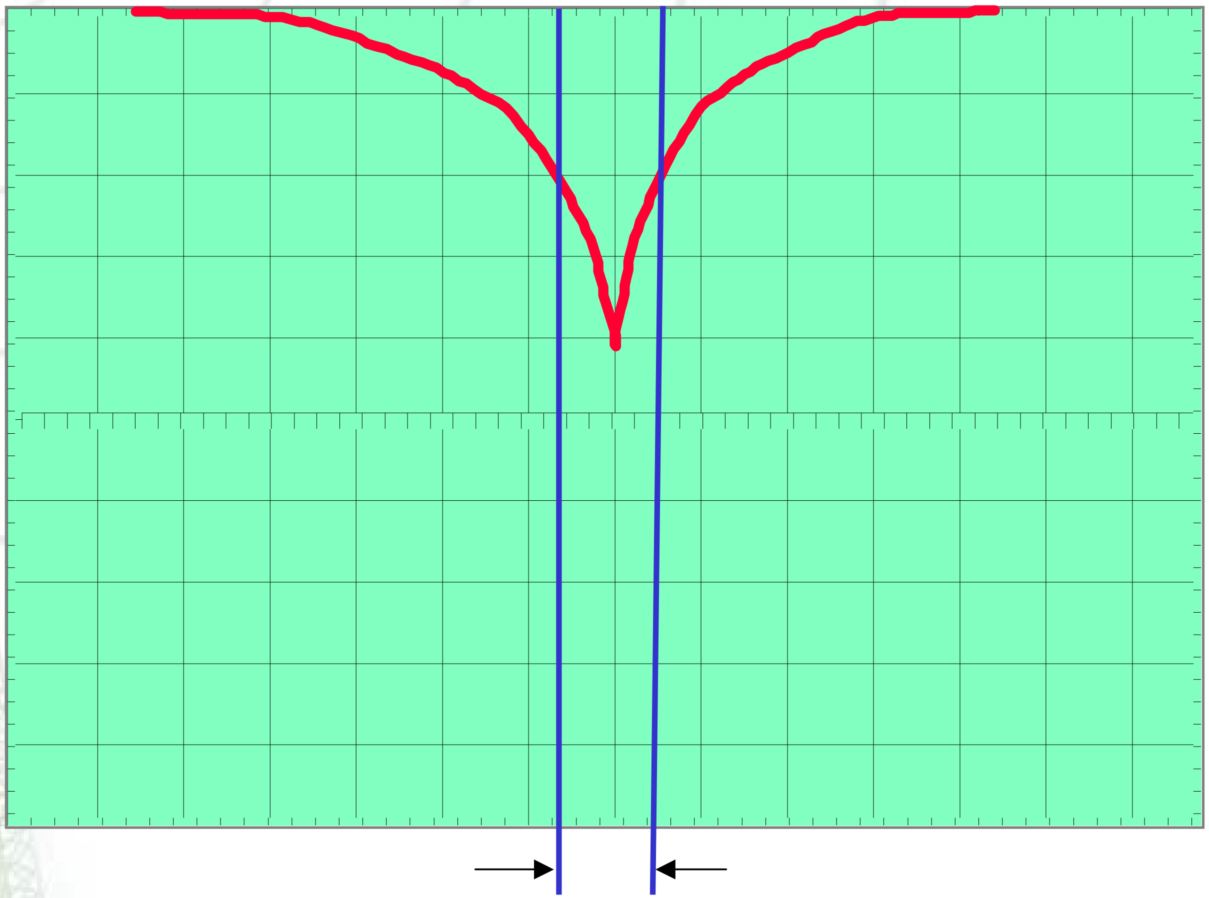


T-Pass Spreadsheet

Site: Example 1

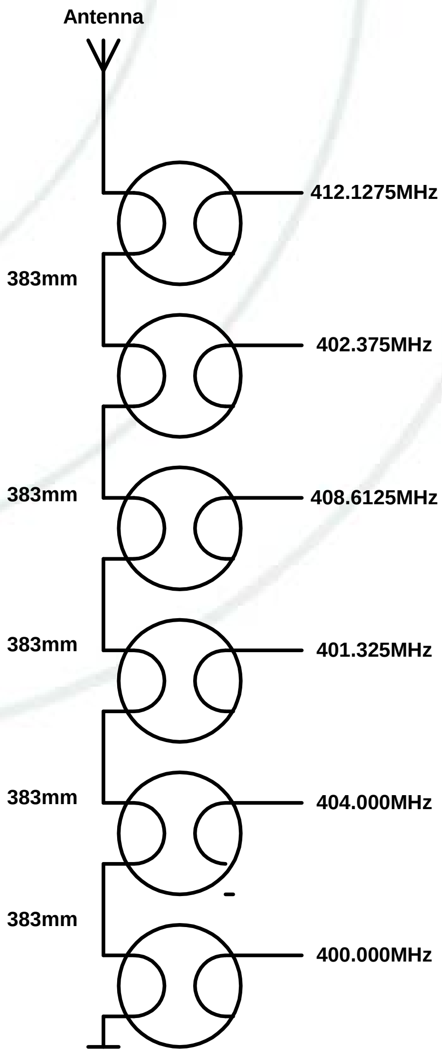
ID No.	Frequency (MHz)	Channel type	Loop type	Multiple	Thruline (mm)	Status	Date	Insertion loss (dB)	Cavity type	Bridging loss (dB)	Isolator	Other loss (dB)	Total loss (dB)
1	412.41250	Sx	d	Short Cct	15	E		1.50	306	0.22			3.53
2	421.71250	Tx	d	2	368	E		1.50	106	0.20	D		3.91
3	413.03750	Tx	d	4	403	E		1.50	306	0.22	D		3.93
4	505.33750	Tx	d	8	522	E		1.50	306	0.45	D		4.16
5	422.63750	Tx	d	9	455	E		1.50	306	0.21	D		3.92
6	472.12500	Sx	d	13	531	E		1.50	306	0.13			3.44
7	468.20000	Tx	d	15	360	E		1.50	306	0.68	D		4.39
8	489.31250	Tx	d	18	384	E		1.50	306	0.12	D		3.83
9	473.87500	Tx	d	20	450	E		1.50	306	0.13	D		3.84
10	468.50000	Tx	d	22	384	E		1.50	106	0.54	D		4.25
11	420.21250	Tx	d	22	448	E		1.50	310	0.16	D		3.87
12	492.21250	Tx	d	28	362	E		1.50	306	0.15	D		3.86
13	499.97500	Rx	d	31	420	E		1.50	306	0.12			3.43
14	404.01250	Rx	d	27	392	E		1.50	306	0.12			3.43
15	515.00000	Rx	d	37	410	E		1.50	306	0.12			3.43
16	505.00000	Tx	d	39	447	E		1.50	306	0.45	D		4.16
17	464.47500	Tx	d	38	368	E		1.50	306	0.15	D		3.86
18	424.00000	Tx	d	37	453	E		1.50	110	0.14	D		3.85
19	465.51750	Tx	d	43	419	E		1.50	306	0.15	D		3.86
20	493.21250	Tx	d	48	404	E		1.50	306	0.15	D		3.86

“Averaged” T-Pass

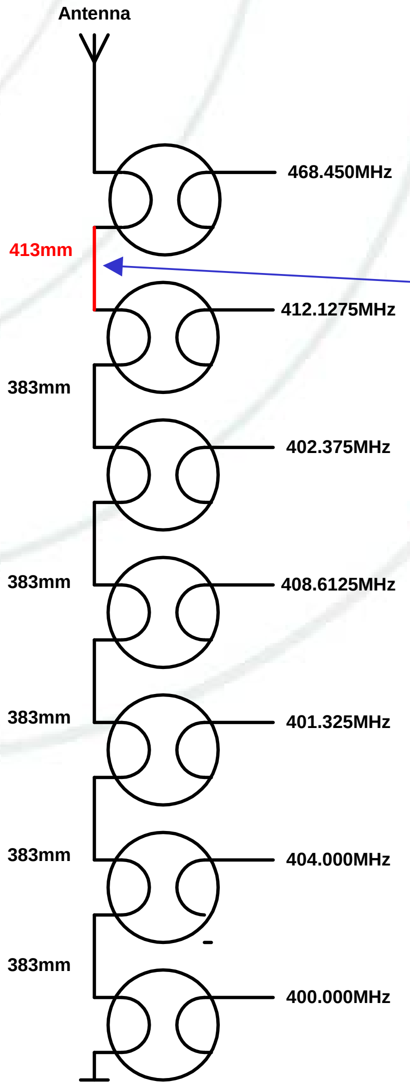


Typical Bridging Loss limits a
Star Combiner Harnessed System with
cables of the same “mean” lengths to 20MHz.

"Averaged" T-Pass

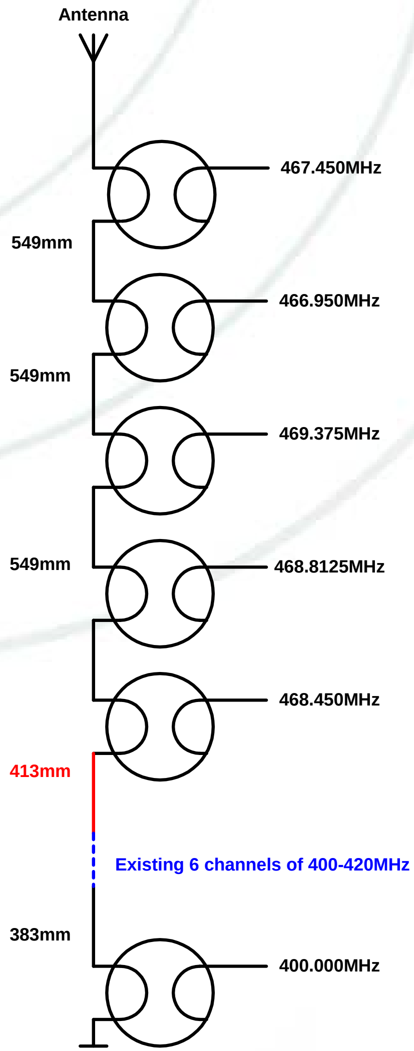


“Averaged” T-Pass



Channel Expansion outside of the “averaged” range may be easily provided by using a critical length cable to re-match the new channel to the “reference”

“Averaged” T-Pass



Another “averaged” grouping can be added using the same principles – simulating two narrow-bandwidth spider combiner systems harnessed together – but without all the disadvantages and high losses!

Multiple “averaged” groups, intermingled specific frequencies, or a combination of both can be implemented as required.

Channel Expansion outside of the “averaged” range may be easily provided by using a critical length cable to re-match the new channel to the “reference”

"Averaged" T-Pass Spreadsheet

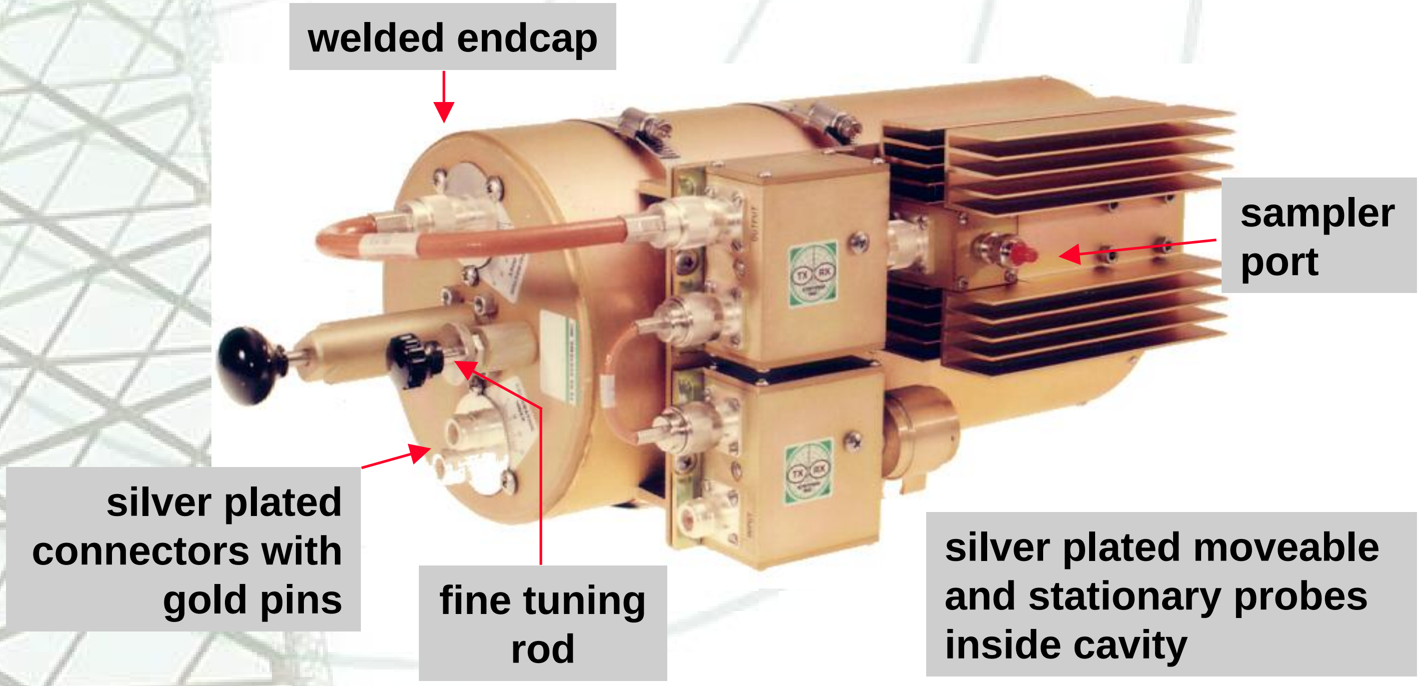
Site: Example 2

ID No.	Frequency (MHz)	Channel type	Loop type	Multiple	Thruline (mm)	Status	Date	Insertion loss (dB)	Cavity type	Bridging loss (dB)	Isolator	Other loss (dB)	Total loss (dB)
1	413.32500	Tx	d	Short Cct	15	E		1.50	106	0.76	D		3.93
2	413.00000	Tx	d	2	378	E		1.50	106	0.78	D		3.96
3	412.50000	Tx	d	4	393	E		1.50	106	0.38	D		3.56
4	414.00000	Tx	d	6	393	E		1.50	106	0.91	D		4.09
5	414.30000	Tx	d	8	393	E		1.50	106	1.16	D		4.34
6	468.00000	Tx	d	12	540	E		1.50	106	0.65	D		3.82
7	465.70000	Tx	d	15	549	E		1.50	106	0.12	D		3.29
8	469.30000	Tx	d	18	549	E		1.50	106	0.07	D		3.25
9	467.70000	Tx	d	20	549	E		1.50	106	0.67	D		3.85
10	466.60000	Tx	d	23	549	E		1.50	106	0.19	D		3.37
11	508.91250	Tx	d	28	481	E		1.50	106		D		3.18
12	414.60000	Tx	d	25	436	E		1.50	106	0.76	D		3.94
13	473.72500	Tx	d	31	423	E		1.50	106		D		3.18
14													
15													
16													
17													
18													
19													
20													

T-Pass Myths

- Frequencies do not have to be high-to-low or low-to-high requiring rearranging of channels when expanding
- Cable lengths are NOT absolutely critical. They do improve matching over broad bandwidths though……..
- *Averaged* T-Pass is still a lot better than Star Junction combiners!

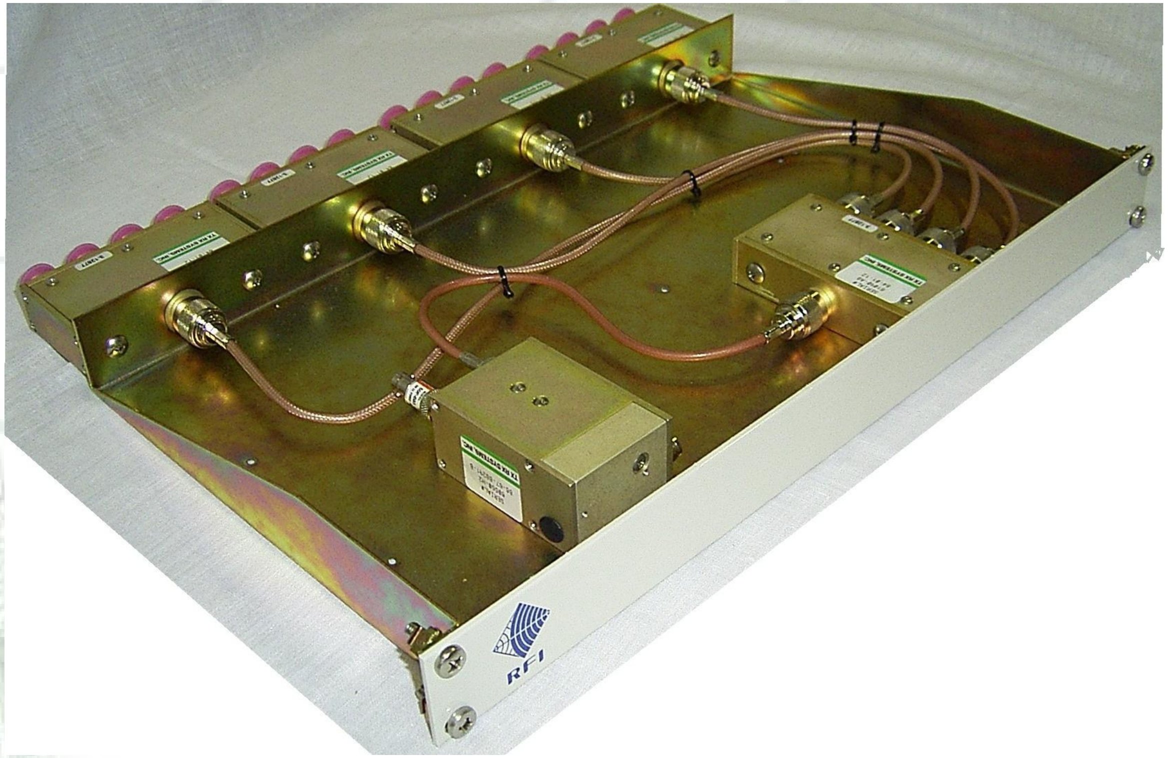
TX Multicoupler Fine-points



Tuning mechanism is "push-pull" as opposed to a threaded tuning rod which is susceptible to frequency shift when being locked down.

Low Level Amps 101

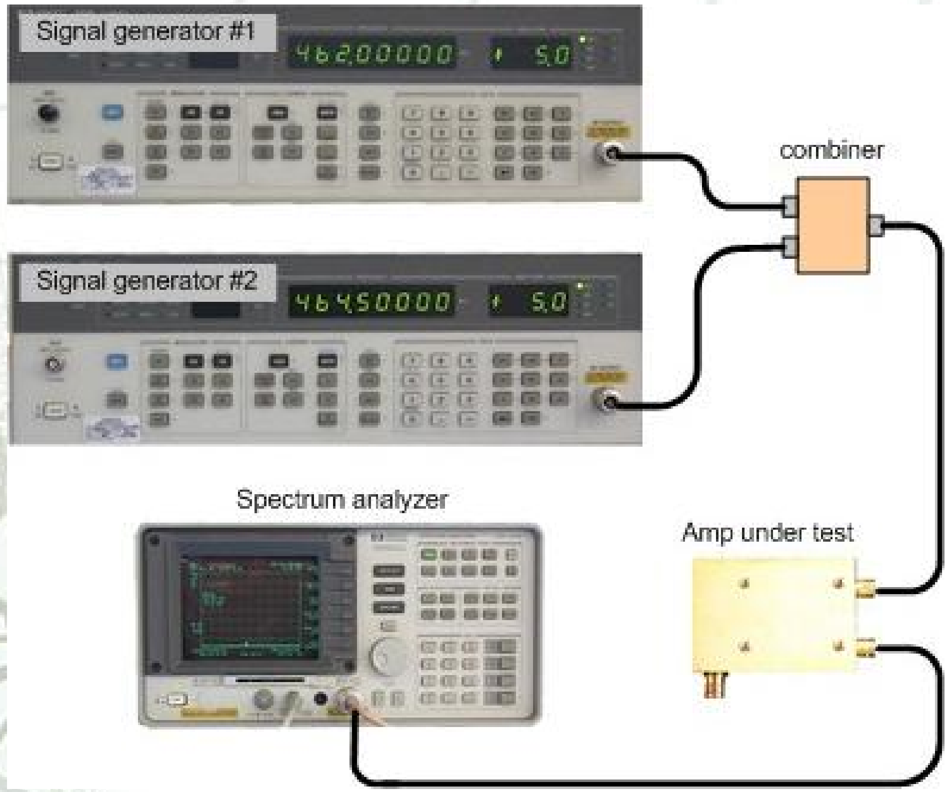
Low Level, Low Noise Amplifiers



3rd Order Intercept Point

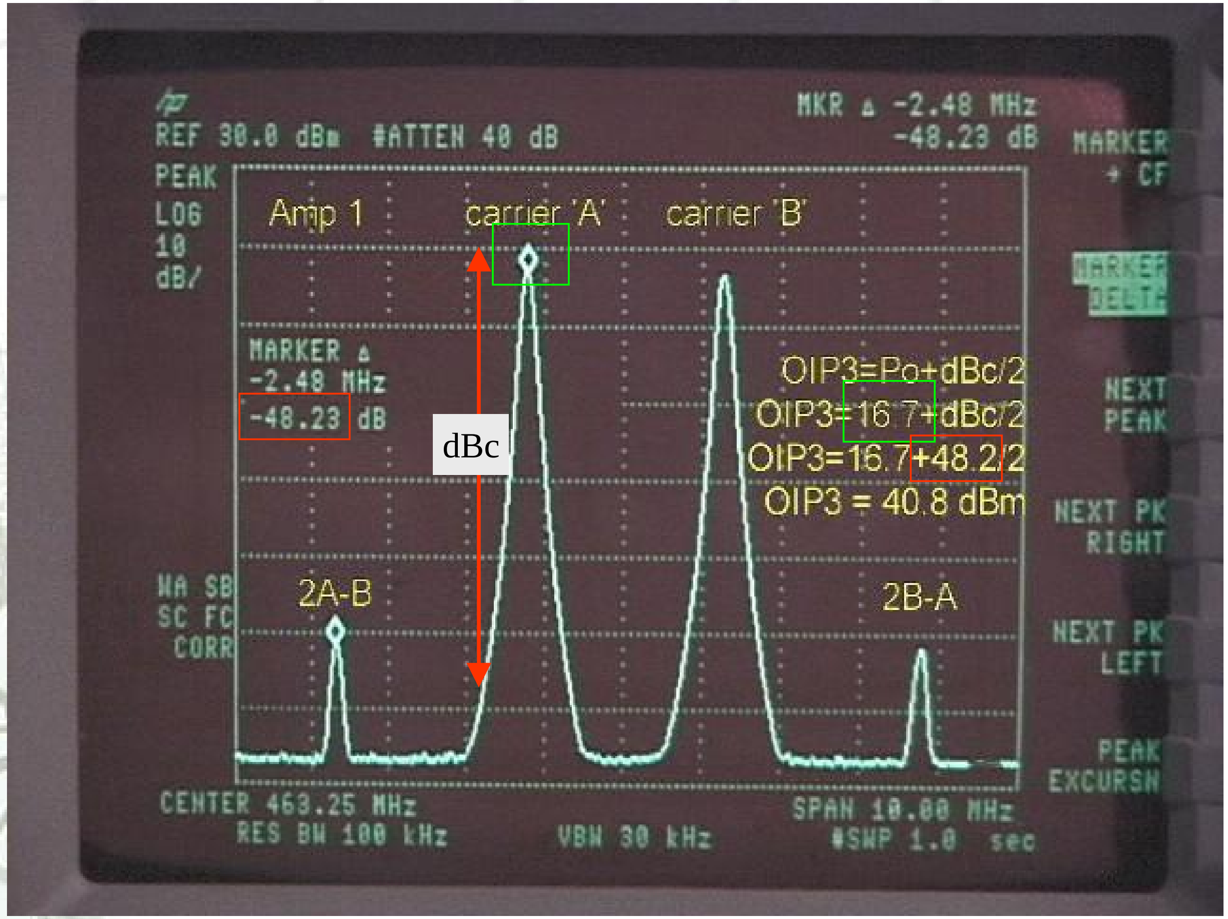
- A higher intercept point means the amplifier can handle more, higher-level signals before it is overdriven into non-linearity, generating intermodulation products.
- A high intercept point is especially critical for the Rx preamp/distribution amplifier, since it can see high RF levels – particularly in near/far digital scenarios (and to a lesser extent in analogue).
- As long as the preselector keeps very high-level TX carriers out of the amplifier, intermod products will never be a problem with these amplifiers.

OIP3 Measurement Test Bed



LNA
(low noise amplifier)

OIP3 Summary



Intermod Summary

- Reducing carrier power prior to the mixing point reduces IM power at a 3:1 rate (IM power drops 3 dB for every 1 dB reduction in carrier power) if both carriers are reduced by an equal amount.

- IM = 3(Po) - 2(OIP3) or OIP3 = Po + dBc/2

- Preamps with lower third order output intercept points (OIP3) generate higher level IM at a rate of 2:1. (IM increases 2 dB for every 1 dB decrease in OIP3)

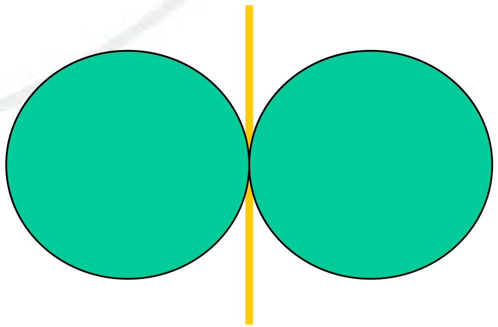
Noise Figure (NF)

- Measure of the degradation in the signal-to-noise ratio between the input and output of any device (usually amplifiers).
- Noise performance of the first stage in a system is typically the most critical
- Desire is to minimize loss before LNA as well as balance gain and losses after LNA to allow LNA noise figure to predominantly set a system’s noise figure

ANTENNAS 101

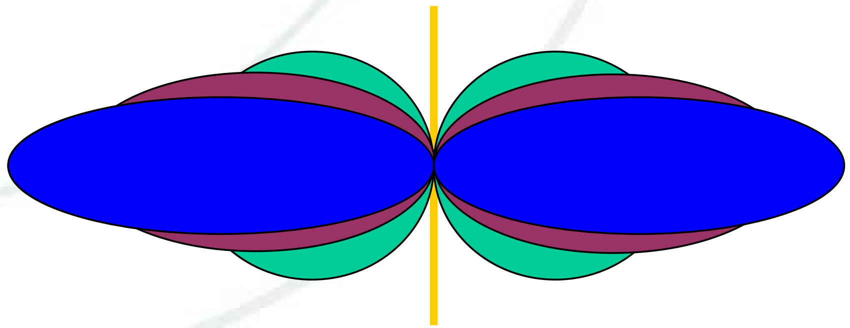
Antenna Gain

- Antennas develop gain by focusing and shaping the radiation pattern.



