

# SEMINAR SUBJECTS

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## INTERFERENCE CONTROL THROUGH USE OF CAVITY FILTERS AND FERRITE ISOLATORS

FROM A TALK GIVEN BY DAN KAEGBEIN  
AT EXPO '84, DENVER, COLORADO



**FROM A TALK GIVEN BY DANIEL KAEGEBEIN  
AT EXPO '84, DENVER, COLORADO**

Page 1

USE OF CAVITY FILTERS AND FERRITE ISOLATORS  
FOR INTERFERENCE CONTROL

I. Common Types of Receiver Interference

1. Transmitter sideband noise
2. Transmitter spurious outputs
3. Transmitter carrier overload
4. Intermodulation

II. Usual Sources of Interference

1. Your own Transmitter
2. Nearby Transmitters
3. TV Stations
4. FM Broadcast

III. Factors Contributing to Non-I.M. Transmit-Receive Interference

A. Related to equipment specifications or characteristics

1. deficient sideband noise filtering in transmit line
2. deficient carrier suppression filtering in receive line
3. poor broadband isolation characteristics in Transmit to receive path, allowing excessive sideband energy to "Leak" around narrow isolation notches, especially troublesome at narrow T-R frequency separations.
4. increased Transmitter sideband spurious as a result of large sideband impedance variations reflected back to the Transmitter or power amplifier by selective filters.

B. Related to physical conditions of equipment and site environment

1. poor joints in RF path, principally in common Transmit and receive paths, as antenna lines and antennas.
2. Loose hardware, guy wires, or old antennas in close proximity to system antenna.
3. poor joints in Transmit filters.

VII150304

#### IV. Origin of Intermodulation Interference

1. Transmitter final
2. Receiver front end, RF and mixer stages
3. Preamps
4. Ferrite Isolators, under certain conditions
5. Ordinary joints in RF conductor paths, particularly multicoupler intercabling, Transmission lines and antennas.

#### V. Two methods used to control I.M. Interference

1. Reduce level of I.M. generated at the source
2. Increase isolation between receiver and source of I.M.

#### VI. A Bandpass Filter can be used to locate sources of Interference as:

1. Insufficient TX Carrier or noise suppression in a duplexed or multicoupled system.
2. I.M. generation in preamps, and receiver front ends
3. I.M. Generation in TX Finals, when cavity selectivity is adequate.

#### VII. A Ferrite Isolator can be used to locate sources of Interference as:

1. I.M. generation in TX finals.
2. Increased TX spurious output on sideband-impedance sensitive Transmitters and power amplifiers.

#### VIII. Sources of Interference against which Cavity Filters are not effective.

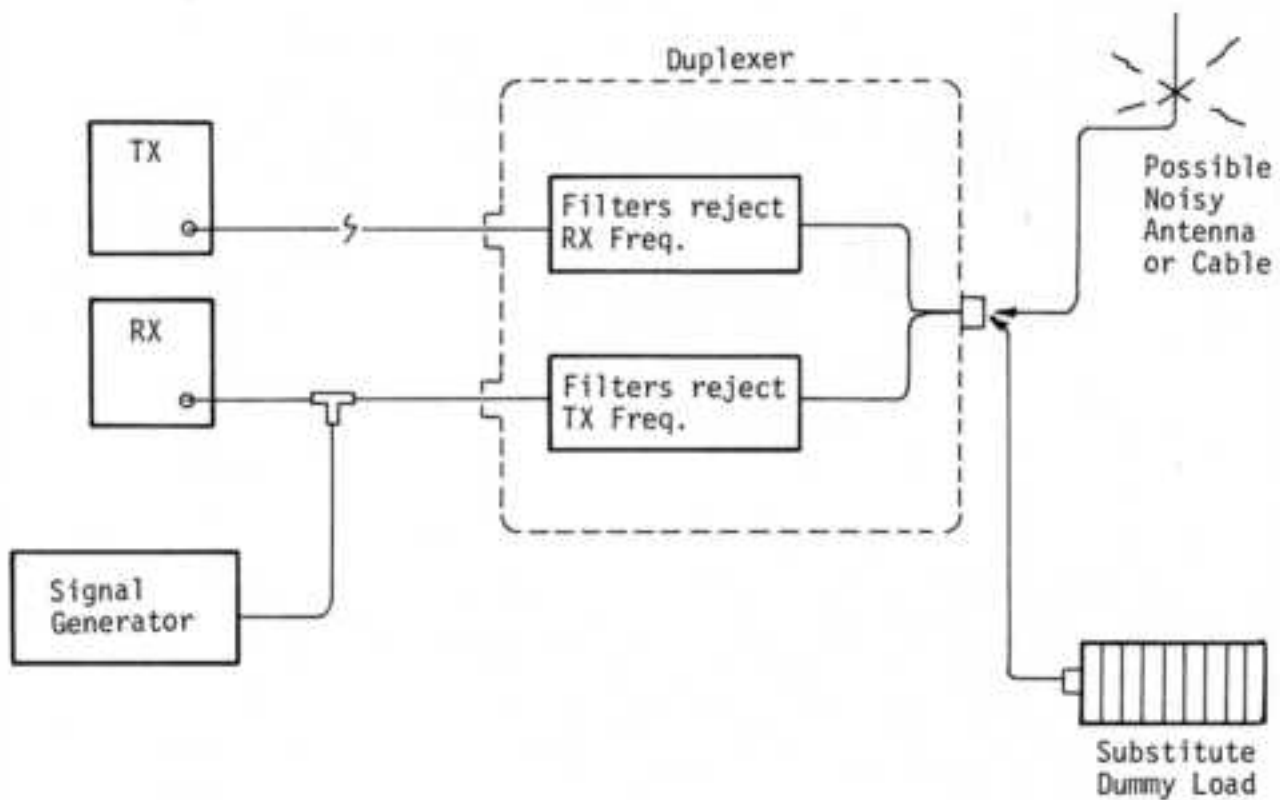
1. Noise generated in the Transmission line and antenna of a duplexed system, or a single antenna multicoupler system.
2. Transmitter noise or carrier desense, when T-R frequency separation is too narrow to allow filter adjustment.
3. High level I.M. generated in ordinary cable joints in single antenna Transmit/Receive Multicoupler Systems.
4. Inadequate shielding of Transmit and Receive modules.