Antenna Gain

- Antennas develop gain by focusing and shaping the radiation pattern.



Two dipoles

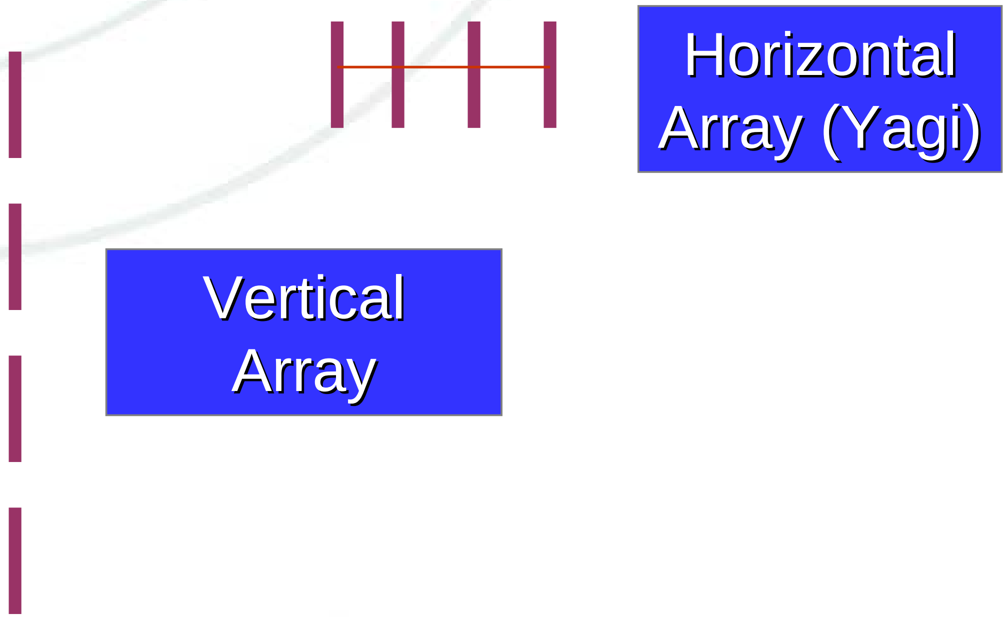
Four dipoles

Eight dipoles

Antennas cannot ADD power, they can only DIRECT it.

Antenna Gain

- Gain antennas use multiple elements specially positioned to focus the power.



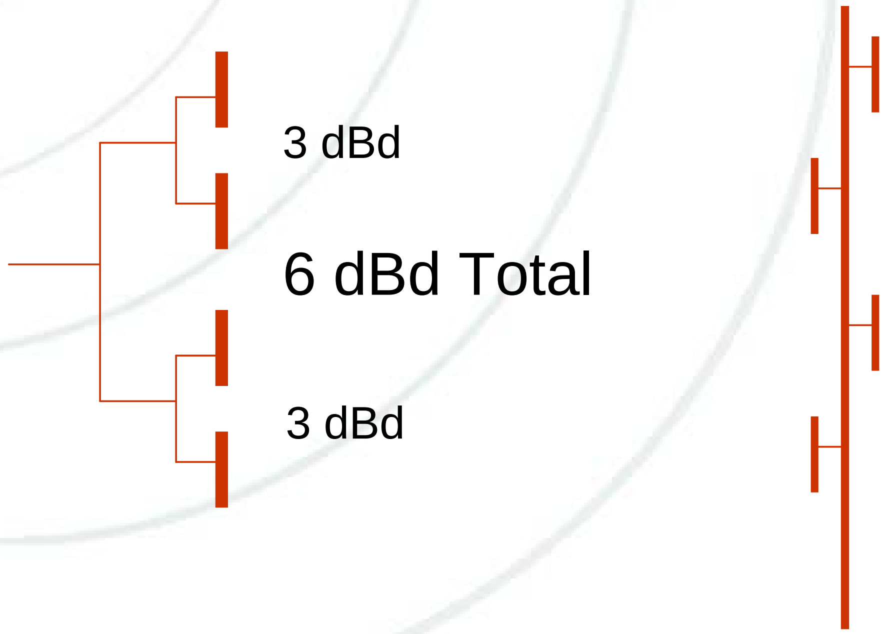
Vertical Arrays

- Multiple half-wave dipoles are placed end-to-end *(collinear)* to focus vertical beamwidth and provide gain.

Vertical Arrays

- Multiple half-wave dipoles are placed end-to-end *(collinear)* to focus vertical beamwidth and provide gain.
- Doubling the number of elements theoretically doubles the Effective Radiated Power (ERP), an increase of 3 dB.

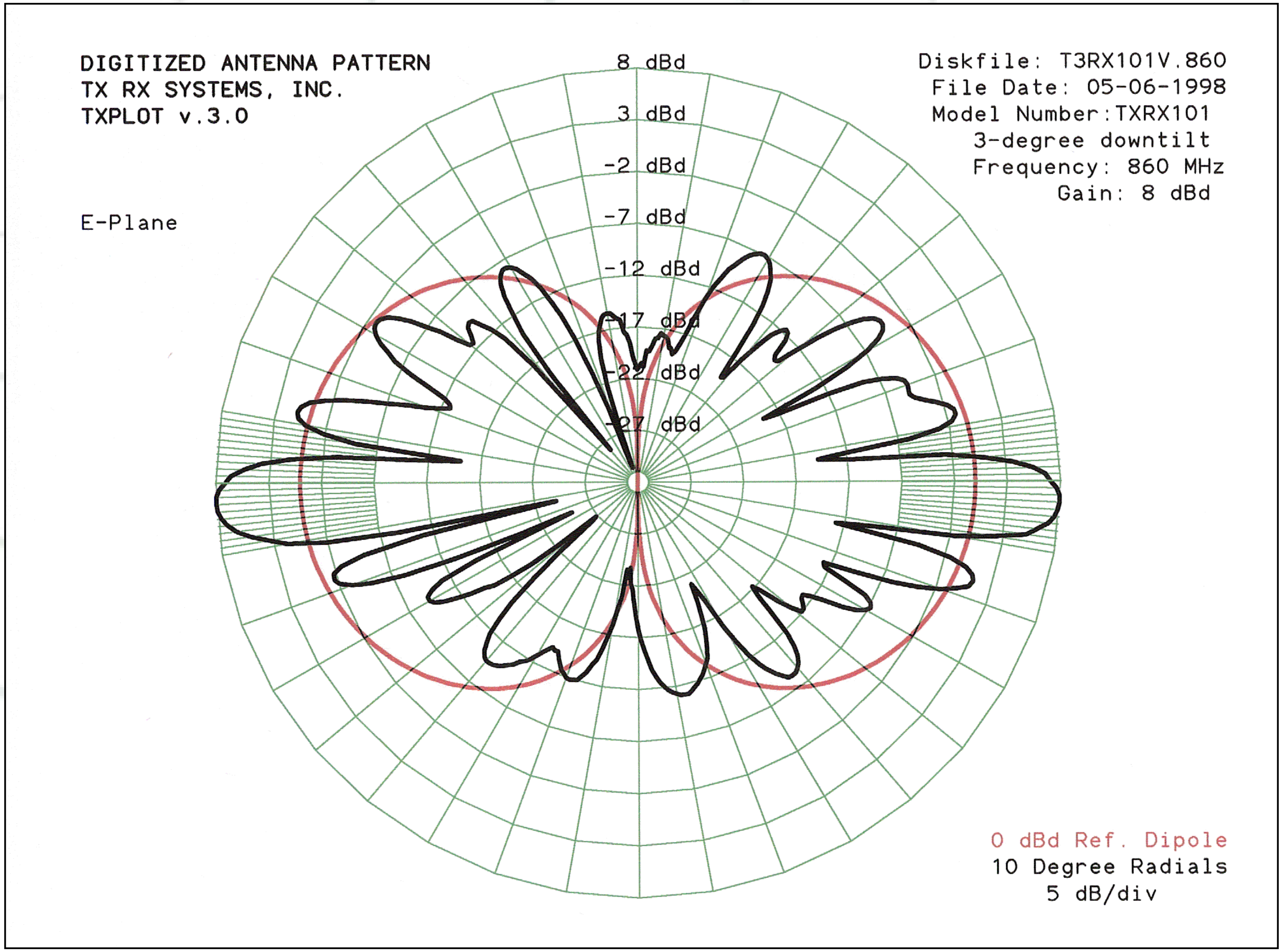
Vertical Dipole Arrays



Corporate Feed: Each element fed with equal power & phase.

True ***Corporate Feed*** is generally only available with exposed dipole arrays.

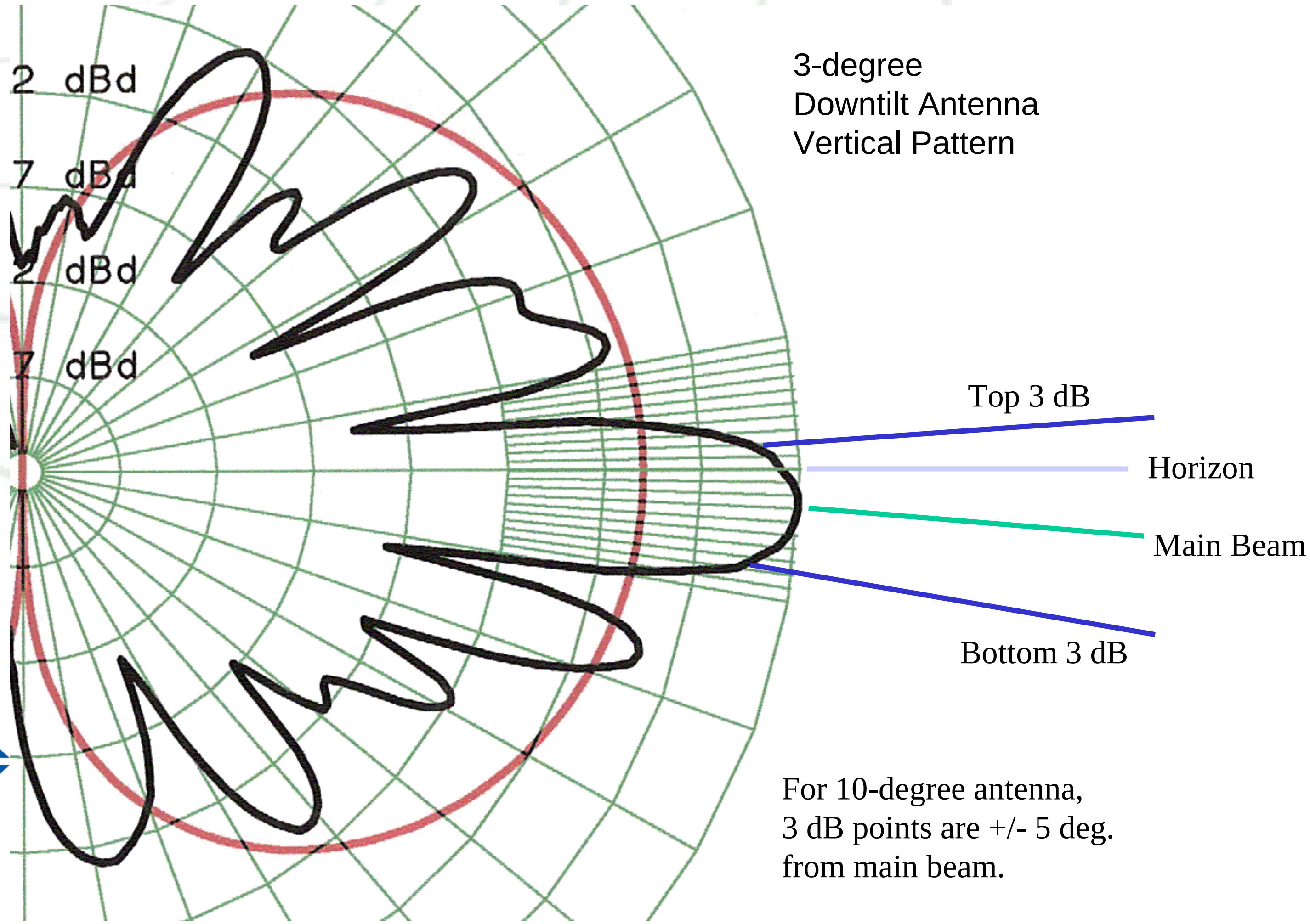
The Basics of Beamtilt



3-degrees Downtilt

The Basics of Beamtilt

3-degree
Downtilt Antenna
Vertical Pattern



For 10-degree antenna,
3 dB points are +/- 5 deg.
from main beam.

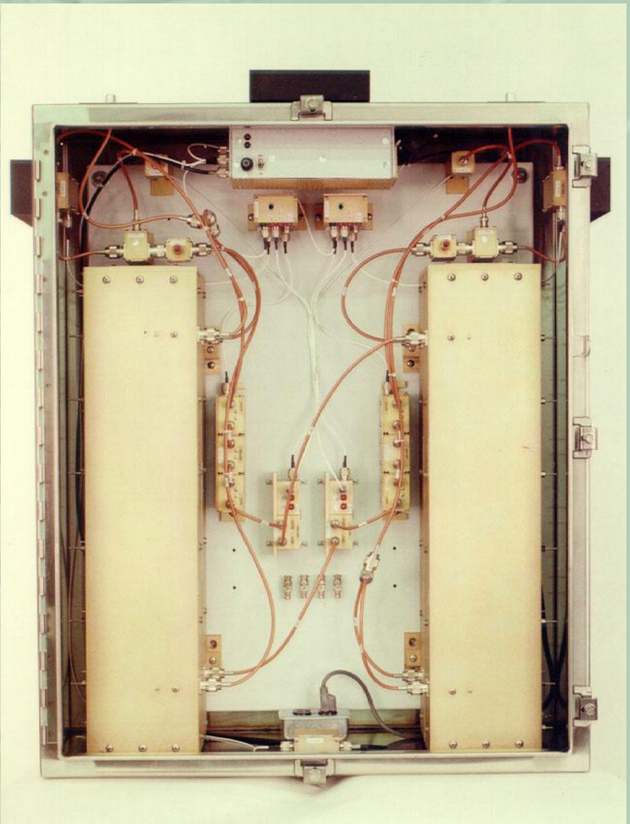
RFI

Recommendations

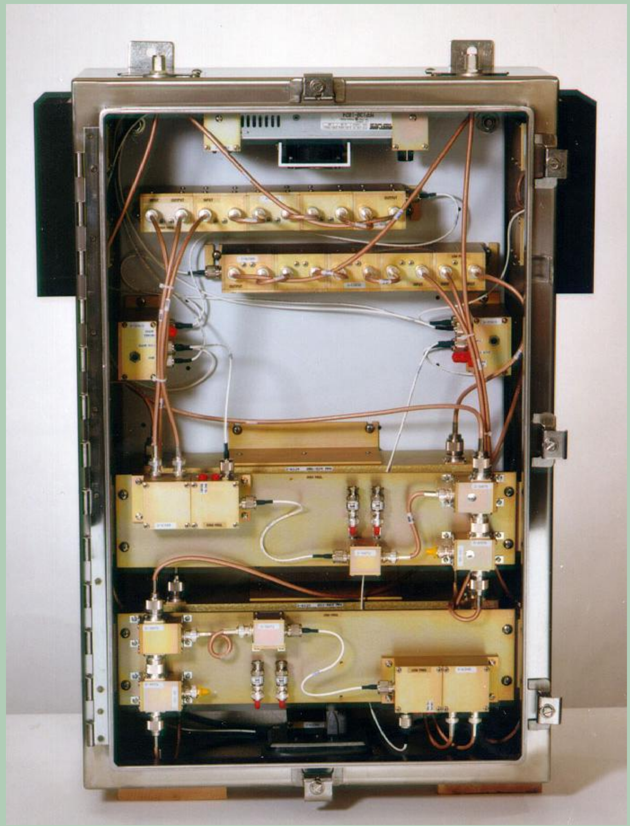
- Use 3 (to 5) degree downtilt antenna for the majority of applications – except flat open terrain (use 0dB) or steep escarpments (use >5 degree).

Multicoupler Systems

An Introduction to Signal Boosters



UHF Signal Booster



800 MHz Signal Booster

Outline

- History and examples
- Types of Signal Boosters
- Class A amplifier characteristics
- Building a Signal Booster
- Sample applications
- System design using spreadsheet analysis
- Limitations
- Summary

An Introduction to Signal Boosters

Problem

Lack of coverage or poor coverage due to a *shielded* environment

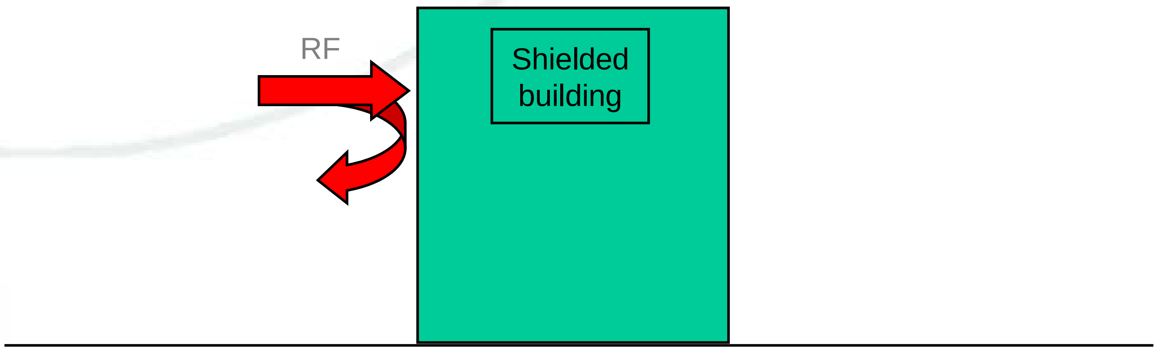
Solution

Amplified distribution system

Applications

Best application for an amplified distribution system:

An adequate signal would be received if it weren't for severe shielding. (Very high abrupt path loss)



Components of Amplified Distribution System

- Antennas
- Leaky cable / RFOF
- Signal Booster
- Power dividers
- Directional couplers
- Transmission line

Signal Booster Aliases

- Repeater Amplifier
- Cell Enhancer
- Network Extender
- Bi-Directional Amplifier (BDA)
- Repeater
- On Channel Repeater (OCR)
- On Frequency Repeater (OFR)

History

<u>First Signal Booster designed, manufactured, and deployed in 1979</u>

- Joint venture, Motorola and TX RX Systems
- UHF system for a coal mine in Illinois
- Leaky cable system using cascaded amplifiers

Examples of Major Projects

- Adelaide Crafers Tunnel
- Sydney Airport Rail
- Parliament House Canberra
- Sydney Olympics
- “Chunnel”
- NSW Rail
- CityLink
- Lamma Power Station HK
- Various Police, Rail, Gov’t

Example Applications

- Hospitals
- Power plants
- Road/Rail Tunnels
- Shopping Centres
- Correctional facilities
- Airports
- Mines
- Casinos & Event Complexes

Standard Models Available

- 0.5MHz - 5800 MHz range
- Both one-way and two-way
- From 0 dB to >80 dB gain
- Various bandwidths, from <1 MHz to >70 MHz @ UHF
- Mechanical options include stainless steel and painted steel enclosures as well as 19” rack mount versions

Types of Signal Boosters

<u>Broadband</u>

- Amplify frequency band segments
- No frequency conversion
- Minimal group delay (nanoseconds)
- Class A amplifiers

Types of Signal Boosters

Channelized

- Amplify discrete frequency
- Frequency is down converted or sharply filtered (i.e. SAW)
- Adjacent channel rejection (>60 dB)
- Can be combined for multiple channel use
- Pwr amps can be class C (if per/ch)
  - Greater output power
  - Linearity not an issue due to single frequency amplification

Quick ‘Class A’ Lesson

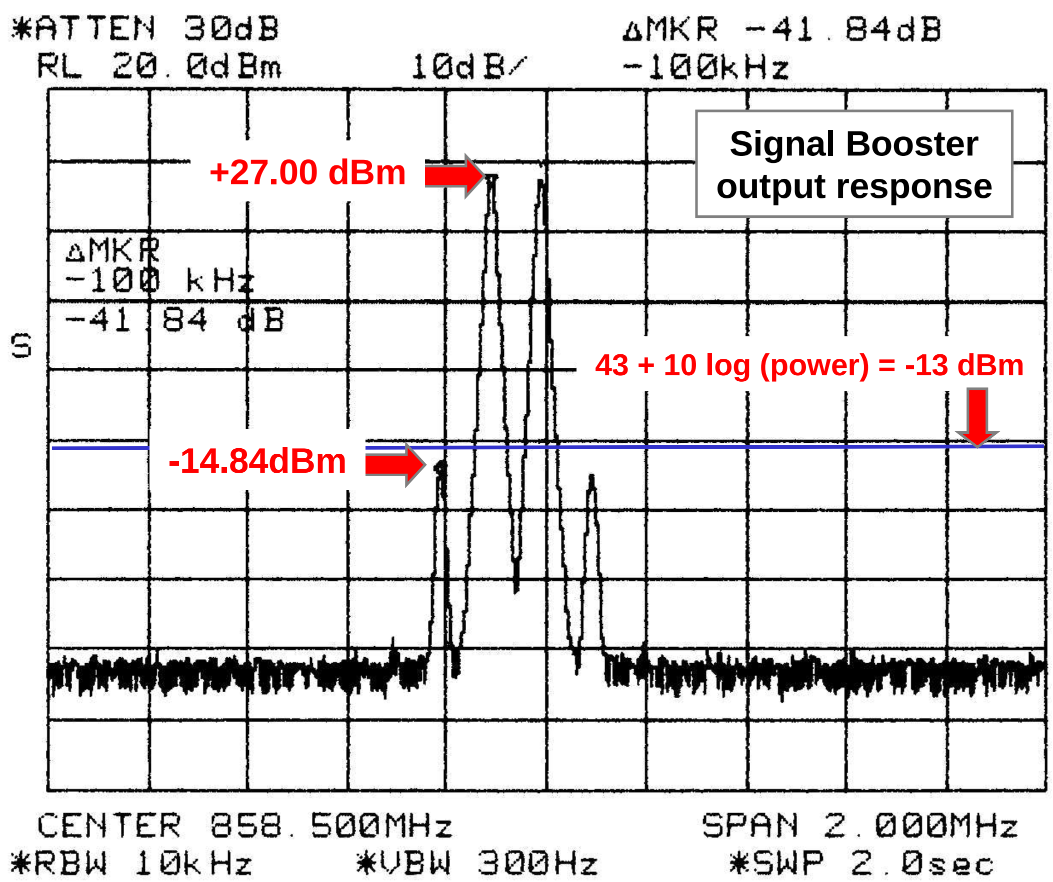
- Transistor power spec is 1dB compression point
  - This level is never reached due to IM concerns
- Useable output power is a function of 3rd order intercept point
  - Two carrier test determines maximum output
- Useable output power decreases (per carrier) as number of carriers in the passband (at similar power levels) increases
- Carriers >15dBc from strongest do not affect output level

Output Level Control (OLC)

- Controls IM output levels
- Control range is 35-40 dB
- Reduces risk of power amp damage

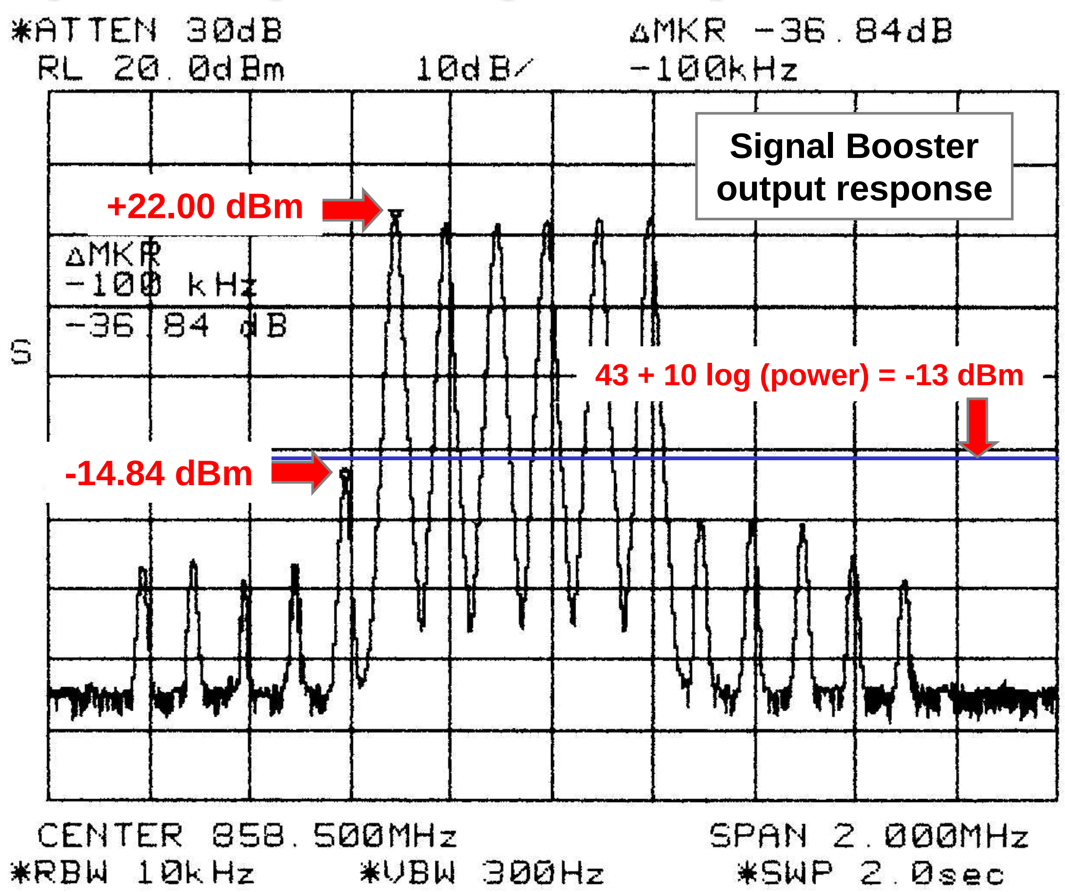
Two Carrier IM Test

- Two carriers at +27 dBm each
- Third order products are down at least 41.84 dBc



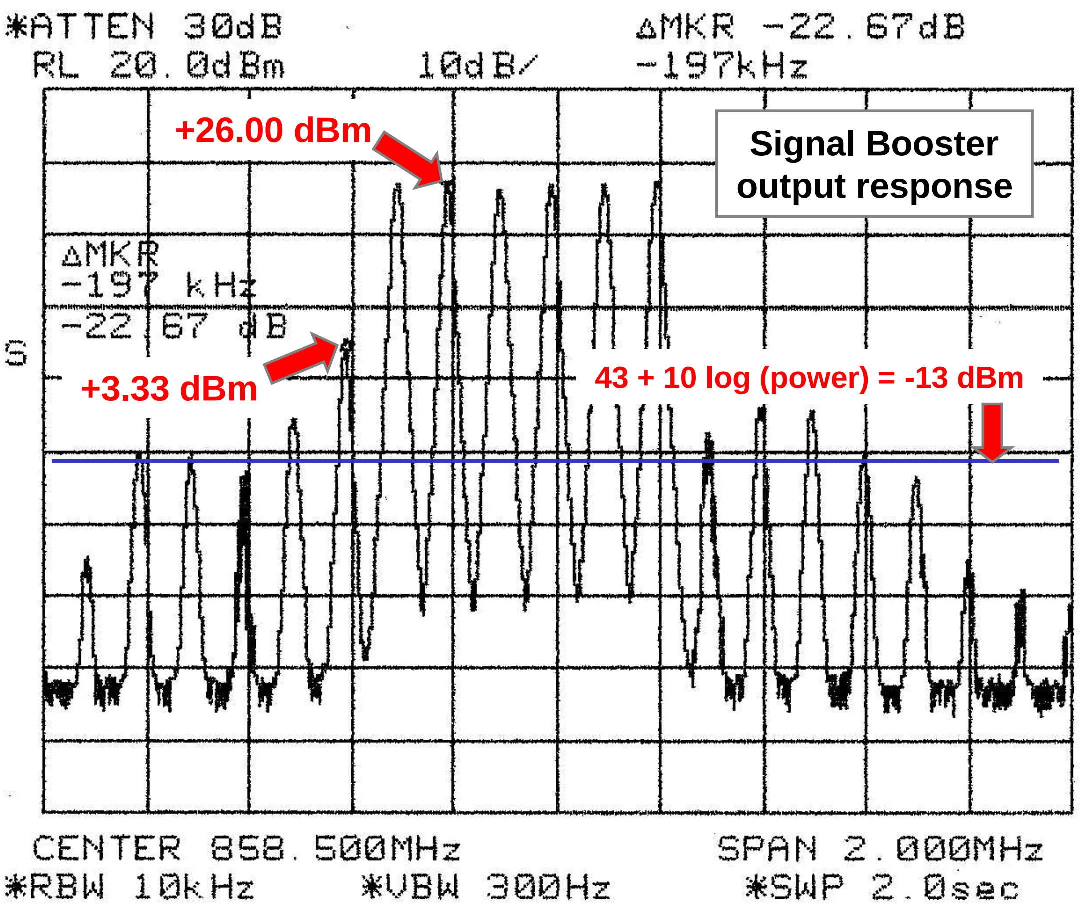
Six Carrier IM Test with OLC

- Number of carriers increased to six
  - same input levels as previous test
- Output level decreases to +22 dBm per carrier
- OLC maintains exactly the same IM level as the two carrier test



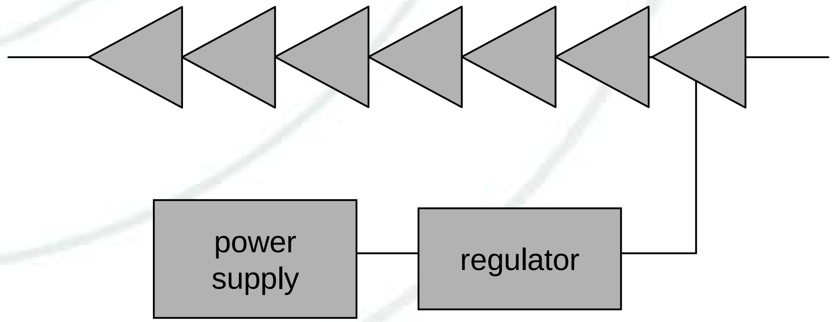
Six Carrier IM Test without OLC

- OLC turned off
  - IM is 22.67 dBc (down from carrier) or +3 dBm
  - IM products increasing at 3:1 (vs. carrier)

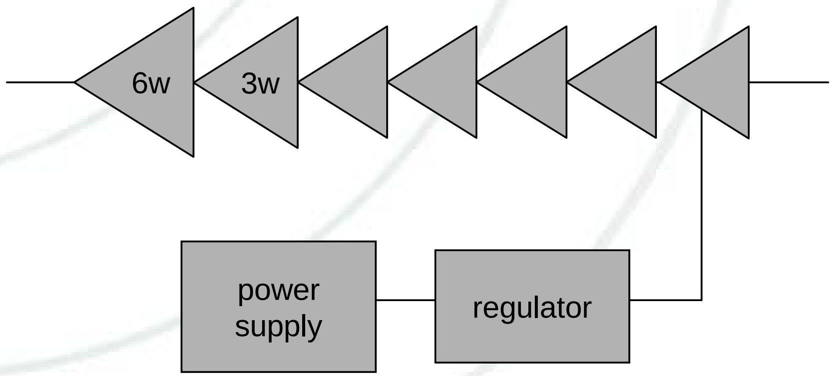


Gain Block

.4 watt low level preamps

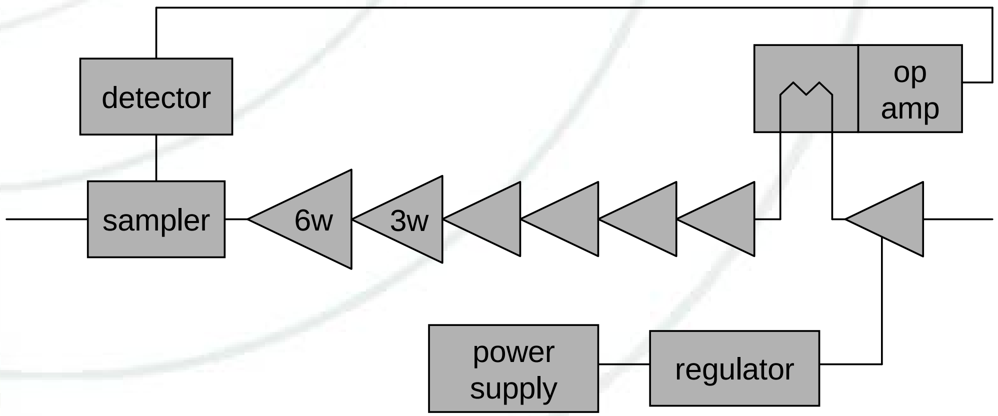


Gain Block with High Level Amps



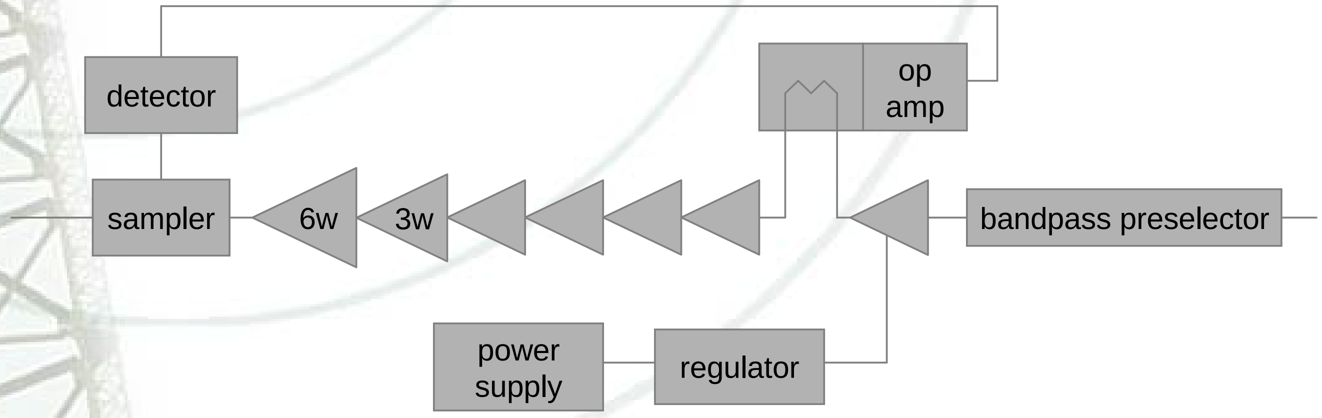
Power amps increase Signal Booster output level capability by approximately 200%

Gain Block with High Level Amps and Output Level Control



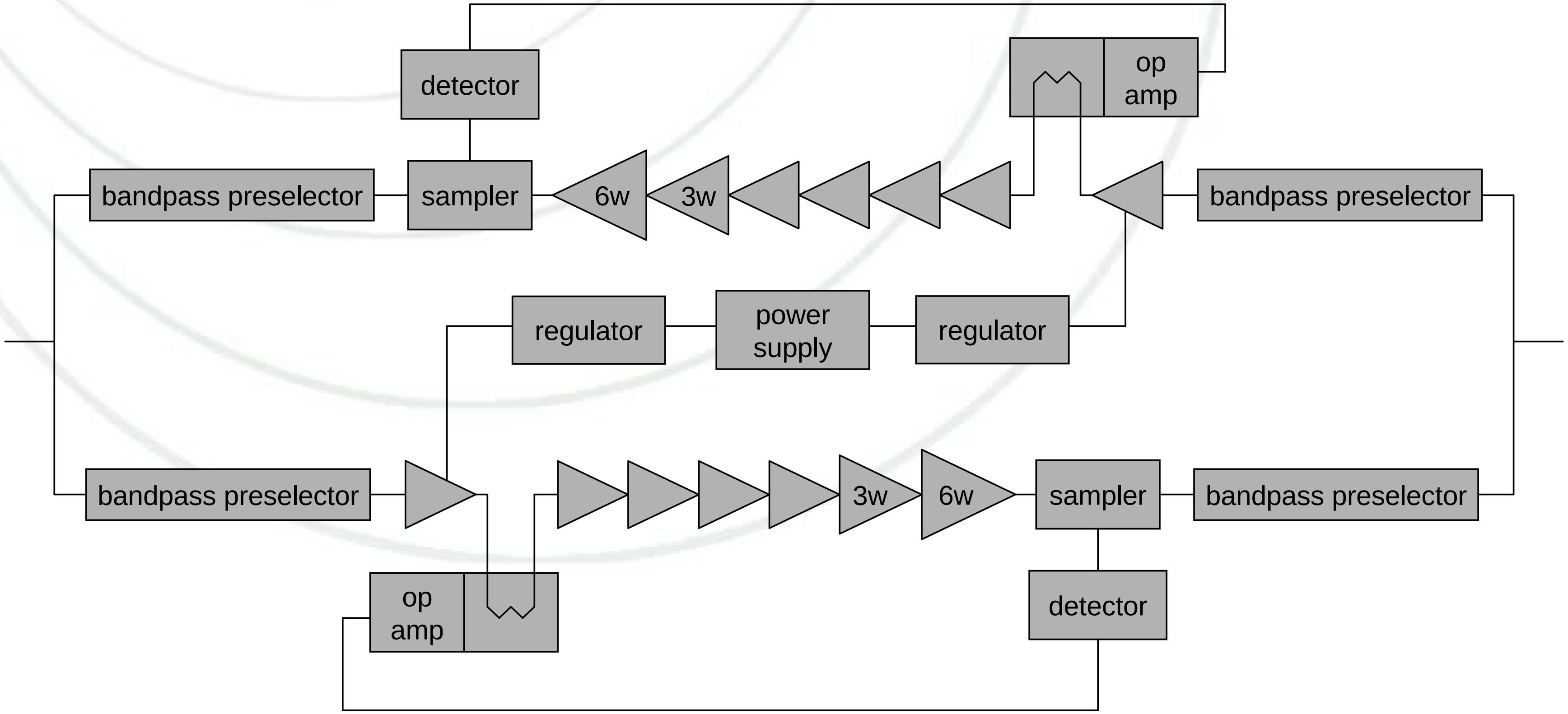
OLC controls IM output level and minimizes risk of power amp damage

One-Way Signal Booster

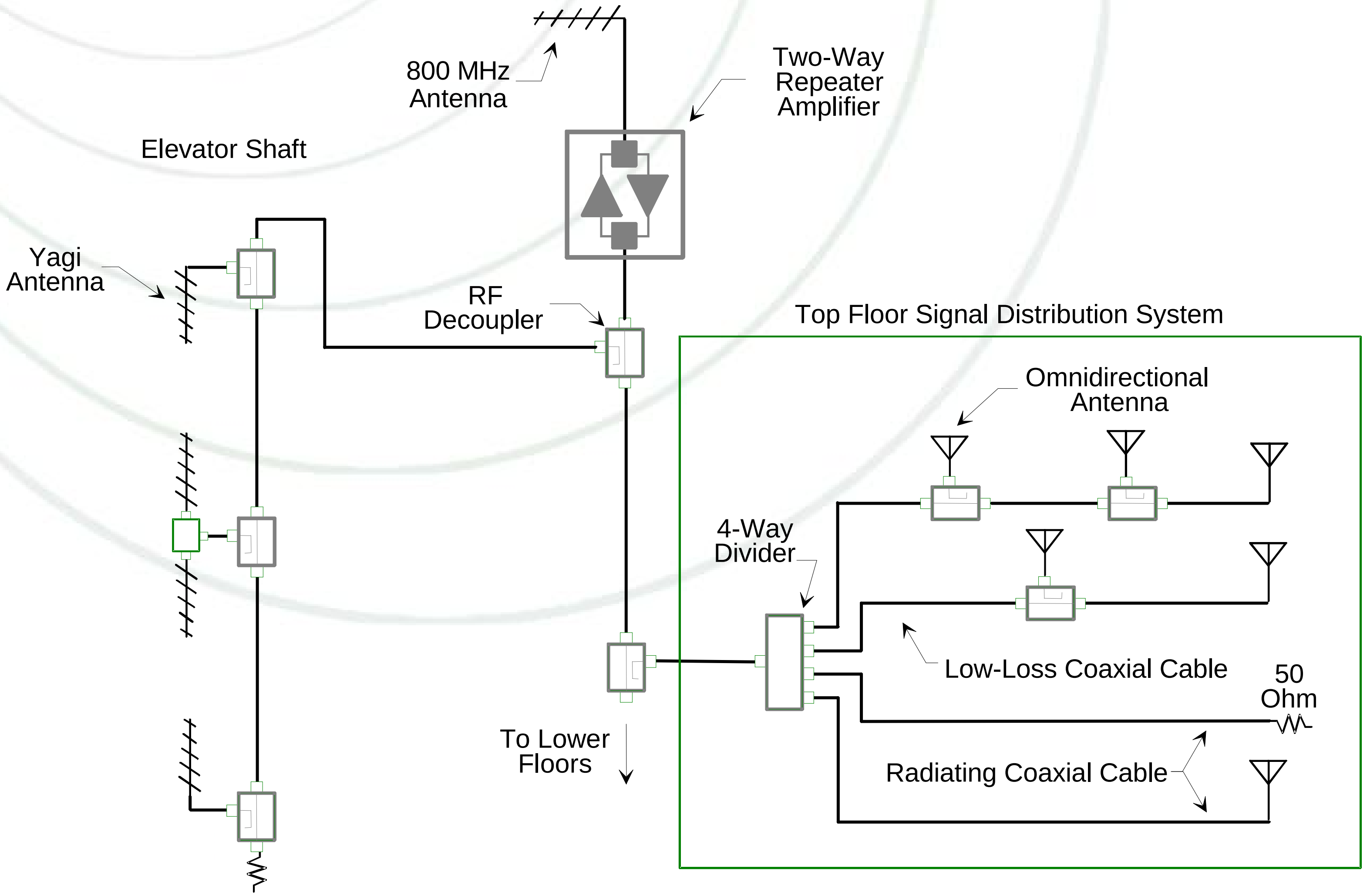


Preselector reduces number of frequencies to be amplified, thus maximizing output level of desired channels

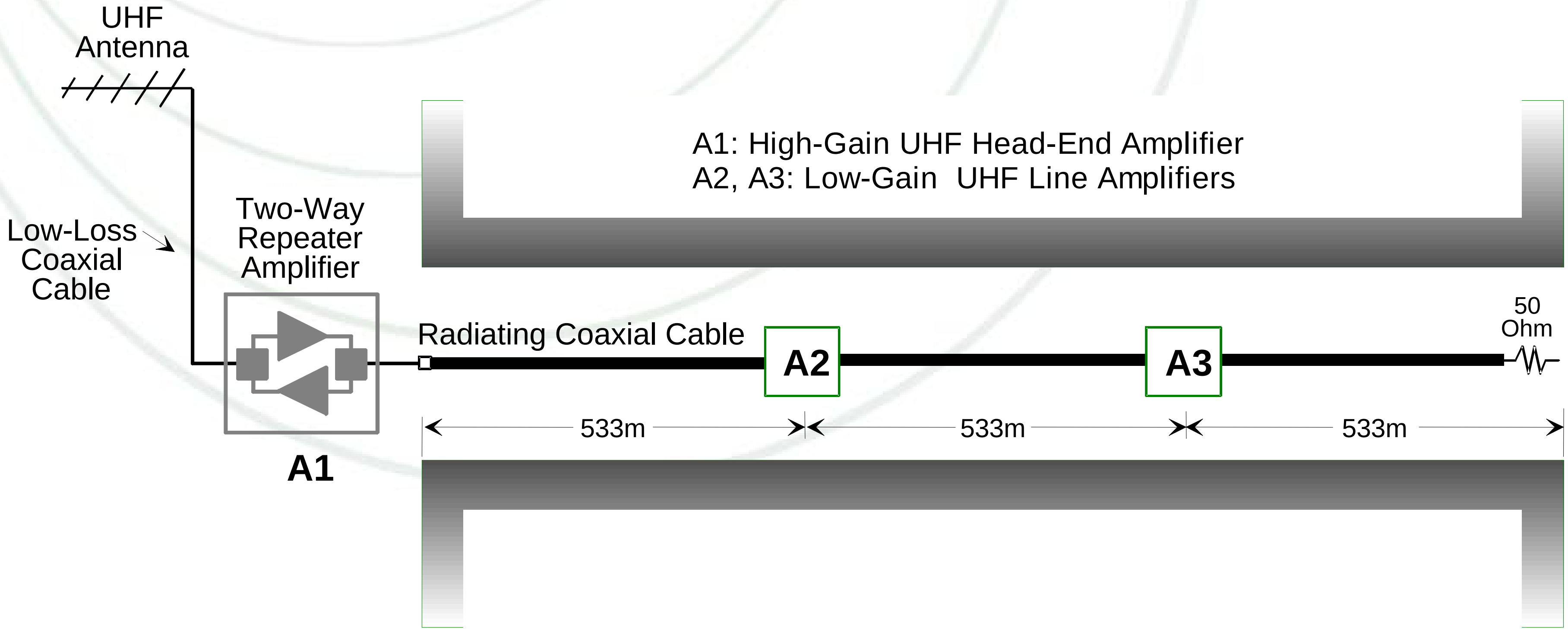
Two-Way Signal Booster



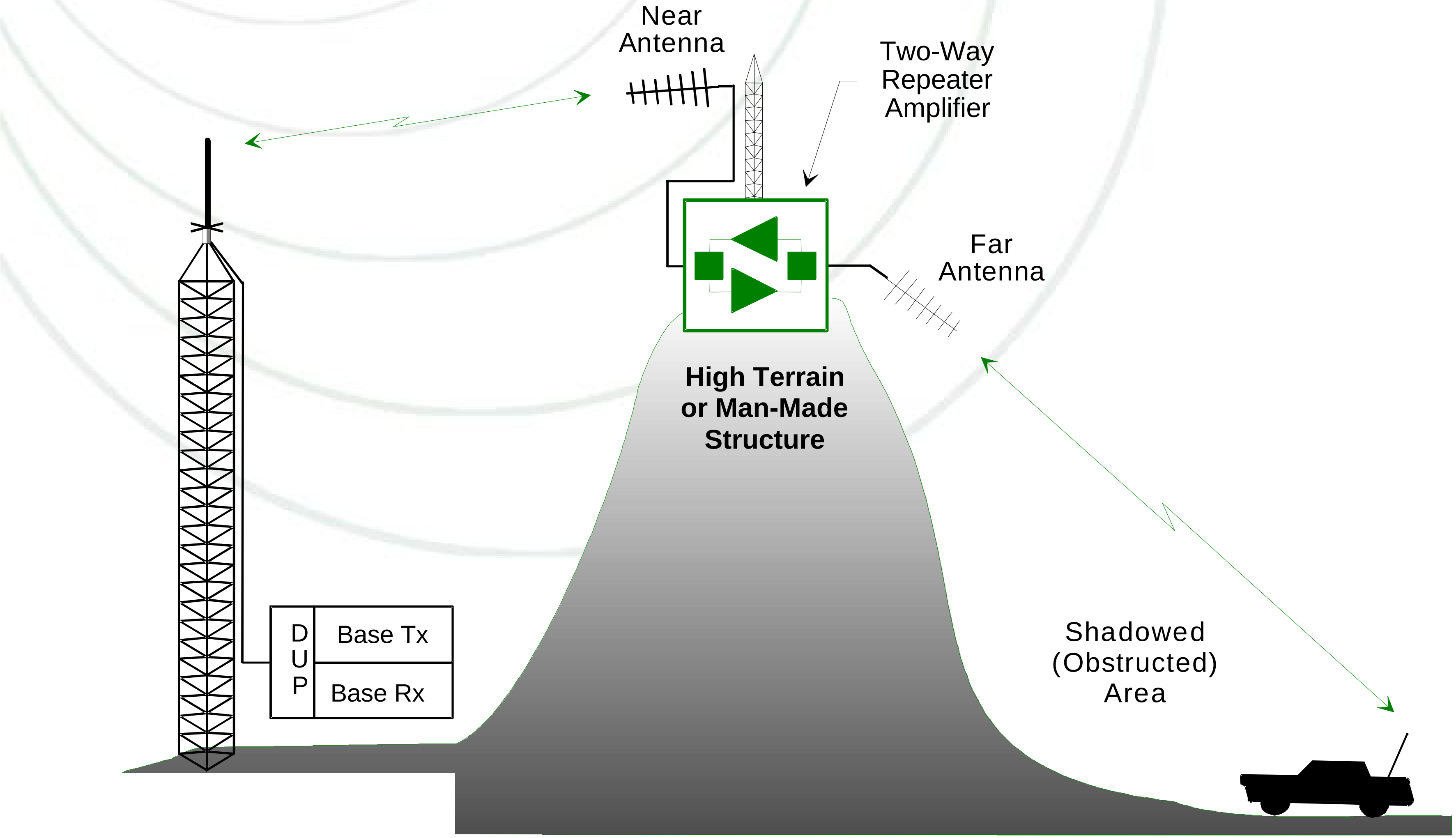
In-building Application



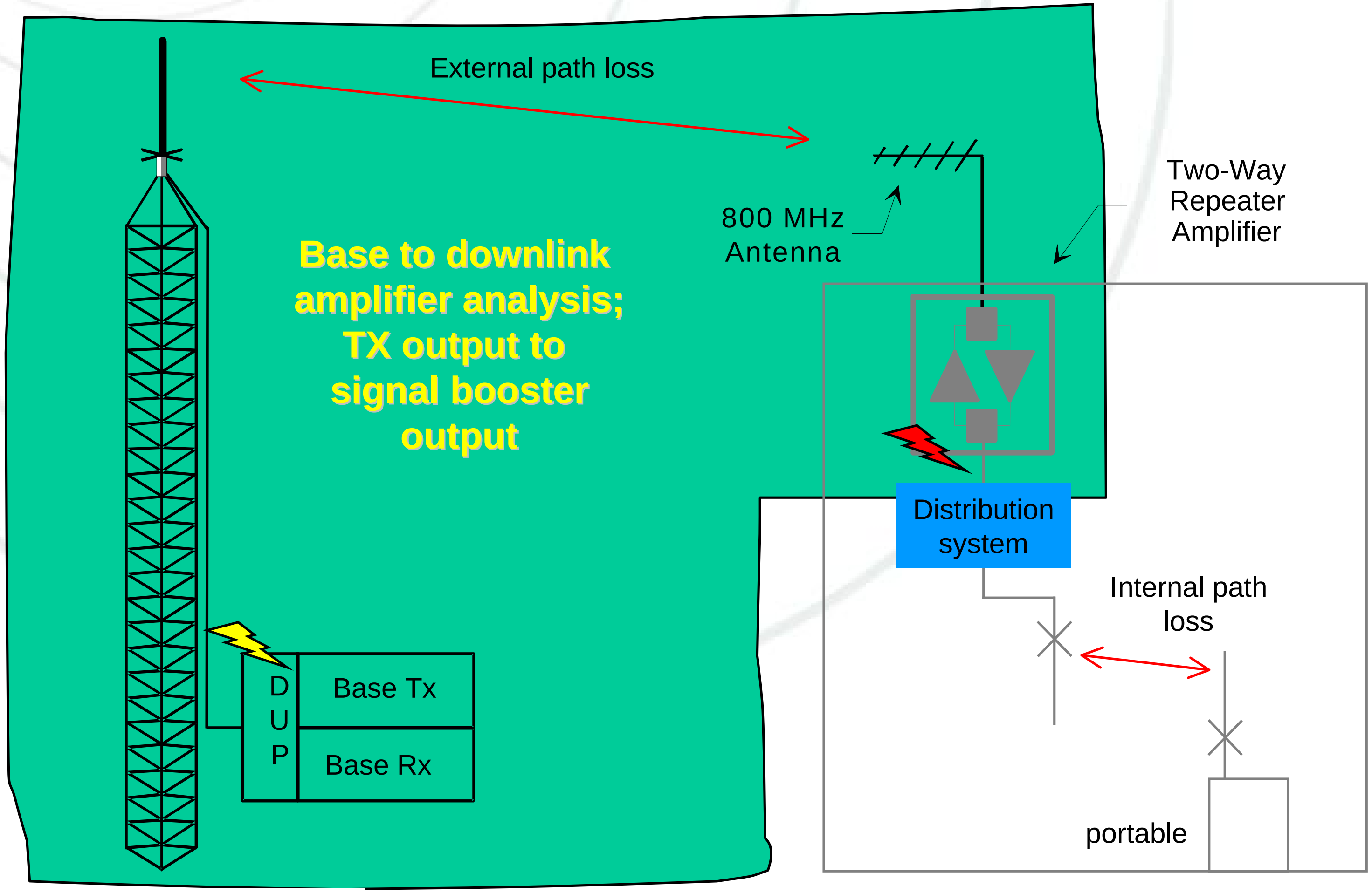
Tunnel Application



Shadowed Area Application



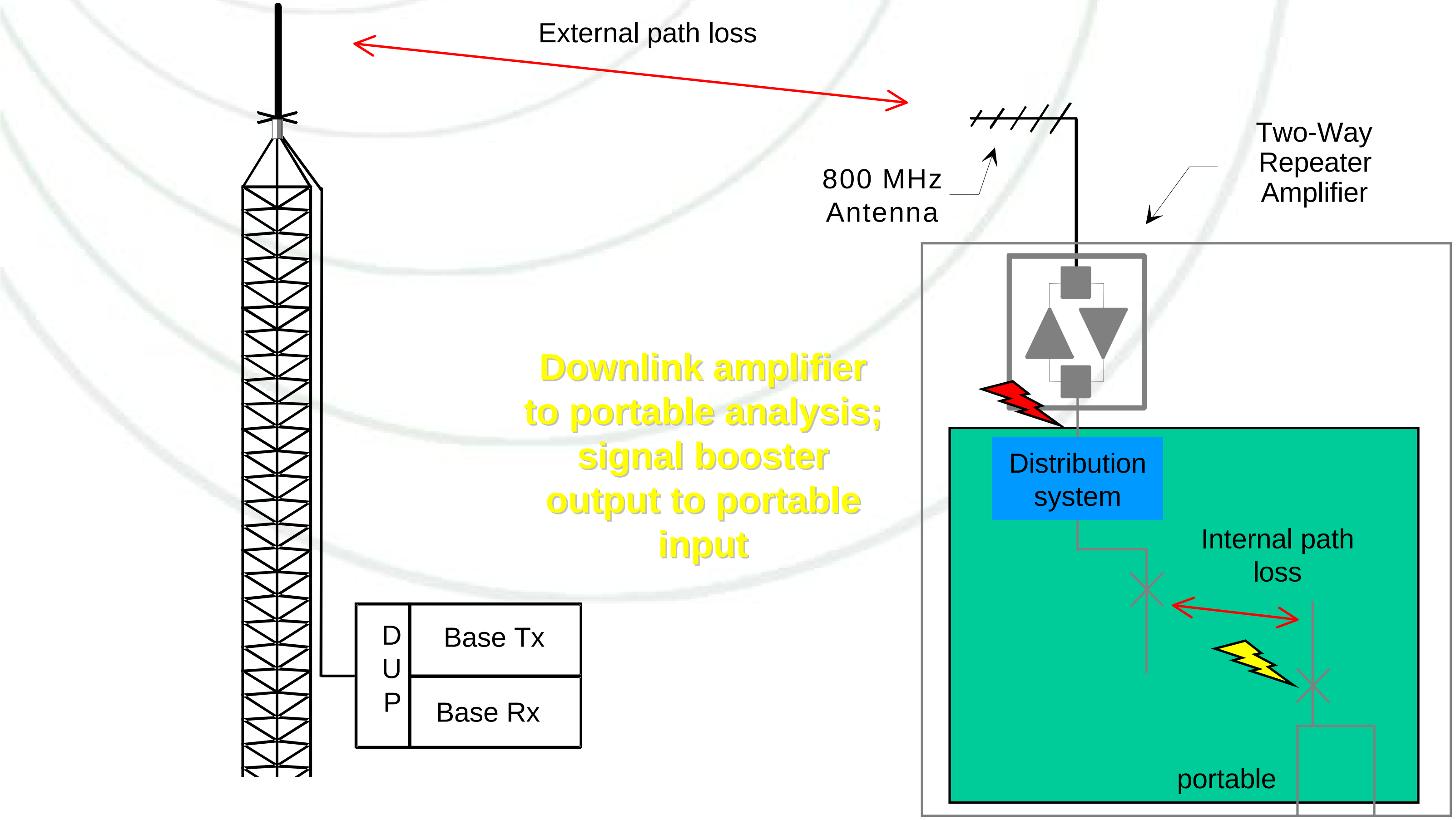
Spreadsheet Analysis



Spreadsheet Analysis

BASE TALK-OUT (DOWNLINK) ANALYSIS		
1. Base Tx Frequency (F1)	851.000	MHz
2. Base Tx Power	65.00	W
3. Portable Squelch Threshold	0.50	uV
BASE TO DOWNLINK AMPLIFIER		
4. Base Tx Combiner/Filter Loss	-4.50	dB
5. Base Tx Feedline Loss	-2.00	dB
6. Base Tx Antenna Gain	+11.10	dBi
7. Base->Site Distance	5.60	mi
8. Base->Site Free-Space Path Loss @ F1	-110.20	dB
9. Shadow and Other Path Losses	-20.00	dB
10. Site Antenna Gain	+12.10	dBi
11. Site Feedline Loss	-1.10	dB
12. Other Loss (HF preselector)	-3.00	dB
13. Total Base -> Downlink Amp Loss	**-117.60**	dB
14. Base Tx Power	**+48.10**	dBm
15. Downlink Amp Input Power	**-69.50**	dBm
16. Downlink Amp Gain	+70.00	dB
17. Downlink Amp Output Power	**+0.50**	dBm

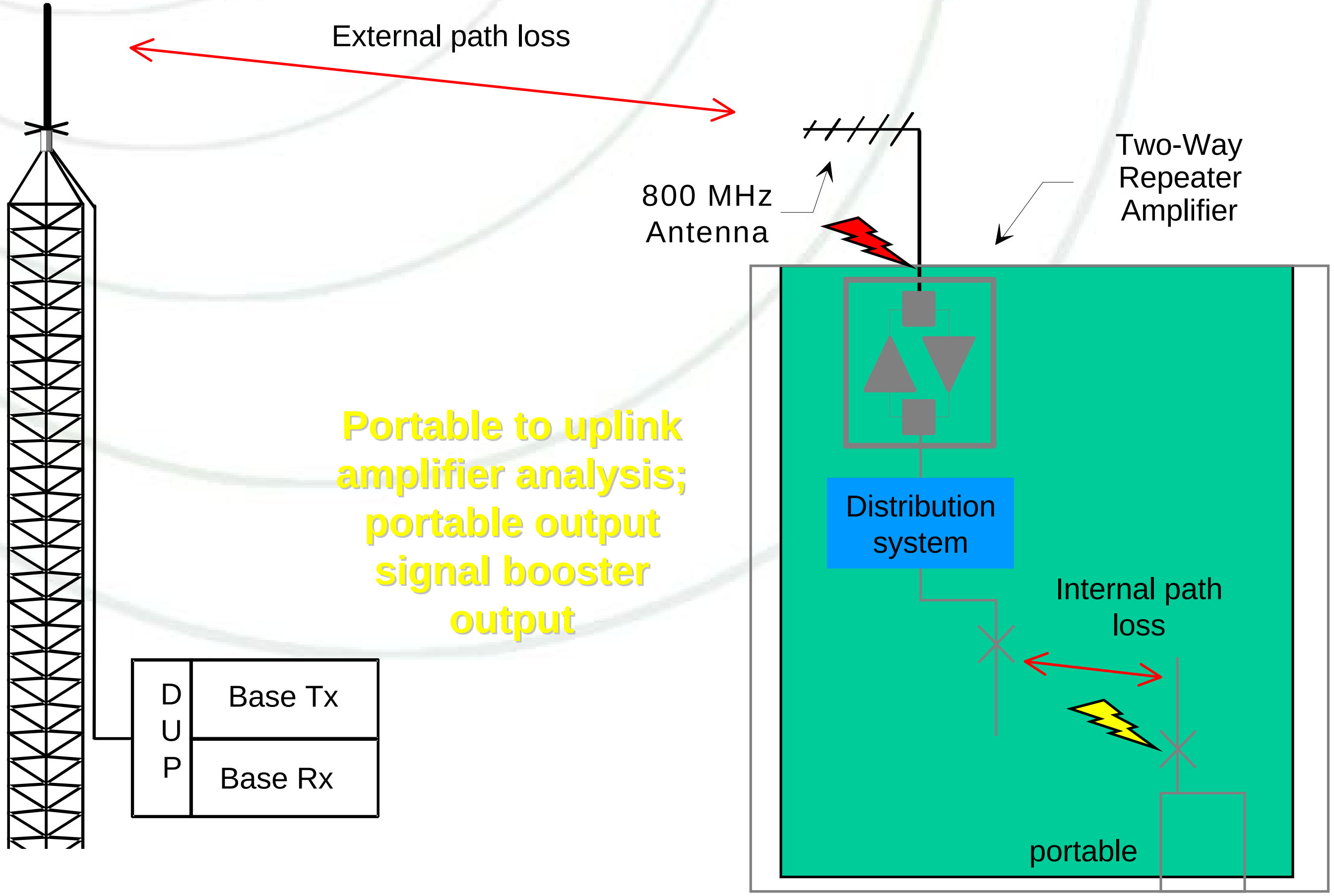
Spreadsheet Analysis



Spreadsheet Analysis

INSIDE CABLE SPECIFICATIONS				
18. Cable Type	RXL5-1			
19. Cable Length	300.00	ft		
20. Nominal Coupling Loss @ 20 ft	69.00	dB		
DOWNLINK AMPLIFIER TO PORTABLE/MOBILE				
21. RF Splitter and Other Losses	-3.00	dB		
22. Cable Transmission Loss	-5.16	dB		
23. Radiax Coupling Loss	-69.00	dB @	20.00	ft
24. Inside Antenna Decoupler Loss		dB		
25. Inside Antenna Gain		dBi		
26. Space Loss to Inside Antenna @ F1		dB @		
27. Design Margin	-15.00	dB		
28. Portable Antenna Gain, Rx Mode	-10.00	dBi		
29. Downlink Amp -> Mobile/Portable Loss	**-102.16**	dB		
30. Downlink Amp Output Power	+0.50	dBm		
31. Portable/Mobile Rx Input	**-101.66**	dBm		
32. Portable/Mobile Rx Sensitivity	-113.00	dBm		
33. MINIMUM RX MARGIN	**+11.34**	dB		
34. Downlink Amp OIP3	+44.00	dBm		
35. Allowable Power per Carrier (EIA)	+15.50	dBm		
Carrier Power Below Maximum by	-15.00	dB		

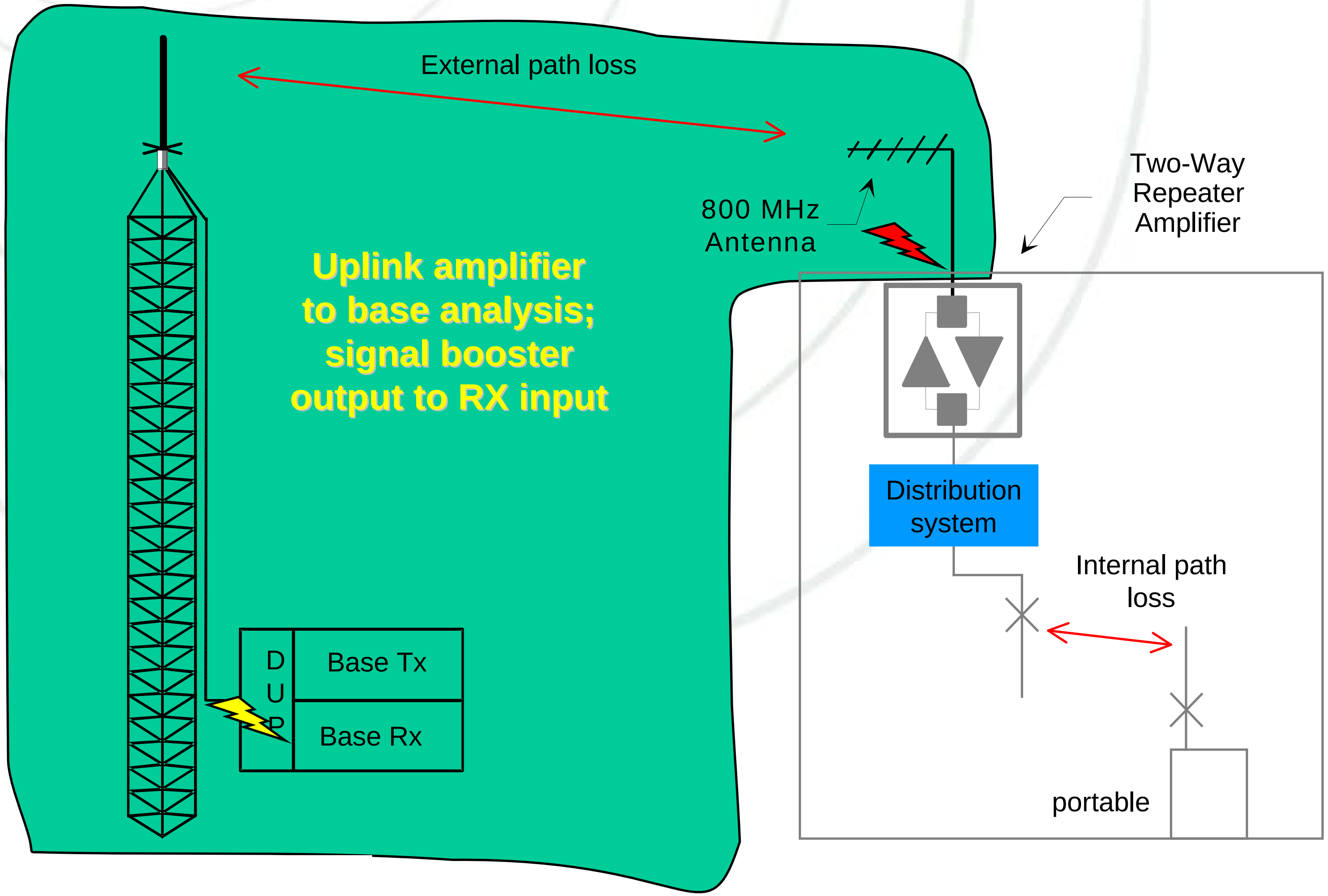
Spreadsheet Analysis



Spreadsheet Analysis

INSIDE CABLE SPECIFICATIONS		
18. Cable Type	RXL5-1	
19. Cable Length	300.00	ft
39. Nominal Coupling Loss @ 20 ft	69.00	dB
PORTABLE/MOBILE TO UPLINK AMPLIFIER		
28A Portable Antenna Gain, Tx Mode	-6.00	dBi
40. Space Loss to Inside Antenna @ F2		dB
25. Inside Antenna Gain		dBi
24. Inside Antenna Decoupler Loss		dB
41. Radiax Coupling Loss	-69.00	dB
42. Cable Transmission Loss	-5.16	dB
21. RF Splitter and Other Losses	-3.00	dB
27. Design Margin	-15.00	dB
43. Loss, Mobile/Portable to Uplink Amp	**-98.16**	dB
44. Mobile/Portable Tx Power	**+34.80**	dBm
45. Uplink Amp Input Power	**-63.36**	dBm
46. Uplink Amp Gain	+70.00	dB
47. Uplink Amp Output Power	**+6.64**	dBm

Spreadsheet Analysis



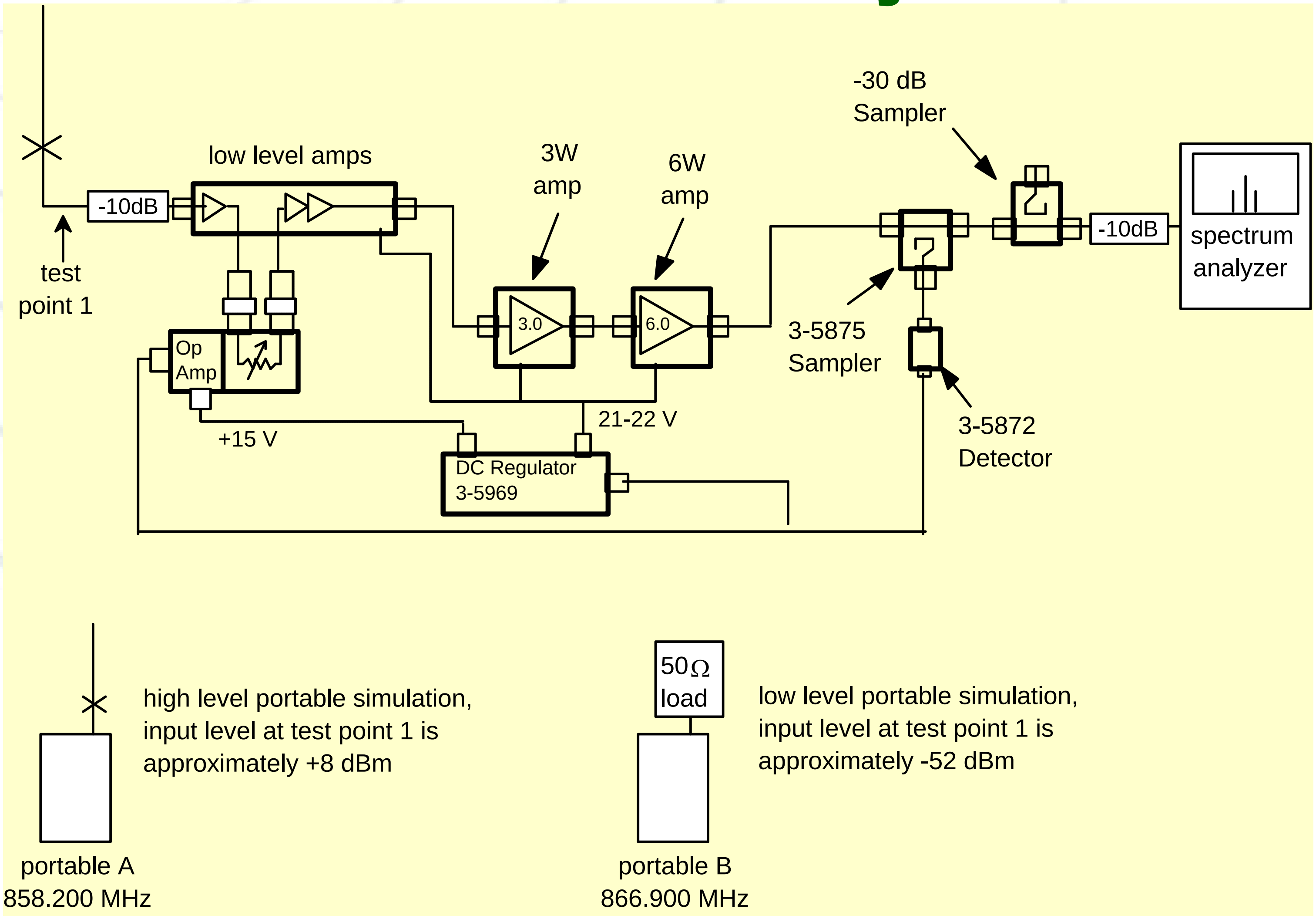
Spreadsheet Analysis

UPLINK AMPLIFIER TO BASE		
12A. Other Loss (LF preselector)	-2.00	dB
11. Site Feedline Loss	-1.10	dB
10. Site Antenna Gain	+12.10	dBi
7. Site->Base Distance	+5.60	mi
48. Site->Base Free-Space Path Loss @ F2	-109.70	dB
9. Shadow and Other Path Losses	-20.00	dB
6A. Base Rx Antenna Gain	+9.20	dBi
5A. Base Rx Feedline Loss	-2.00	dB
49. Base Rx Multicoupler Net Gain	+5.00	dB
50. Loss, Uplink Amp to Base	**-108.50**	dB
51. Uplink Amp Output Power	+6.64	dBm
52. Base Rx Input	**-101.86**	dBm
53. Base Rx Sensitivity	-113.00	dBm
54. MINIMUM RX MARGIN	**+11.14**	dB
55. Uplink Amp OIP3	+44.00	dBm
56. Allowable Power per Carrier (EIA)	+15.50	dBm
Carrier Power Below Maximum by	-8.86	dB

Limitations

- Antenna isolation must be 20 dB greater than Signal Booster gain
- Signal Boosters are low power and are usually not meant to replace repeaters or base stations
- Signal Booster input levels should be -70 dBm or greater (S/N becomes an issue below this level)
- Guard band should be greater than the band width

OLC Demo - System Balance



OLC Voltage Matrix

RFI

OLC REPEATER AMPLIFIER DATA SHEET

Model No. 2483E

Serial No. 2483E

Date 14-Jul-97

Technician DDB

Test with two equal carrier outputs per passband.
All levels indicated are per carrier.
A unit adjusted for single carrier per passband must
have OLC circuit readjusted for two carriers per passband.

Low Freq. Passband 859.5-860.5 MHz

Output Level, OLC Circuit disable 27 dBm

Output Level, OLC Circuit set at 26 dBm

Output Intercept Point 46.75 dBm

Max. Gain 82.1 dB

Test Freqs 859.9/860.1 Mhz

Control Voltage 6.16 VDC

Control Voltage 3.29 VDC

1dB Compression Point 37 dBm

Level of Overload (dB)	Control Voltage (V)	Output Level (dBm)
5	1.52	26.00
10	1.27	26.00
15	1.15	26.00
20	1.07	26.00
25	1.00	26.00
26	0.99	26.00
27	0.98	26.00
28	0.96	26.00
29	0.95	26.00
30	0.93	26.00
35	-0.19	26.00
40	-0.19	30.67

Max. Power Out 31.4 dBm

One carrier

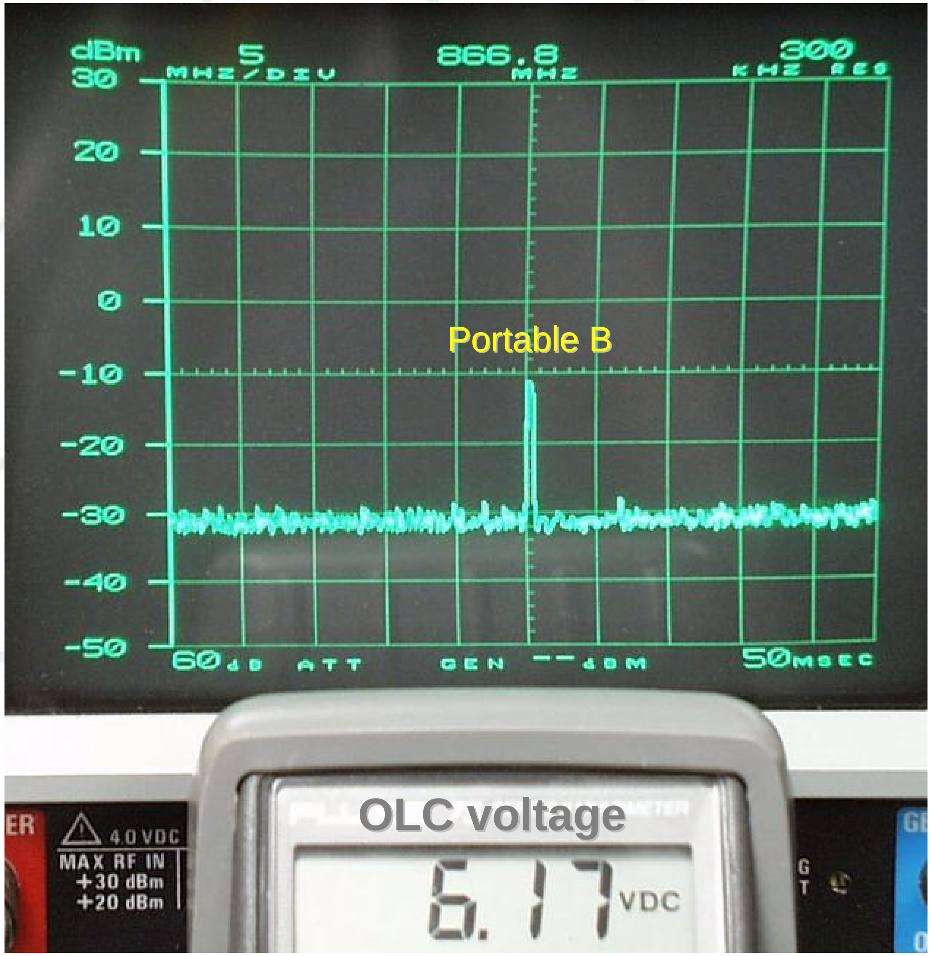
Unit Gain - 82.1 dB

Max. Input

One Carrier -50.7 dBm

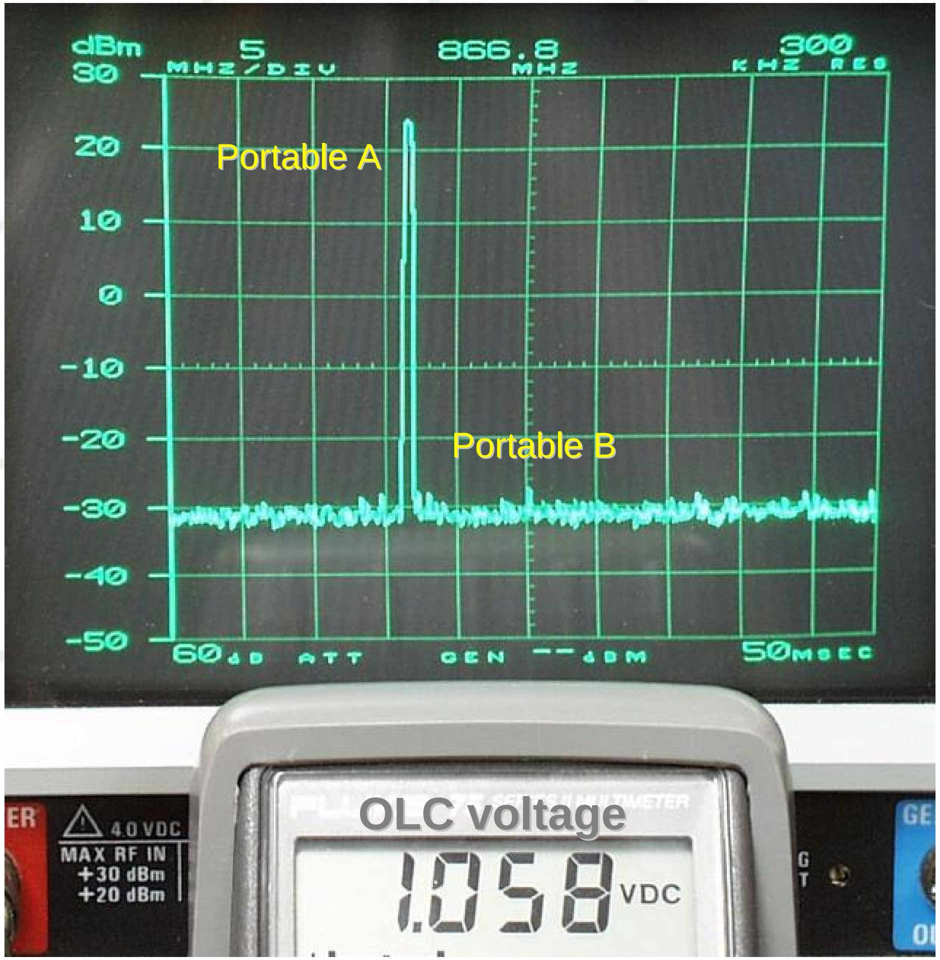
OLC Demo - System Balance

- Weak signal received from portable B
- OLC not active

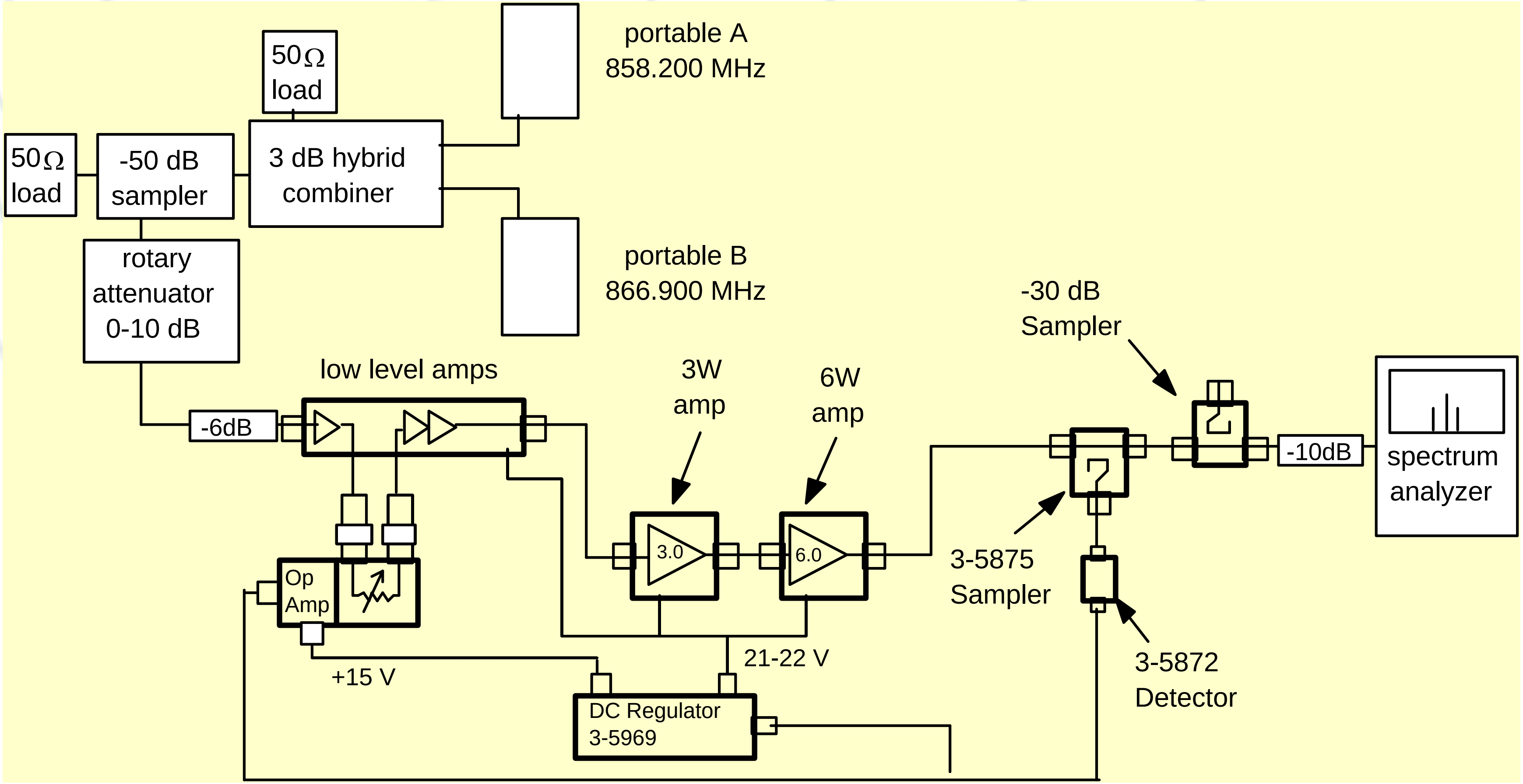


OLC Demo - System Balance

- Strong signal received from portable A
- OLC activates and reduces gain
- Weak signal from portable B "disappears"

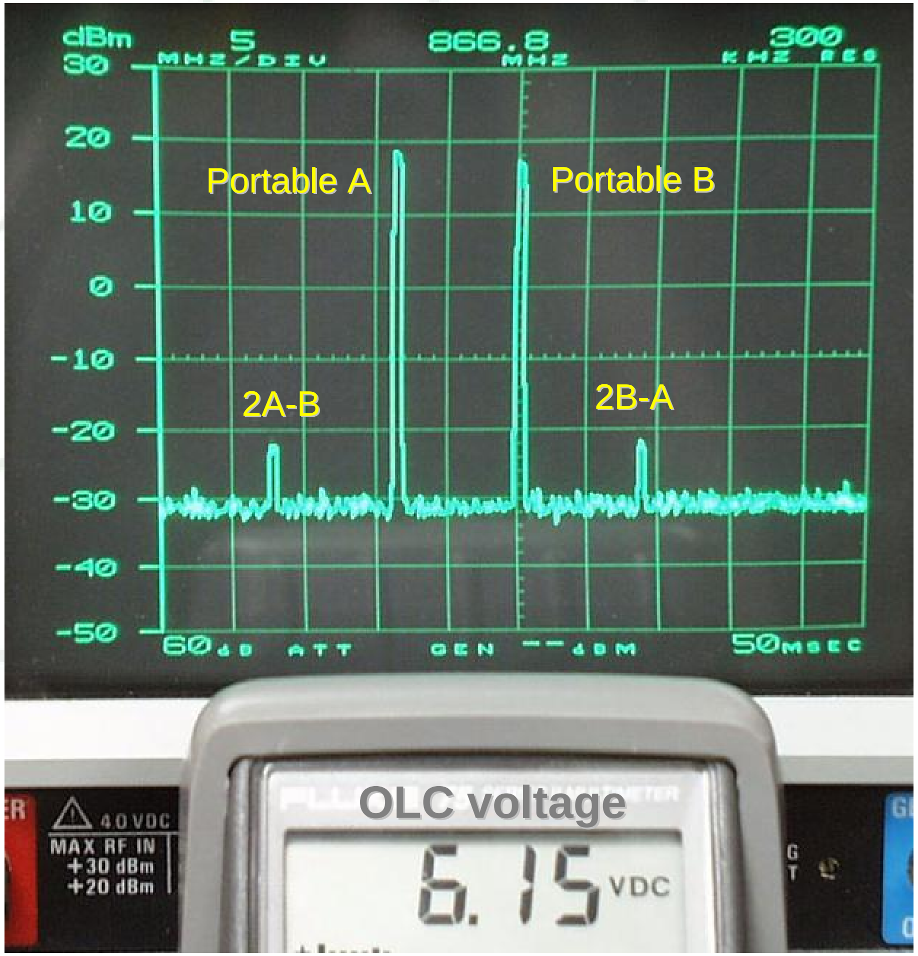


OLC Demo - IM Control



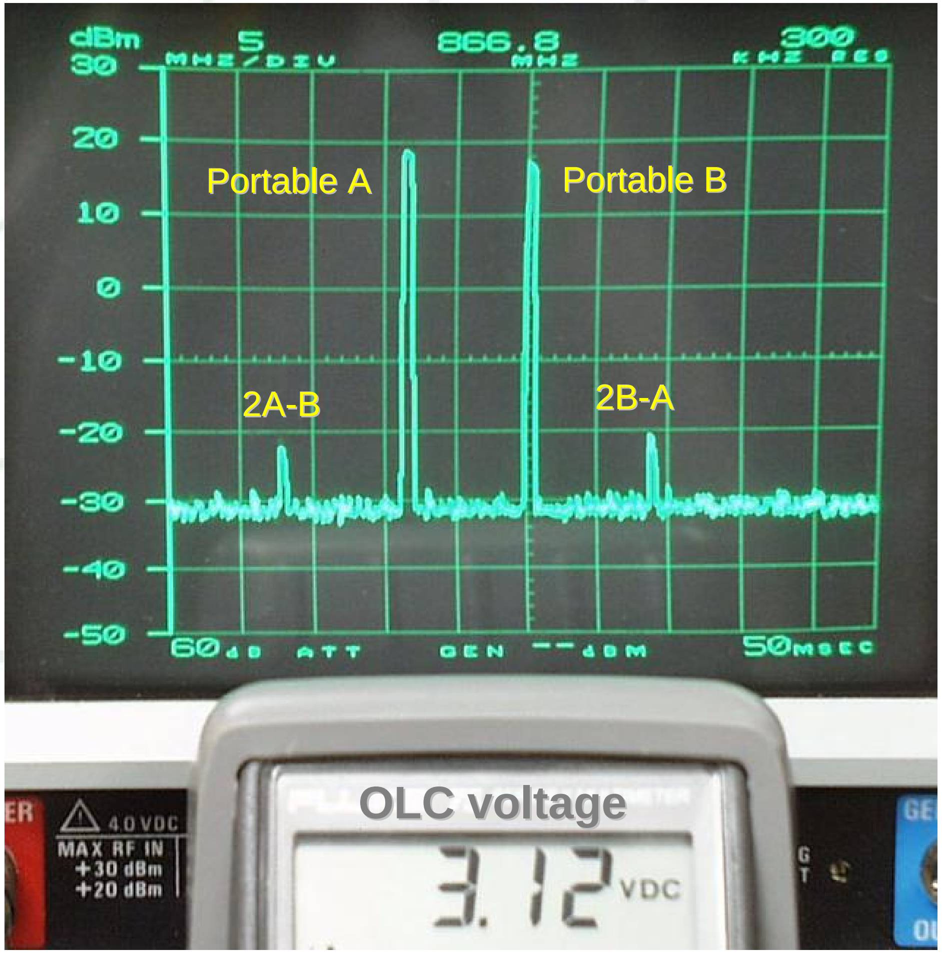
OLC Demo - IM Control

- Both portables keyed
- OLC not active
- 3rd order IM within spec



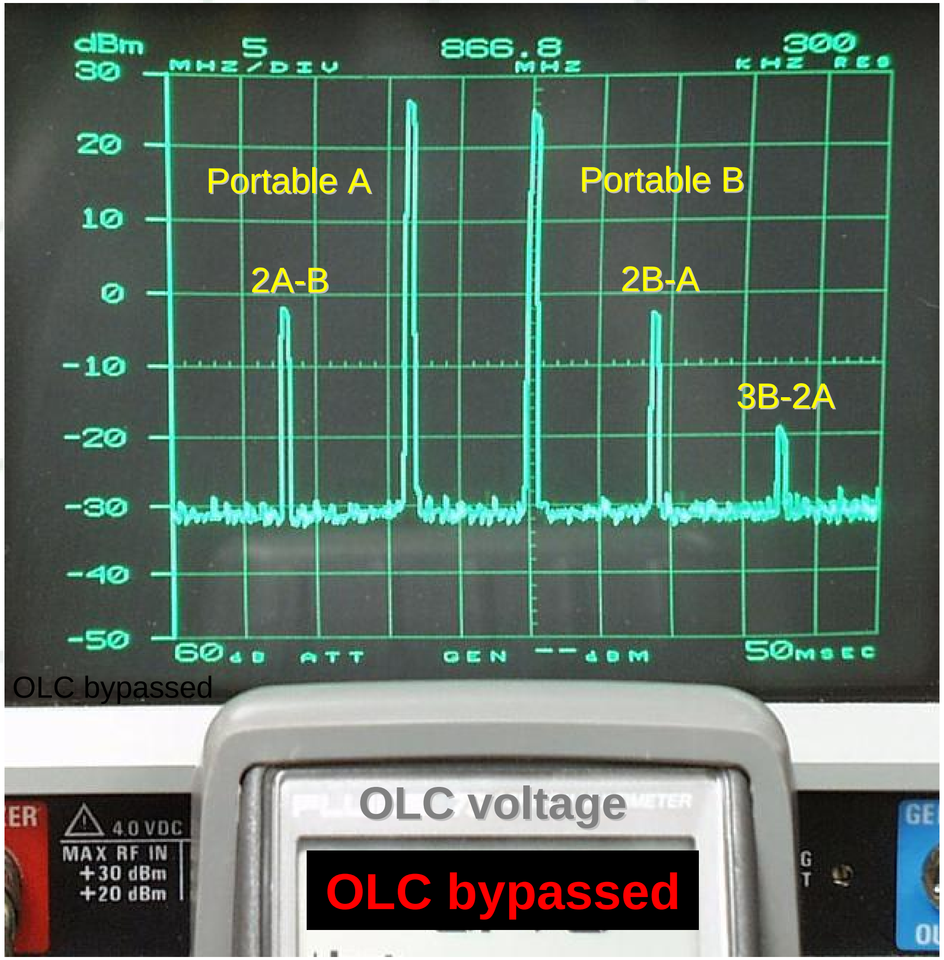
OLC Demo - IM Control

- Increased input signal level activates OLC
- Carriers and IM levels controlled



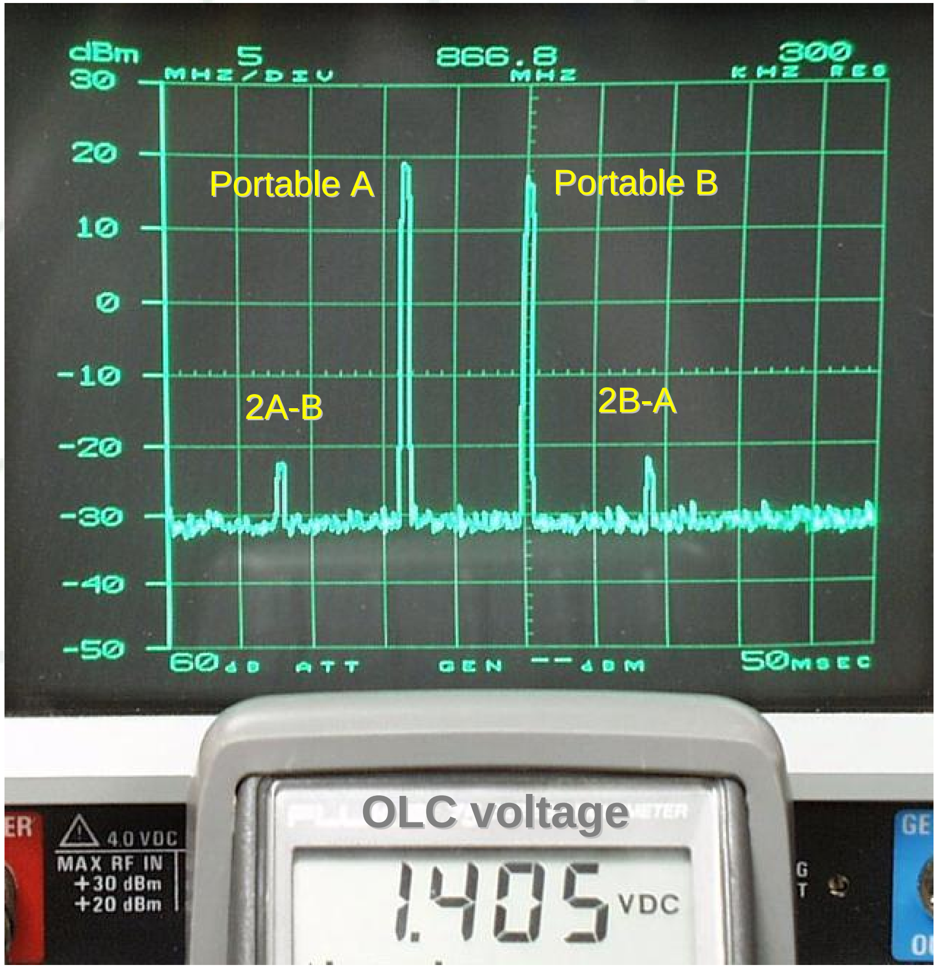
OLC Demo - IM Control

- OLC *bypassed*
- IM increasing at 3:1 vs. carrier



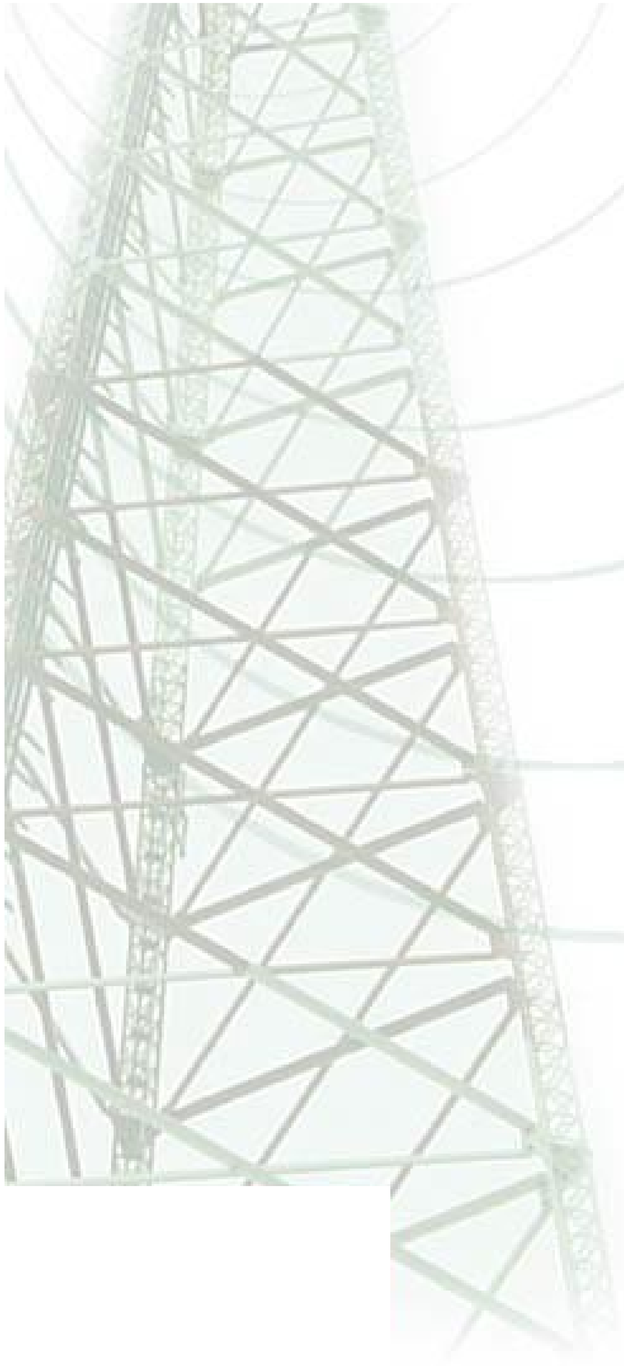
OLC Demo - IM Control

- OLC re-activated
- IM levels drop dramatically



Summary

- Amplified distribution systems are a cost effective solution for coverage problems
- Each application must be analyzed which includes spreadsheet analysis and a site survey



Questions?

Intermodulation and Interference Analysis

RF Interference - Intermodulation

<u>Passive</u>

Slightly to moderately non-linear

- Antenna elements, connectors, towers, etc.

<u>Active</u>

Moderately to excessively non-linear

- Class A amplifiers (moderate)
  - Signal boosters, multicouplers
- Class C amps. (excessive)
  - Transmitter power amplifiers
  - Receiver mixers

Applications

Component specifications need to be replaced by system specifications:

- **System noise figure**
- **System 3OIP intercept point**
- **System 1 dB compression point**

Tools & Solutions

- Intermodulation Programs
- Isolation Requirement Programs
  - radio specific duplex operating curves
- Filters
- Isolators
- Multiple antennas
  - channel re-arrangement
- Frequency change

RF Interference Resolution

Type:

- TX Noise Suppression (TX circuit), as determined by duplex operating curves
- Carrier Rejection (RX circuit), as determined by duplex operating curves
- IM, as determined by system analysis

Achieved through:

- Cavity filters (noise, carrier, IM)
- Isolators (IM)
- Antennas (noise, carrier, IM)

Tools & Solutions – Filters

- Bandpass
- Notch
- Pseudo Bandpass (or pseudo notch)

Filters - Why We Need Them

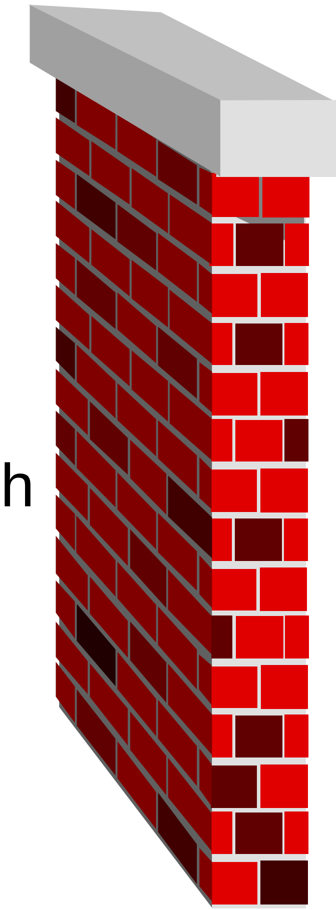
- Limit Receiver Desense
- Limit Intermodulation Problems
- Multicoupling or Combining

Receiver Desense

- Contributing Factors
  - Transmitter Carriers
  - Transmitter Noise
- Contribution from each of these is EQUAL

Tx Carrier Desense

- Rx front ends filter out unwanted signals
- Filters are not “brickwall”
- Unwanted signals are *attenuated*, not completely removed
- Attenuation is generally not enough
- Unwanted signals “break through”



Tx Carrier Desense

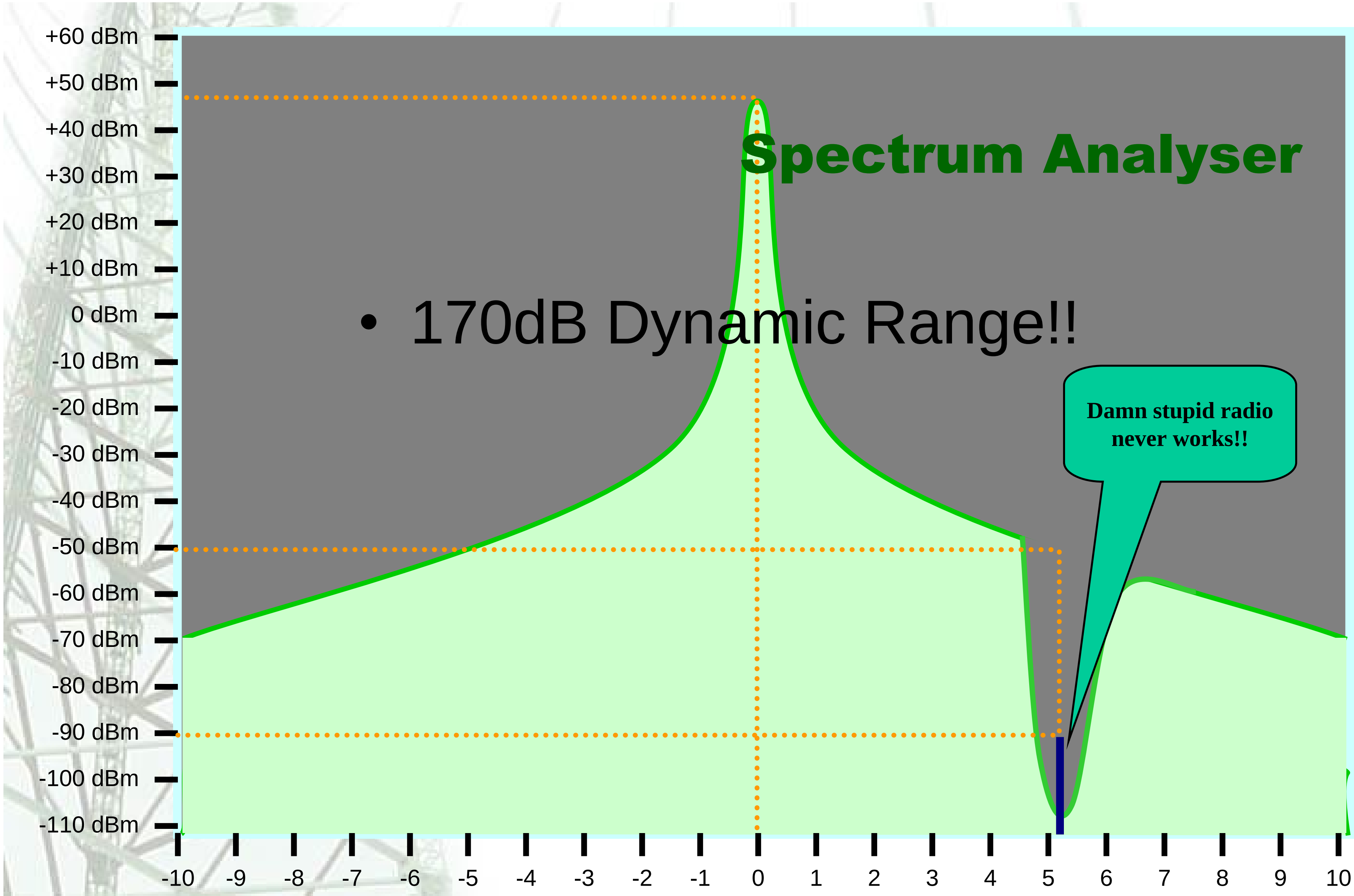
– Causes gain cutback - “Blocking”
– Receiver is “deaf” to weak signals
– Problem is exacerbated as Tx to Rx separation decreases

Tx Noise Desense

- Transmitter outputs are not “spectrally pure”
- Significant noise floor is unavoidable
- Noise is broadband
- Noise will exist at Rx frequency
- Noise swamps mobile signal - “Desensitisation”
- Receiver is again “deaf” to weak signals
- Problem is also exacerbated as Tx to Rx separation decreases

Spectrum Analyser

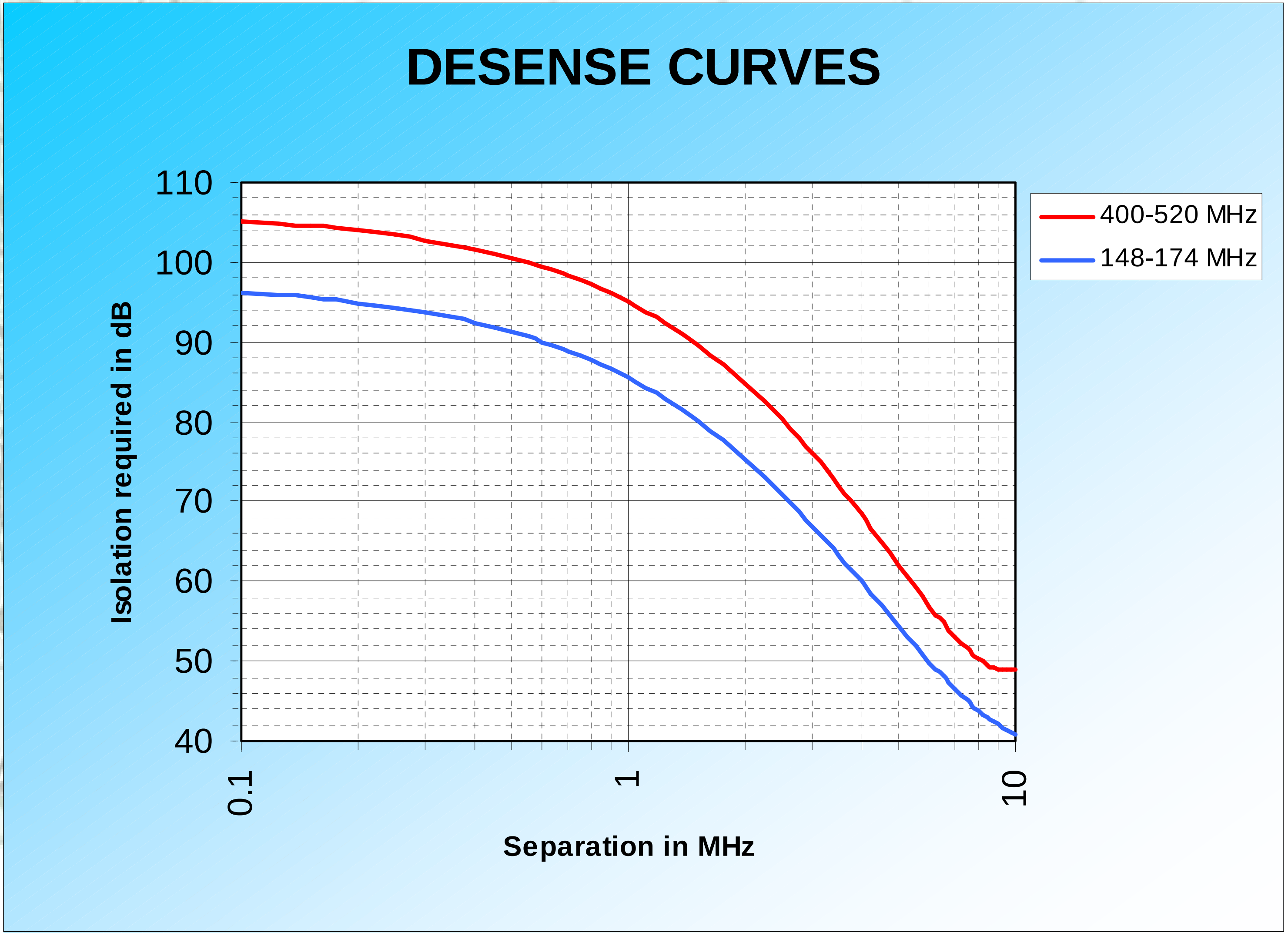
- 170dB Dynamic Range!!



How Much Filtering Do I Need?

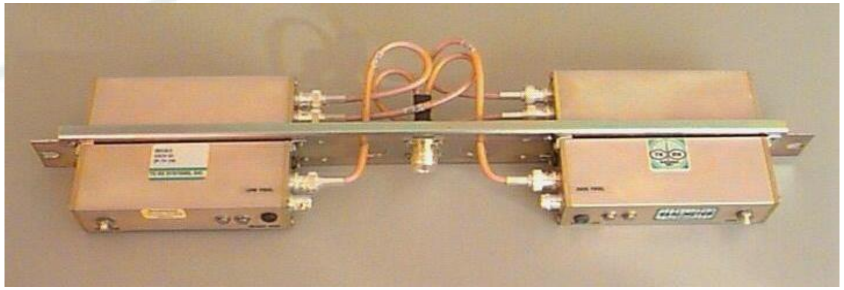
- Will vary slightly from base to base
  - Some transmitters are noisier than others
  - Some receivers are broader than others
- Need to attenuate (by equal amounts):
  - Transmitter carrier level at receiver
  - Transmitter noise level at transmitter
- Use receiver Desense Curve to work out

Typical Desense Curves



What Contributes?

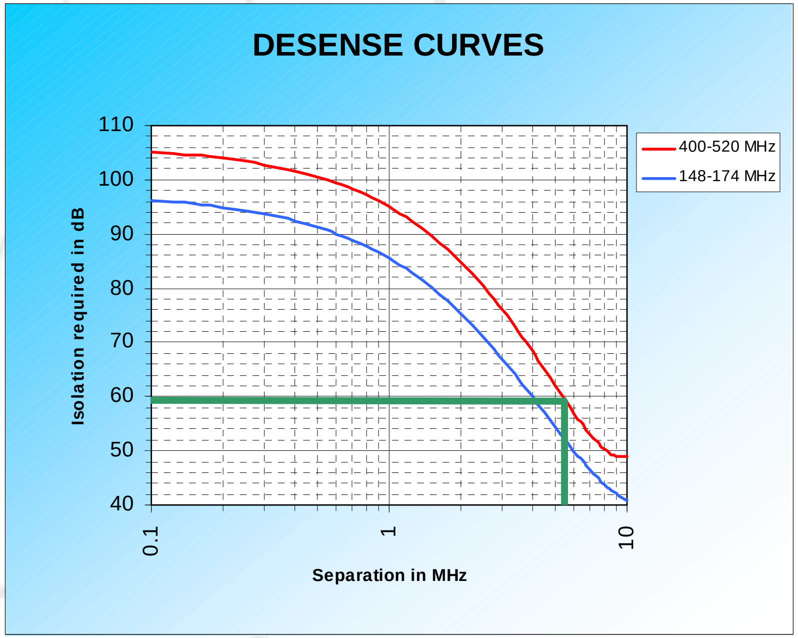
- Isolation gained through:
  - Filtering
  - Antenna isolation
  - Combinations of both



Example Calc

	Tx	Rx
Base 1	461.000	451.500
Base 2	465.000	455.500

Minimum Tx-Rx = 5.5 MHz



	Running total
Total isolation required	59 dB
Antenna isolation available	35 dB
Filtering required	24 dB

What About Other Co-Sited Bases

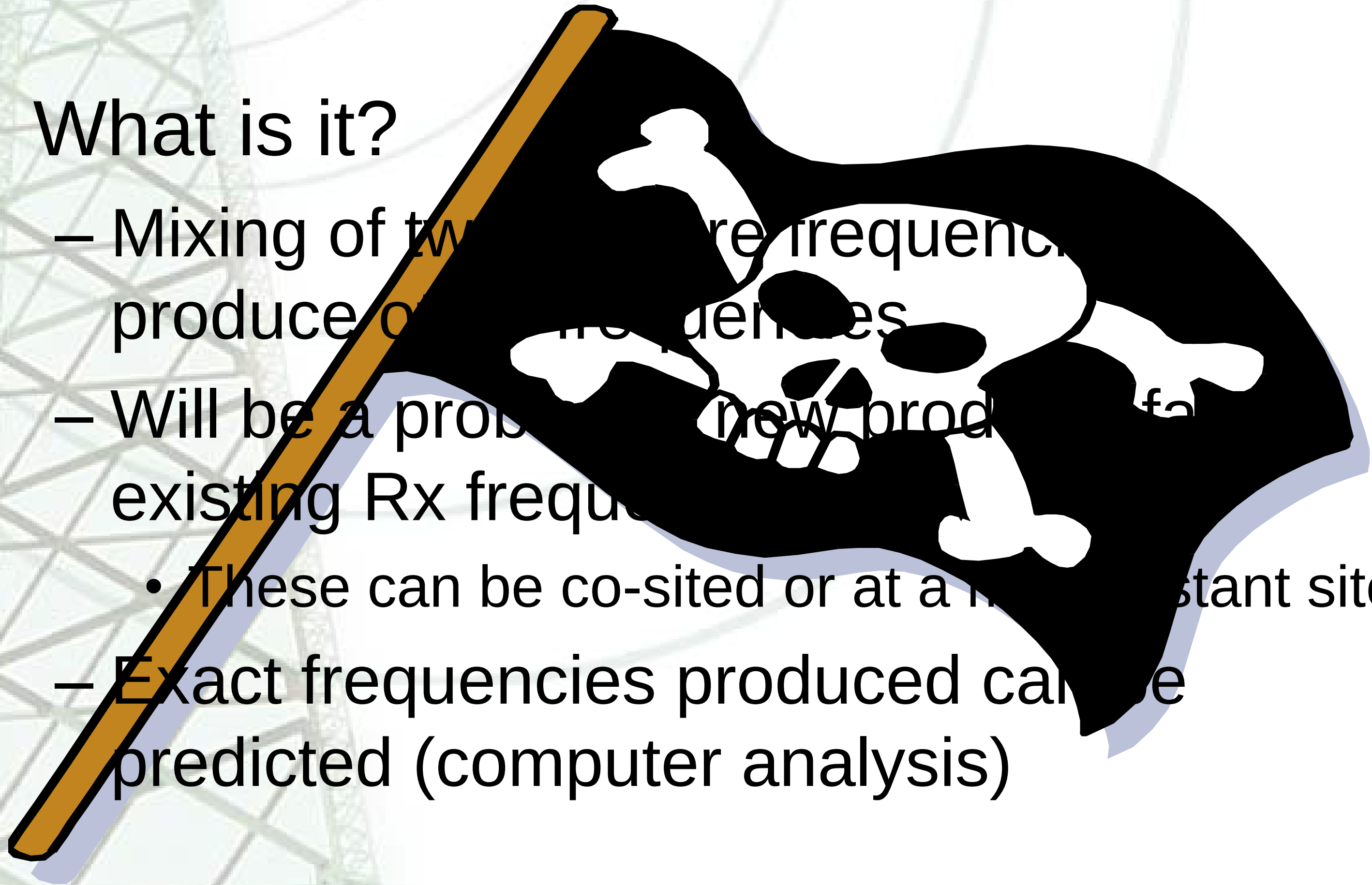
- Need to look at other services
  - Especially if these are in-band
  - Must know frequencies
  - Must know approximate antenna placements

Filters - Why We Need Them

- Limit Receiver Desense
- Limit Intermodulation Problems

Intermodulation

- What is it?
  - Mixing of tw[illegible]re frequenc[illegible] produce o[illegible] frequencies
  - Will be a prob[illegible] new prod[illegible] fa[illegible] existing Rx frequ[illegible]
    - These can be co-sited or at a n[illegible]stant site
  - Exact frequencies produced can be predicted (computer analysis)



Intermodulation

- How is it controlled?
  - If possible, eliminate the mixing medium (eg rusty bolt)
  - Intermod levels are reduced by reducing the level of the component signals
  - Reducing the level of only *one* of the component signals will reduce the intermod!

Where Do Mixes Occur?

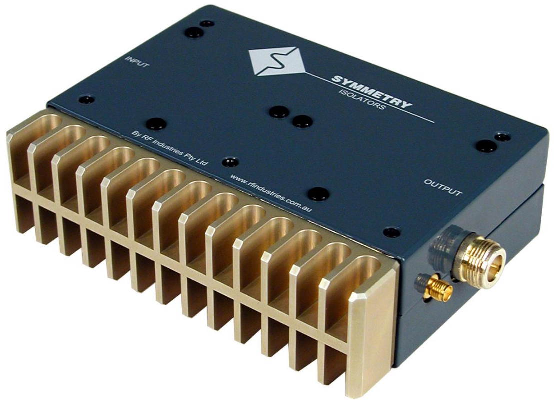
- At any non-linear device
  - – Can be an amplifier, such as Tx PA's or RF preamps (active devices)
  - – Can be metallic junctions or surfaces (passive devices)

Mixes In Tx Power Amplifiers

- Class C amplifiers
- Inherently non-linear
- Carrier will mix with other signals present and produce intermods
- Typical "conversion efficiency" is -15dB for 3rd order products
- Isolators are used to reduce intermod signal levels

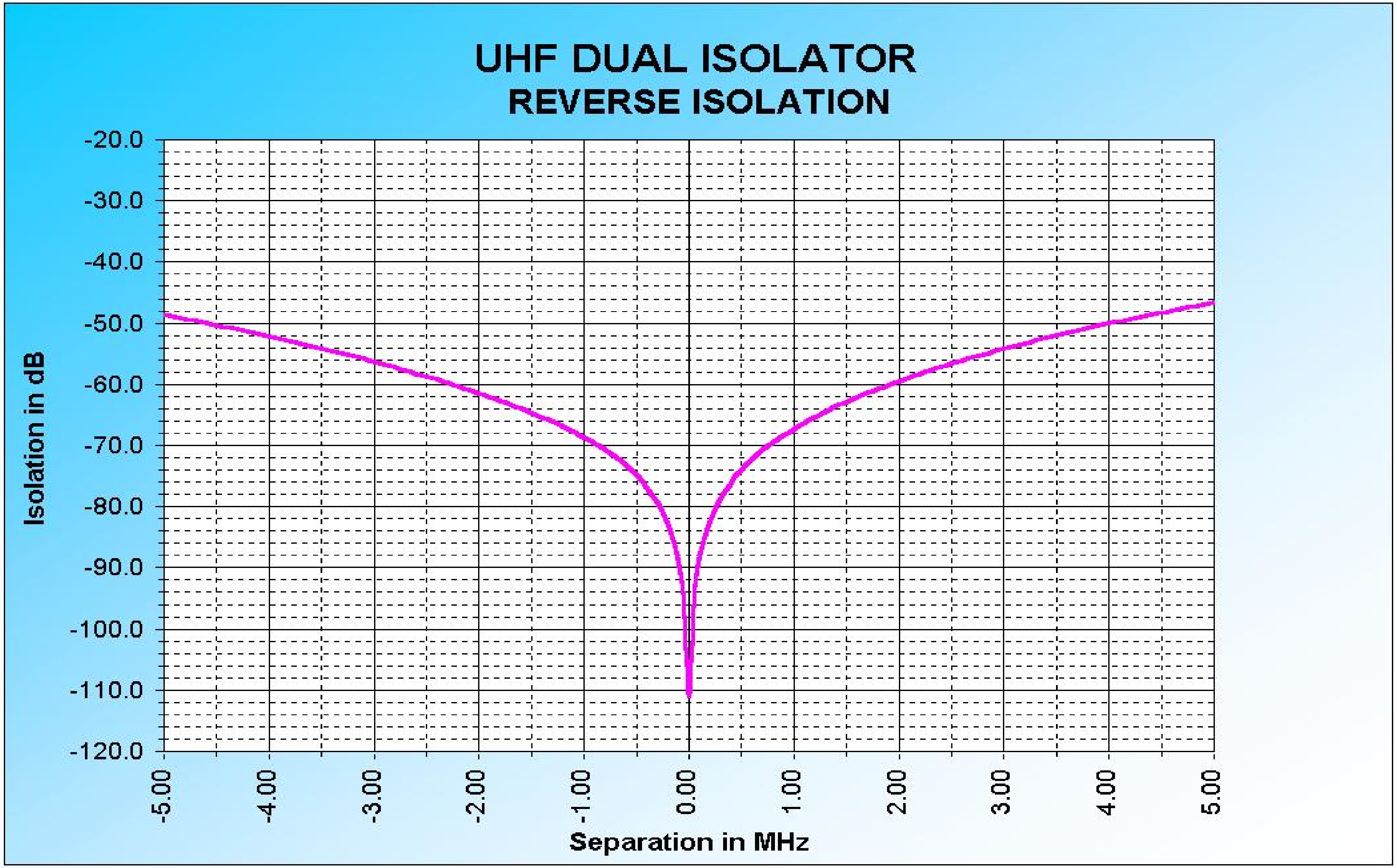
Mixes In Tx Power Amplifiers

- Role of Isolators
  - Have *nothing* to do with providing Tx to Rx isolation!
  - RF equivalent to a diode



Mixes In Tx Power Amplifiers

- Provide intermod suppression by reducing the level of unwanted signals in Tx output stages
- Reverse isolation figure of merit relates directly to level of suppression of intermod
- Isolation reduces as the signal frequency moves away from the tuned frequency of the isolator

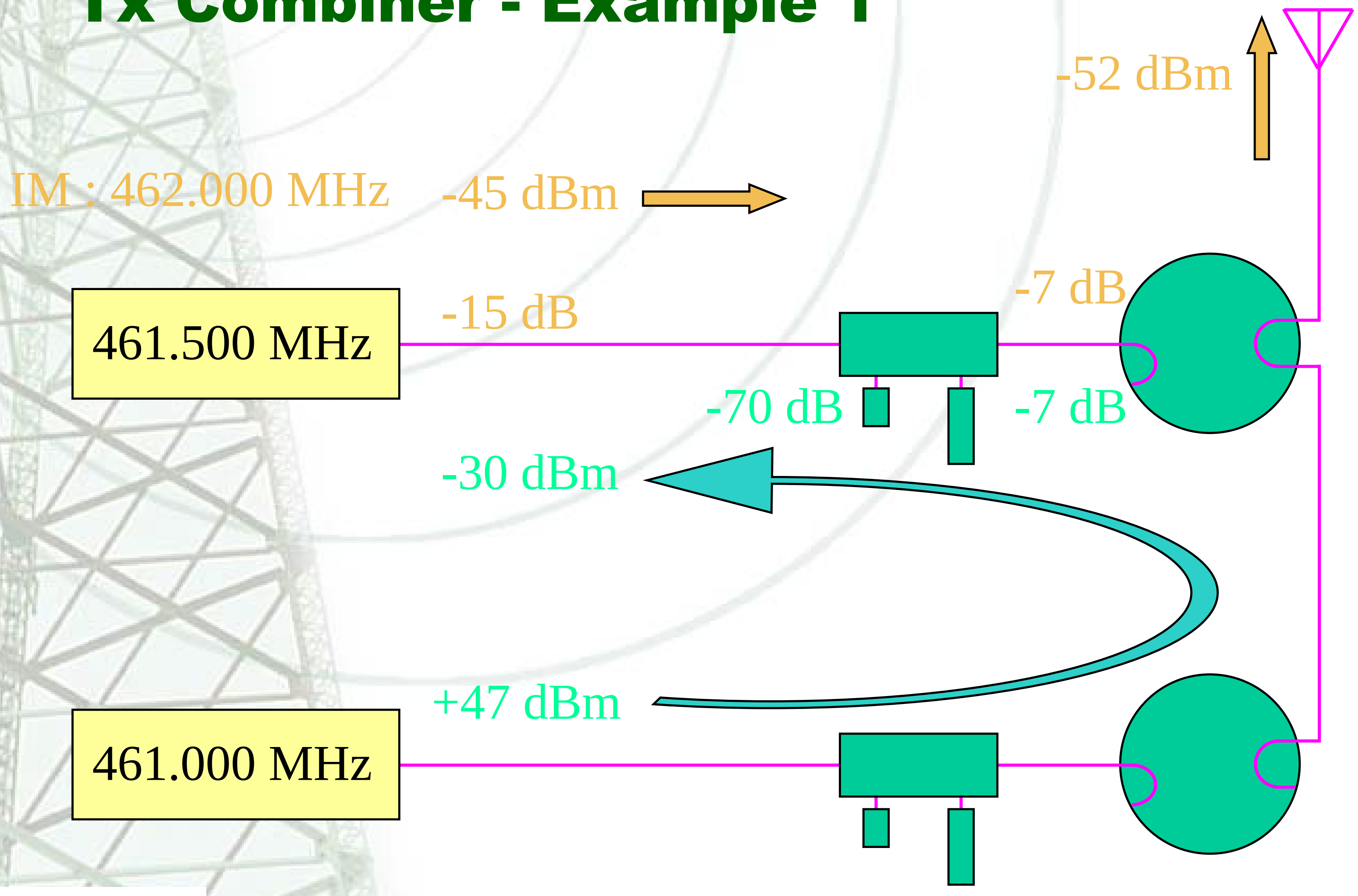


UHF DUAL ISOLATOR
REVERSE ISOLATION
Isolation in dB
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
Separation in MHz

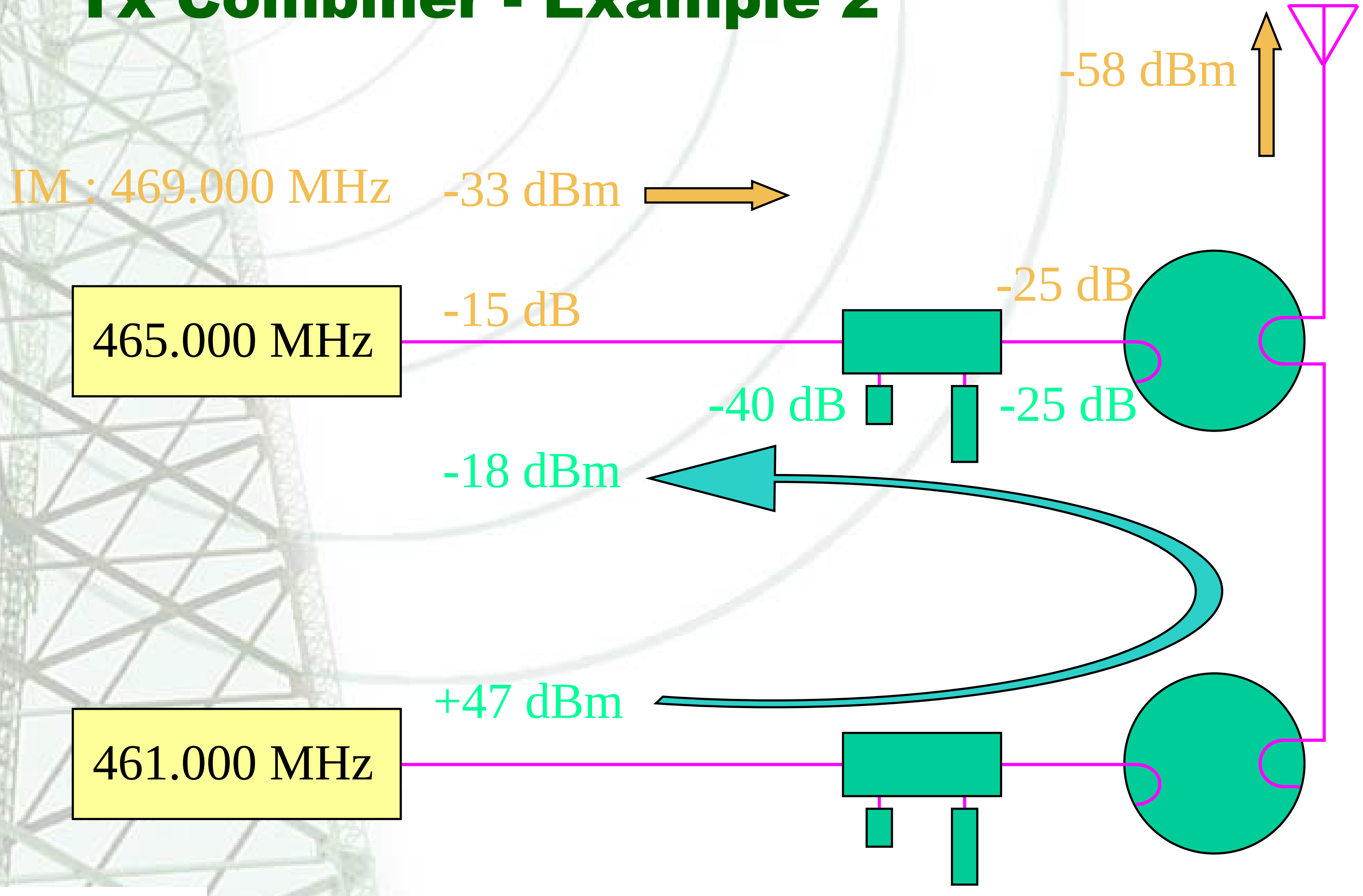
Mixes In Tx Power Amplifiers

- Role of Bandpass Filters
  - Primarily to provide transmitter noise suppression
  - Can also provide a high level of intermod suppression
  - The level of suppression depends on how close the intermod frequency is to the resonant frequency of the filter
  - Filter response complements isolator response

Tx Combiner - Example 1



Tx Combiner - Example 2

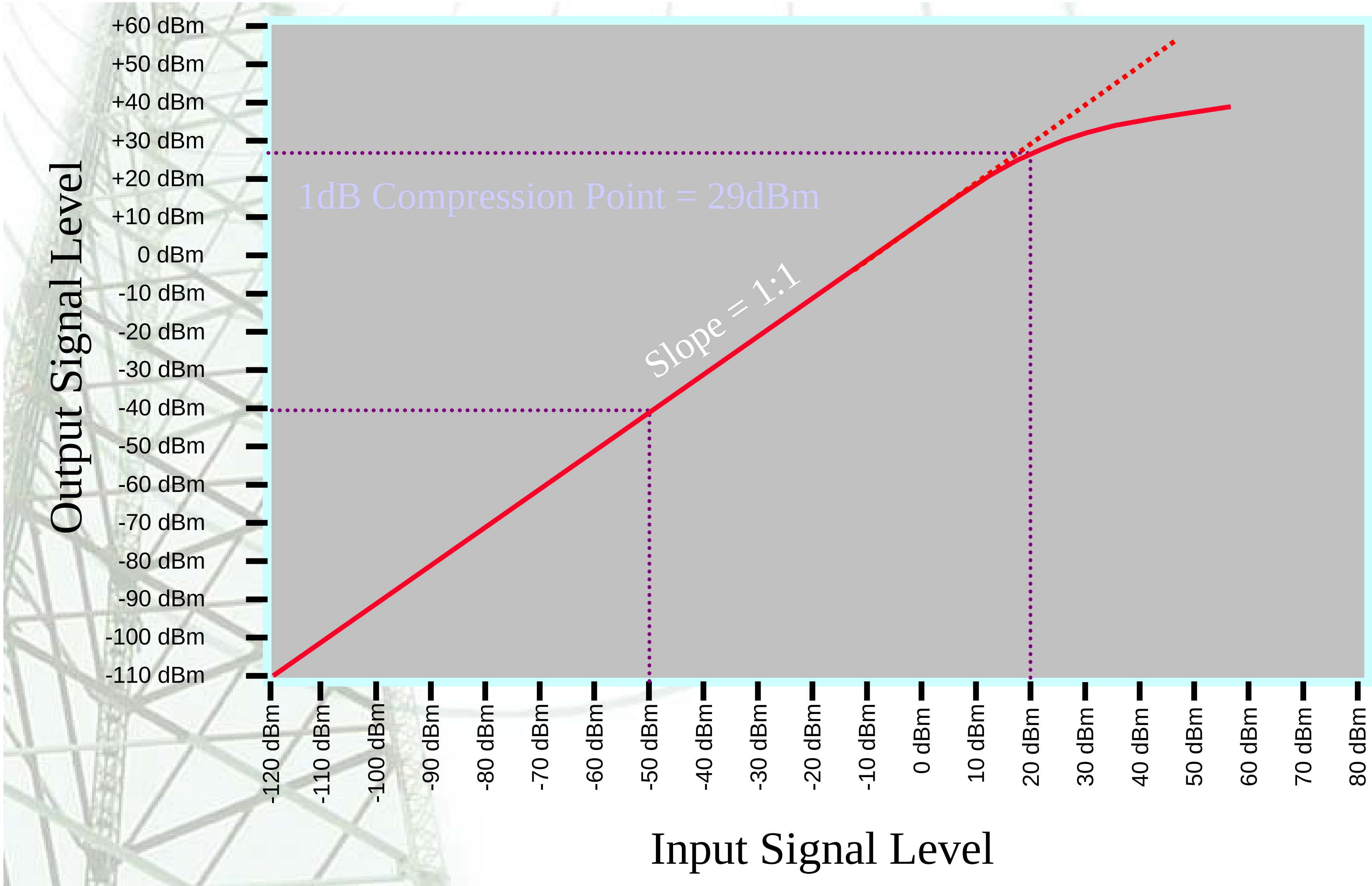


How Are Tx PA Intermods Reduced?

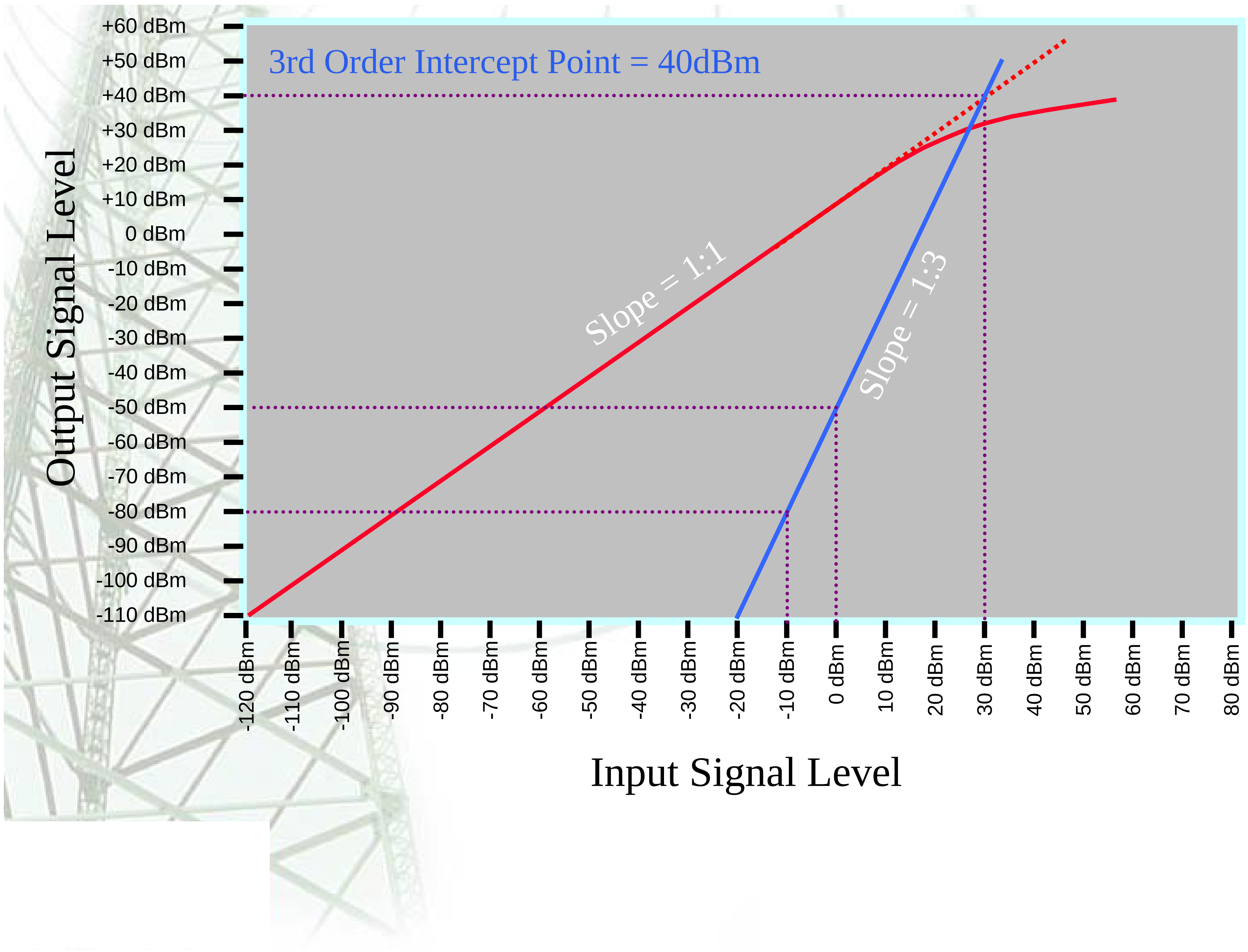
- As mentioned before, reduce component signal levels
  - Split up over different combiners
  - Filter out offending component
  - Increase isolator suppression
  - Combinations of all of these

Mixes In Rx Systems

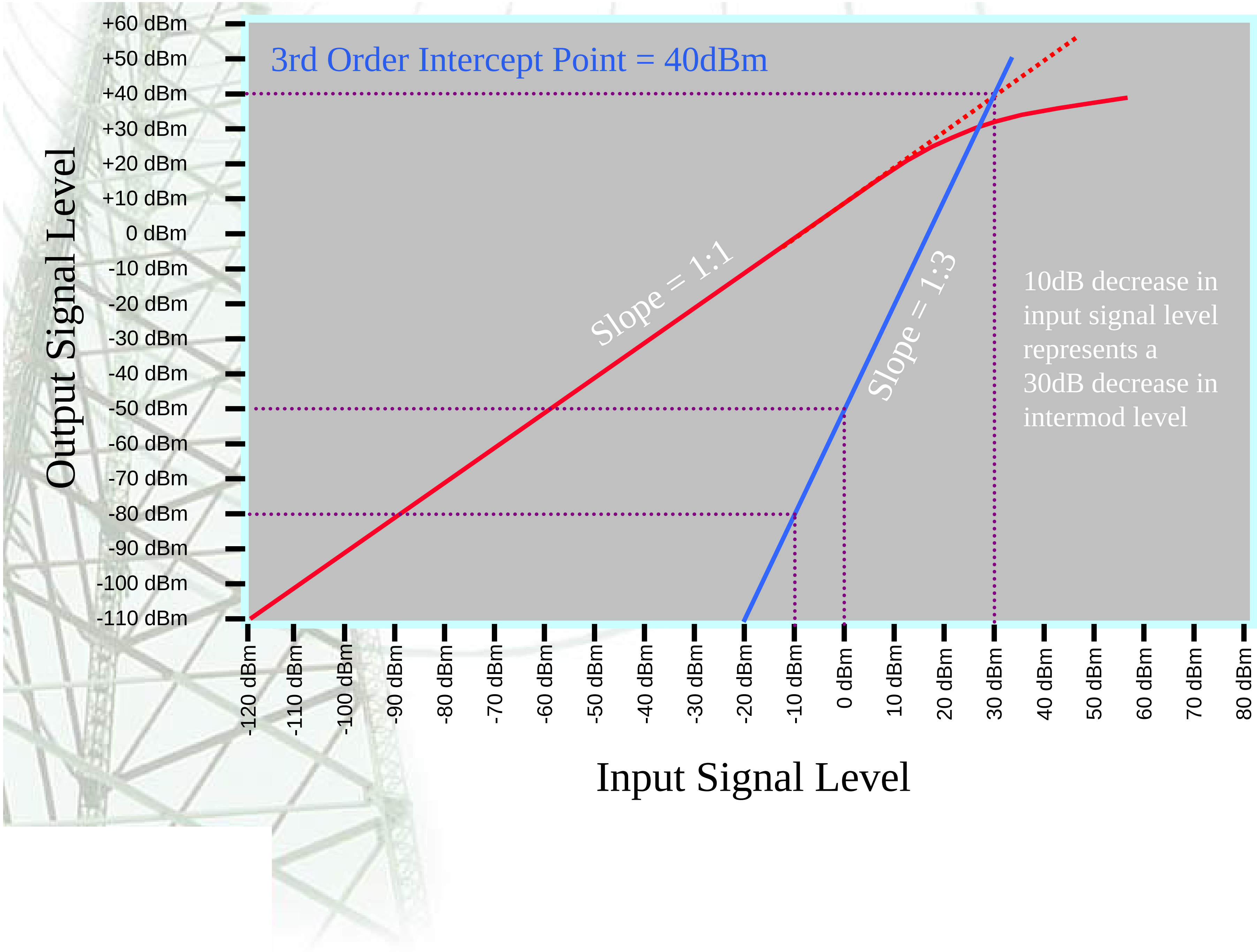
- Receiver Pre-Amplifiers (& Receivers)
  - Ultra-linear class A amplifiers
  - Some degree of non-linearity always exists
  - This non-linearity produces mixing
  - Measure of how well the amplifier performs with respect to producing intermods is given by the 3rd Order Intercept Point specification

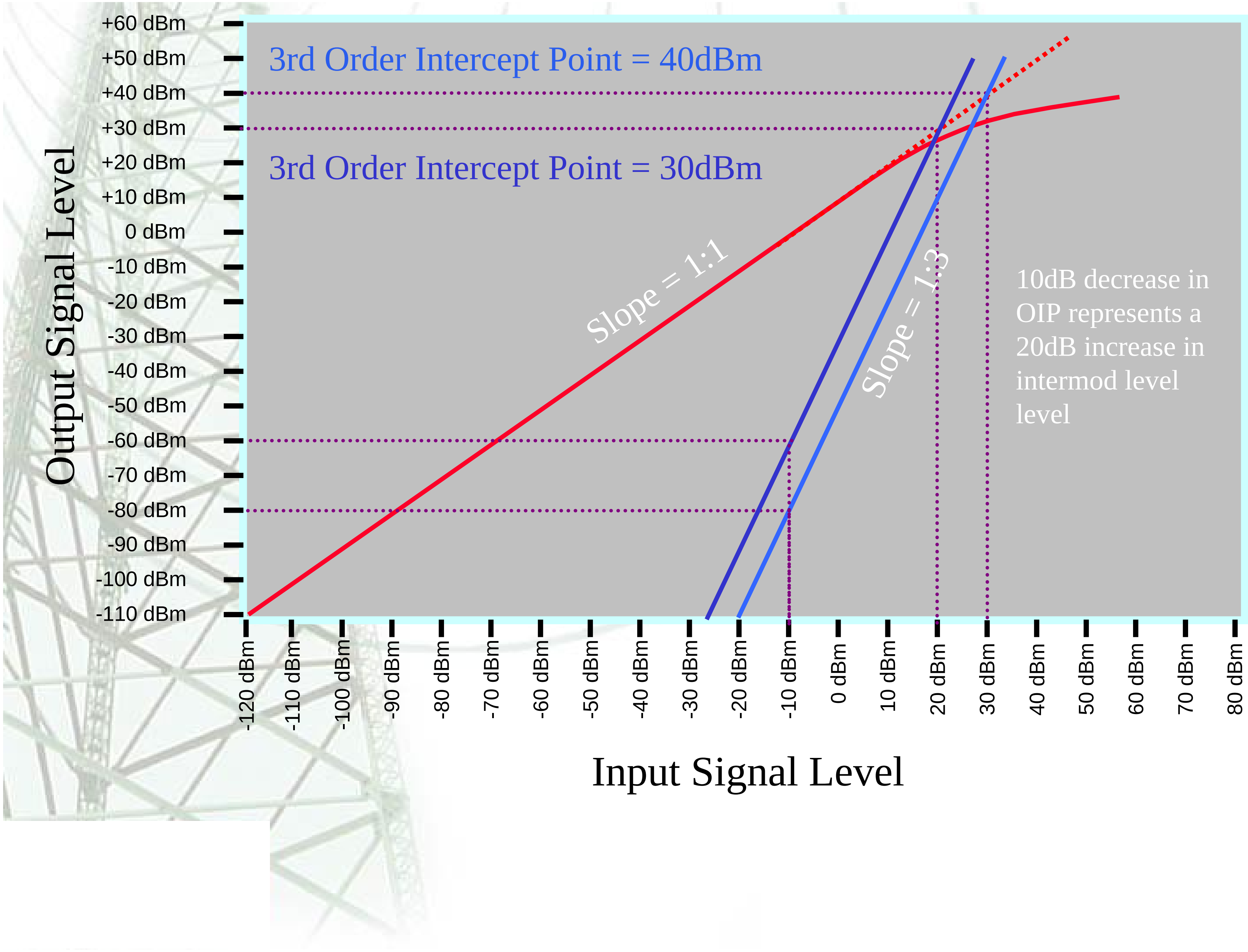


Output Signal Level
+60 dBm
+50 dBm
+40 dBm
+30 dBm
+20 dBm
+10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
-100 dBm
-110 dBm
1dB Compression Point = 29dBm
Slope = 1:1
-120 dBm
-110 dBm
-100 dBm
-90 dBm
-80 dBm
-70 dBm
-60 dBm
-50 dBm
-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
10 dBm
20 dBm
30 dBm
40 dBm
50 dBm
60 dBm
70 dBm
80 dBm
Input Signal Level



3rd Order Intercept Point = 40dBm
Slope = 1:1
Slope = 1:3
Output Signal Level
+60 dBm
+50 dBm
+40 dBm
+30 dBm
+20 dBm
+10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
-100 dBm
-110 dBm
-120 dBm
-110 dBm
-100 dBm
-90 dBm
-80 dBm
-70 dBm
-60 dBm
-50 dBm
-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
10 dBm
20 dBm
30 dBm
40 dBm
50 dBm
60 dBm
70 dBm
80 dBm
Input Signal Level


3rd Order Intercept Point = 40dBm
Output Signal Level
+60 dBm
+50 dBm
+40 dBm
+30 dBm
+20 dBm
+10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
-100 dBm
-110 dBm
Slope = 1:1
Slope = 1:3
10dB decrease in input signal level represents a 30dB decrease in intermod level
-120 dBm
-110 dBm
-100 dBm
-90 dBm
-80 dBm
-70 dBm
-60 dBm
-50 dBm
-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
10 dBm
20 dBm
30 dBm
40 dBm
50 dBm
60 dBm
70 dBm
80 dBm
Input Signal Level



3rd Order Intercept Point = 40dBm
3rd Order Intercept Point = 30dBm
Slope = 1:1
Slope = 1:3
10dB decrease in OIP represents a 20dB increase in intermod level level
Output Signal Level
+60 dBm
+50 dBm
+40 dBm
+30 dBm
+20 dBm
+10 dBm
0 dBm
-10 dBm
-20 dBm
-30 dBm
-40 dBm
-50 dBm
-60 dBm
-70 dBm
-80 dBm
-90 dBm
-100 dBm
-110 dBm
-120 dBm
-110 dBm
-100 dBm
-90 dBm
-80 dBm
-70 dBm
-60 dBm
-50 dBm
-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
10 dBm
20 dBm
30 dBm
40 dBm
50 dBm
60 dBm
70 dBm
80 dBm
Input Signal Level

Intermod Output Level in dBm =

[3 x (IP + Gain)] - [2 x OIP]

For 2-carrier products

Where: IP = Input signal level in dBm

and OIP = 3rd Order Intercept Point of amp

Intermod Output Level in dBm =

$$[3 \times (IP + Gain)] - [2 \times OIP] + 6$$

For 3-carrier products

Where: IP = Input signal level in dBm

and OIP = 3rd Order Intercept Point of amp

How Are Rx Intermods Reduced?

- Reduce level of component signals with filters
- Upgrade to amps with higher OIP
- Ensure you are not running too much gain

Mixes in Metallic Structures

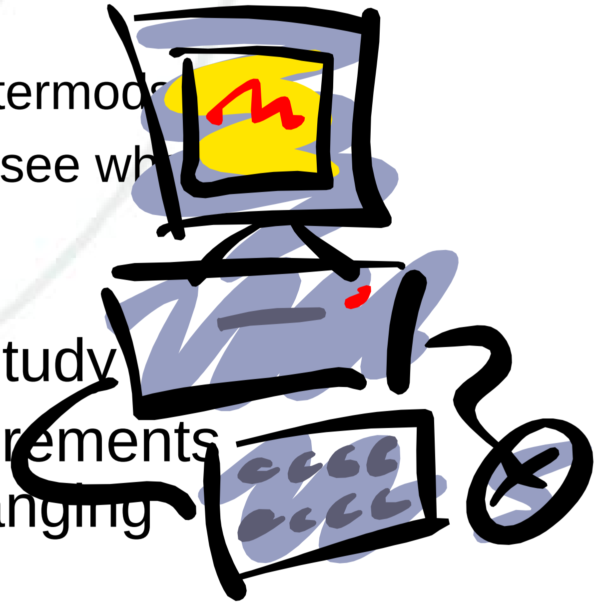
- Where these mixes are likely
  - Antennas
  - Clamps and other fastening hardware
  - Tower joints, cables, connectors, combiners, wire fences, reo in concrete, guy wires, old antennas, steel roofs, drink cans…..
  - You get the picture!!!

Practical Testing for Intermods

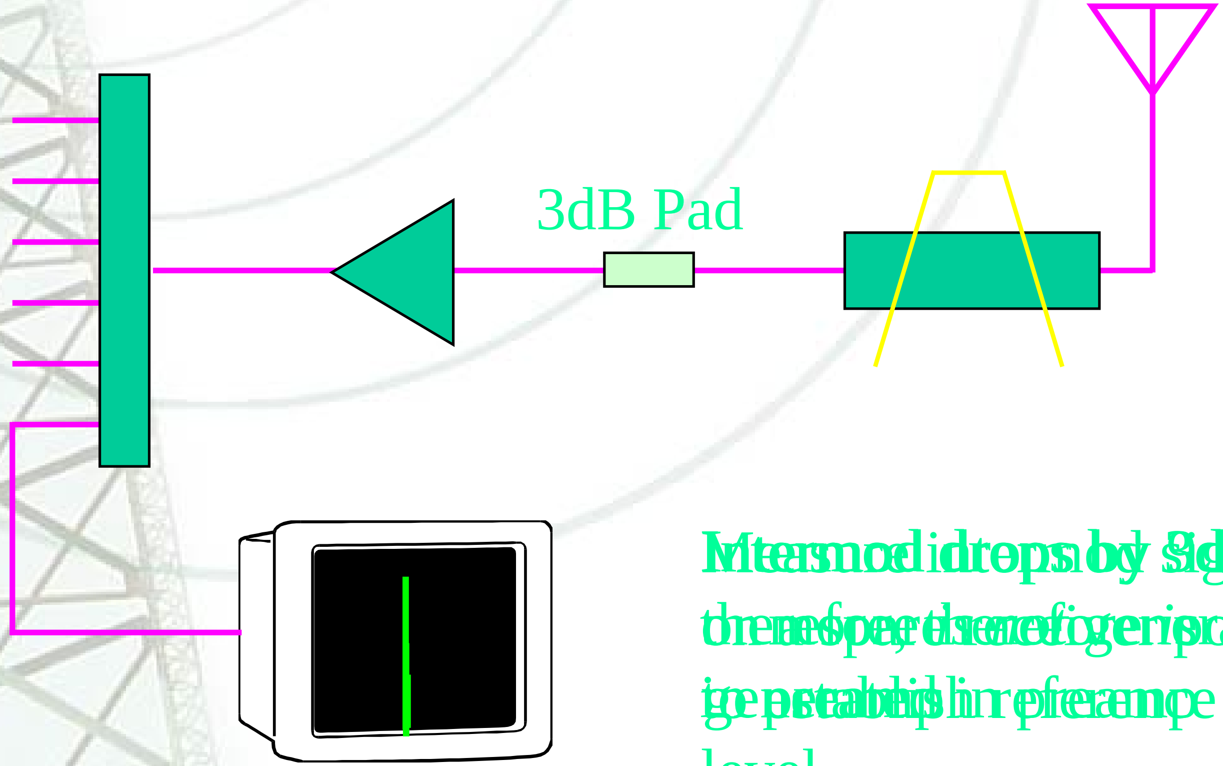
- At all times when testing, be wary of overdriving test instrument!
- First step is to determine where mix is occurring
  - Receiver preamps
  - Transmitter PA’s
  - Hardware

Practical Testing for Intermods

- Check receiver intermods first!
- Remember:
  - You can expect to see intermod
  - Do the homework *first* to see wh you can expect
  - Run a computer IM study
  - Make a set of measurements at the site *before* changing anything



Preamp intermod test procedure



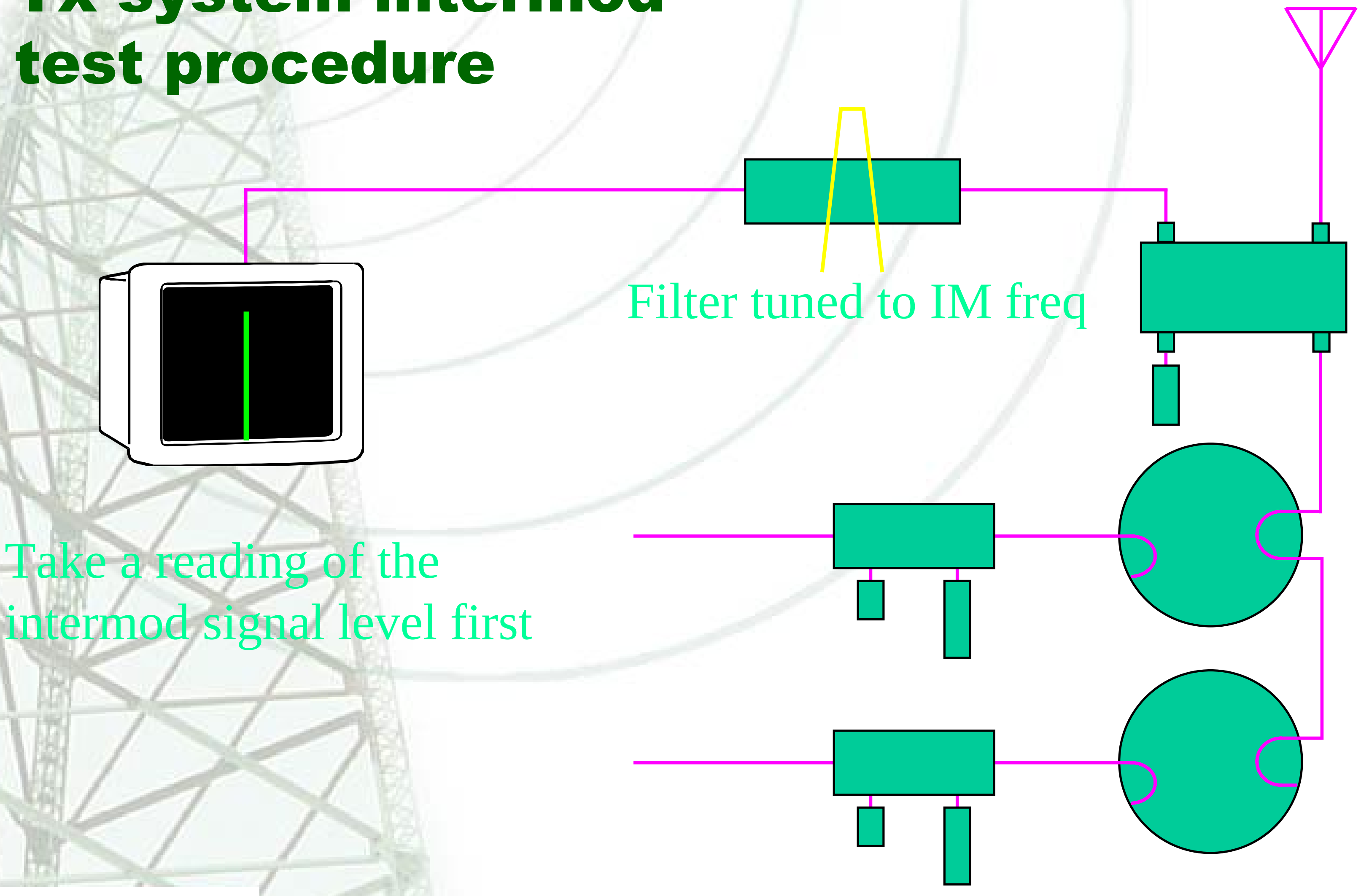
Intermod drops by 9dB, therefore, the intermod is generated in preamp

Measure intermod signal to establish reference level

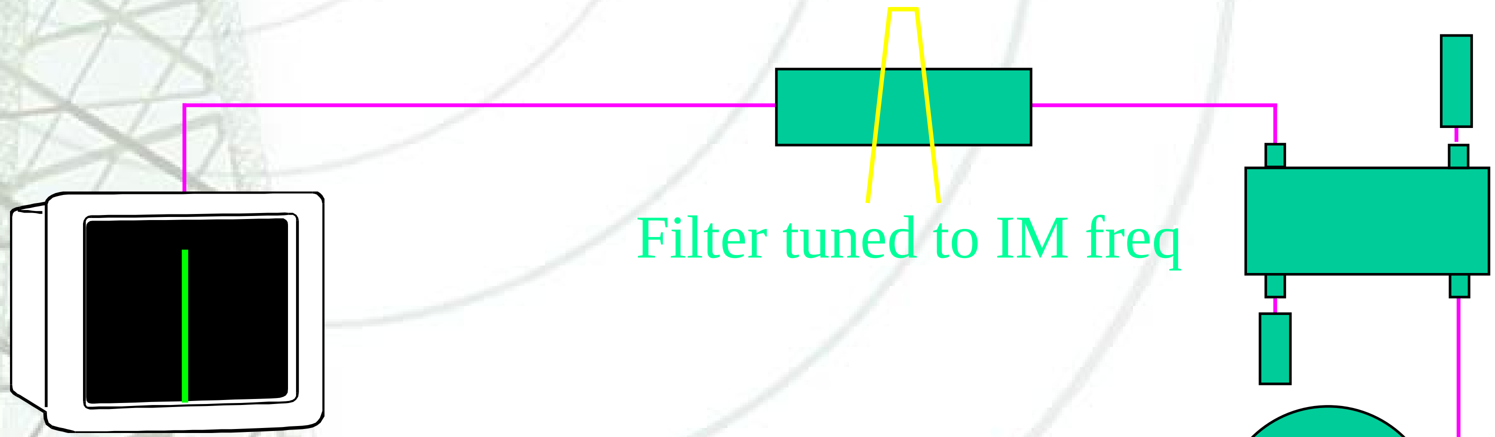
Transmitter PA Intermods

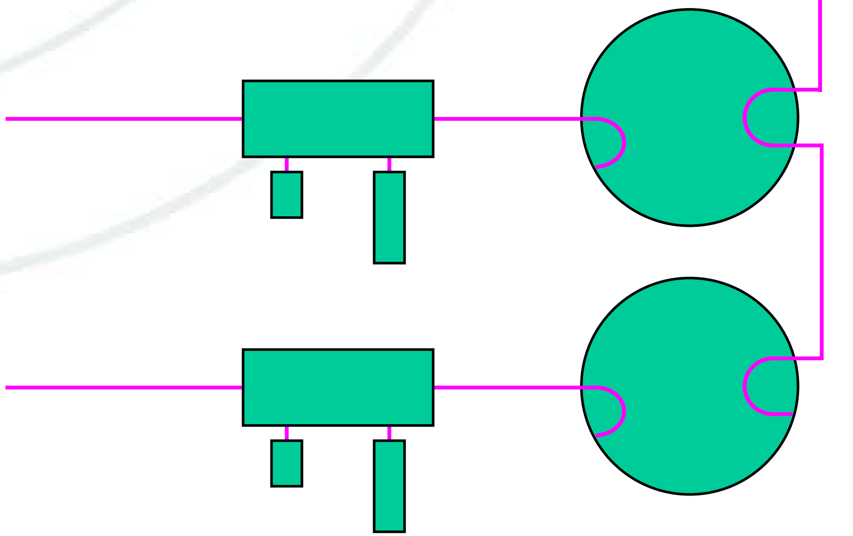
– Need to isolate where from
  - Transmitter combiner
  - Feeder
  - Antenna

Tx system intermod test procedure



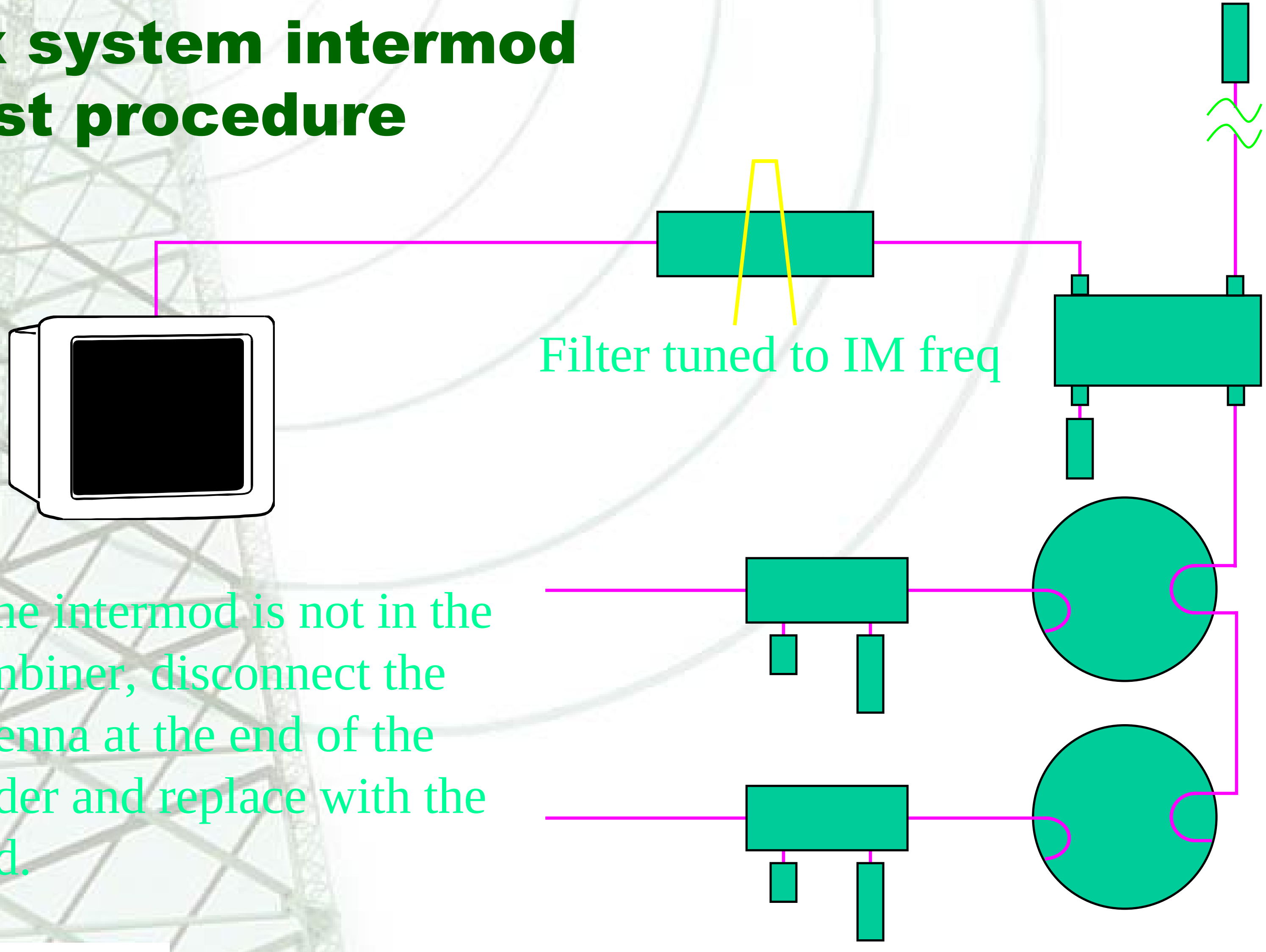
Tx system intermod test procedure





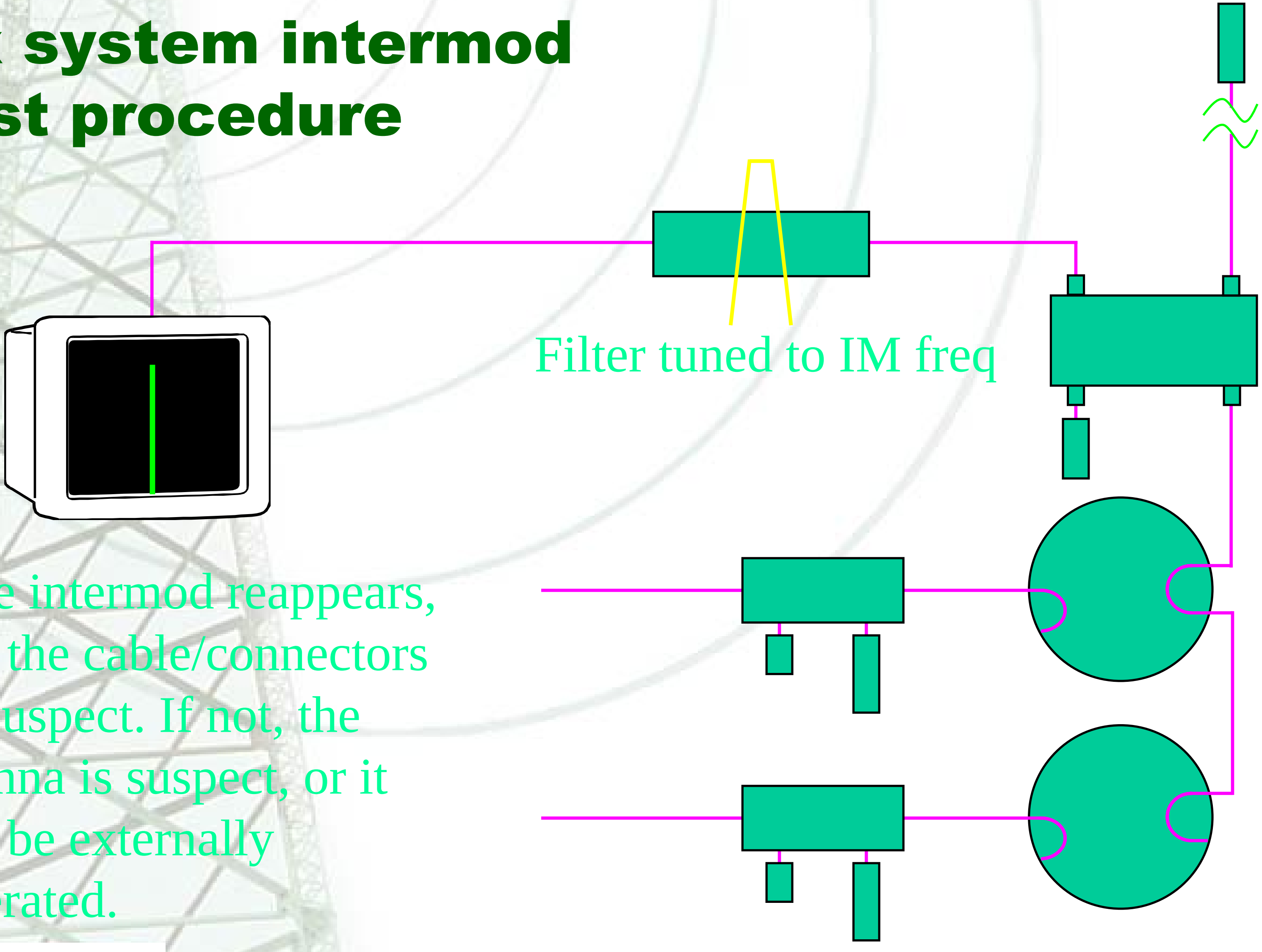
Disconnect the antenna and connect a dummy load. If intermod is still present at the same level, then it is most likely combiner generated.

Tx system intermod test procedure



If the intermod is not in the combiner, disconnect the antenna at the end of the feeder and replace with the load.

Tx system intermod test procedure



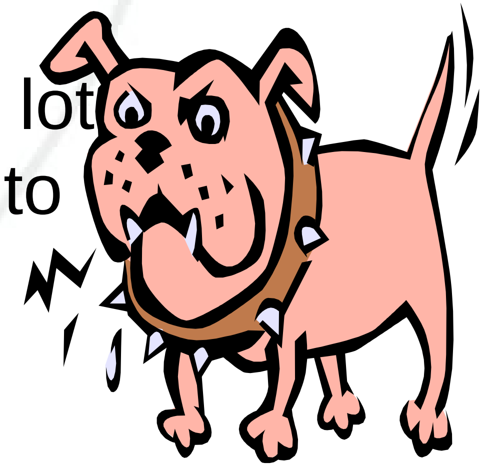
If the intermod reappears, then the cable/connectors are suspect. If not, the antenna is suspect, or it may be externally generated.

Hardware Generated Intermods

- Attack what is obvious first!
  - Remove metallic debris
  - Clean and treat any rusty clamps, bolts etc.
  - Check all connectors to make sure they are properly fitted, watertight where necessary, and screwed down tight

Hardware Generated Intermods

- Make a “sniffer” to try and identify hot spots
- Be prepared to spend a lot of time and effort trying to track it down!
- Don’t forget to check lightning suppressors



The Rest!

- Have looked only at 3 major areas
- So many other issues such as:
  - Case radiation effects
  - RF sampler intermods
  - Base receiver local oscillator mixes
  - A+B-C mixes where strong mobile signals are present
  - AND SO ON!

Overview

- Apply simple rules
- Ensure enough transmitter noise suppression
- Ensure enough transmitter carrier suppression
- Ensure enough Tx intermod protection
- Ensure good 3rd OIP amps

Overview

- ensure enough Tx carrier suppression for intermod for close mobile sites
- ensure good housekeeping
- remove un-used antennas or terminate in loads
- employ good grounding techniques to reduce site noise floor

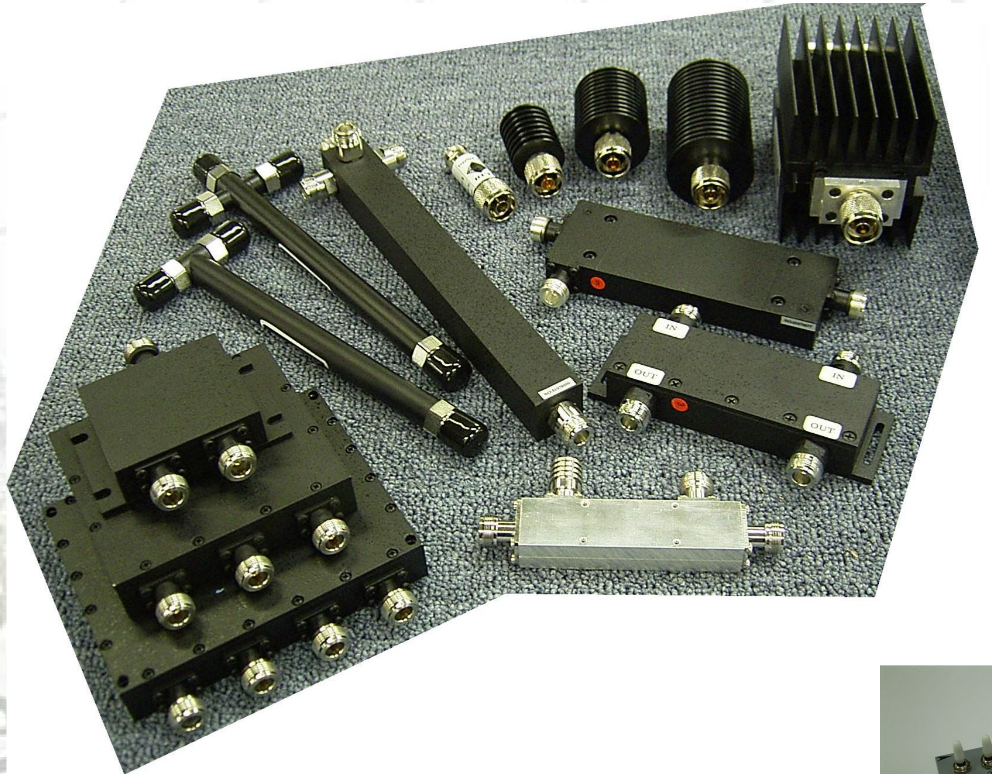
RF Industries

- We can assist you with planning
- We can provide appropriate consultation
- We provide Quality Equipment
- We provide before, during and after sales support

Questions?

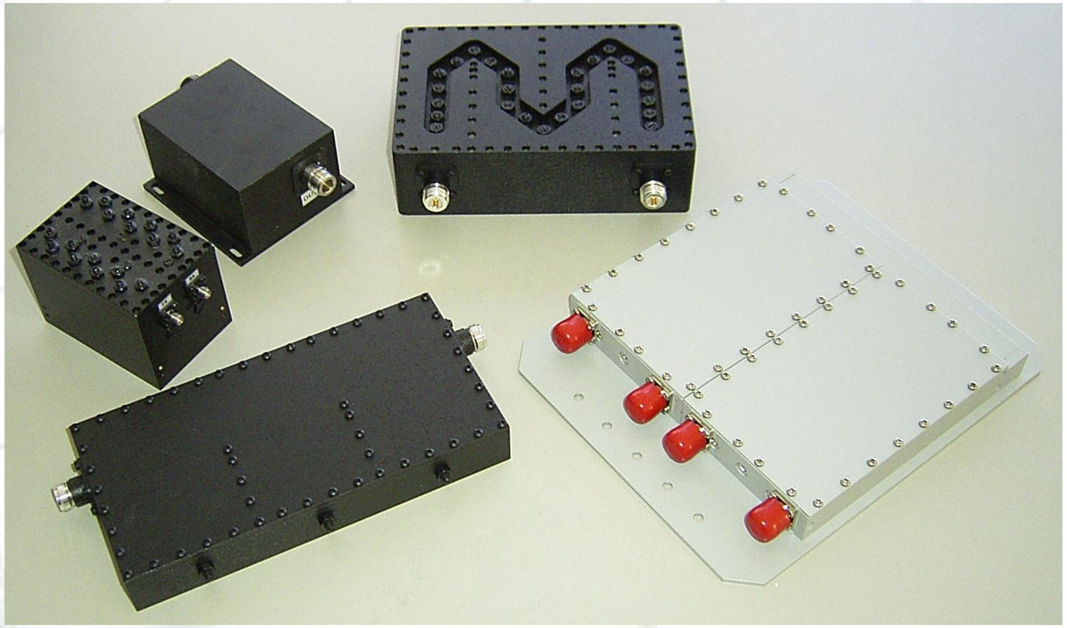
Intermodulation and Interference Analysis

Recent New Products



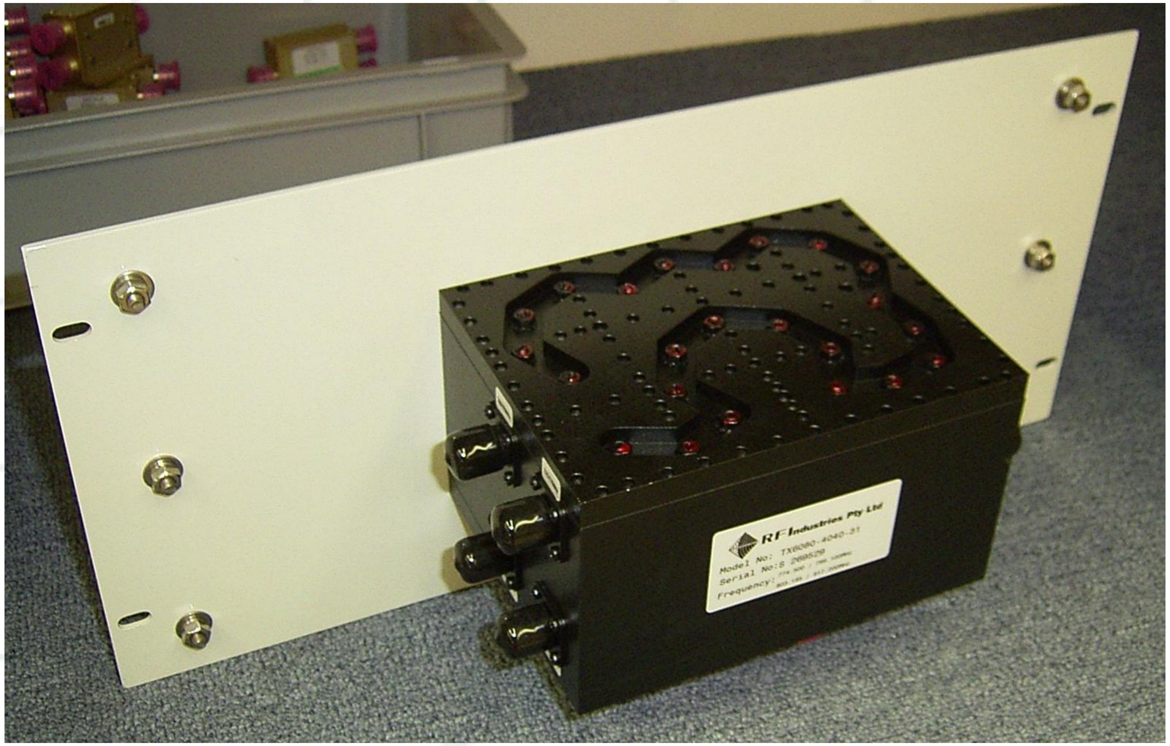
A full range of 800-2500MHz Dividers, Hybrids and Couplers.

DC-2500GHZ Loads and Attenuators



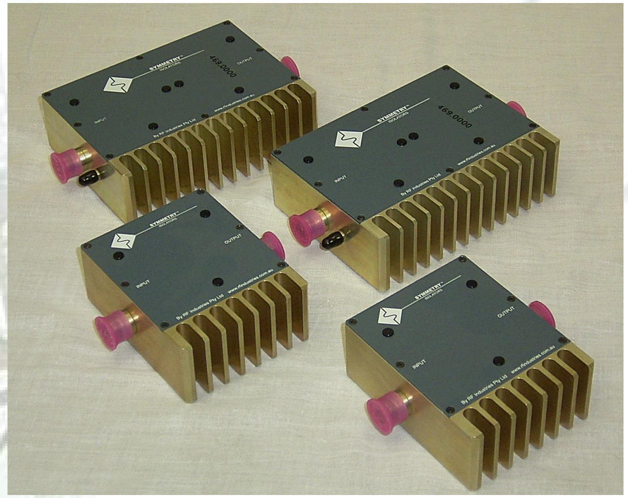
A range of specialised filters from 300MHz to 5.8GHz.

The ability to supply one-offs and small runs of solid milled filters to project specific requirements.

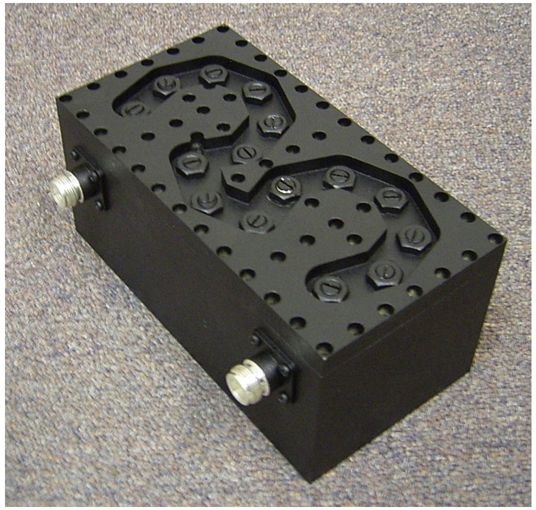


A new range of UHF TV and FM Broadcast Combiners in 2-to-8 channel configurations.

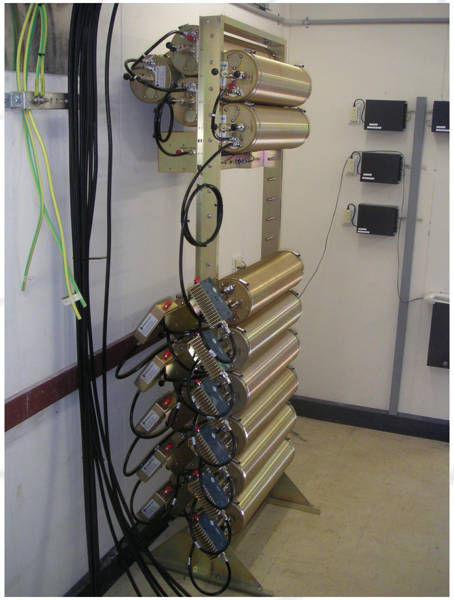
A complete range of UHF and 800MHz full bandpass duplexers.



Single and Dual stage circulators and isolators are now available from 66-1000MHz.



A complete range of UHF and 800MHz full bandpass preselectors.



A new style of T-Pass Peg Racking that provides easy access for testing and maintenance from one end of the combining rack