#### IX. Sources of Interference against which Ferrite Isolators are not effective

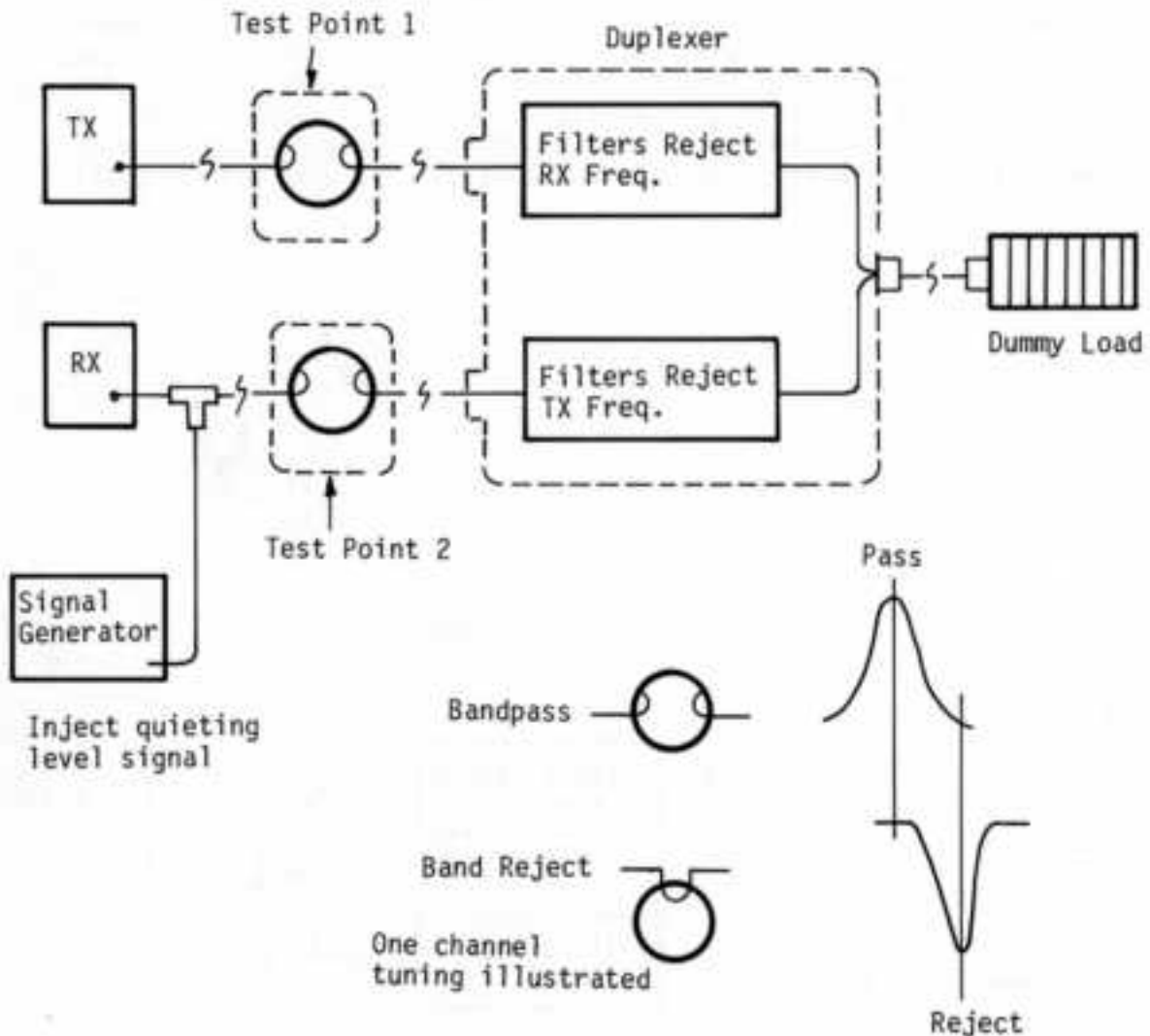
1. Transmitter sideband and spurious radiation.
2. Preceding sources 1, 3 and 4 for cavity filters.

### ONE TEST FOR ELIMINATING DUPLEXER AS A SOURCE OF SYSTEM DEGRADATION

Inject the receive frequency into the line between the duplexer and the receiver using a sampling tee, and adjust signal generator for reference quieting level. Replace the antenna with a 50 ohm dummy load. Make sure all cable connections are sound and tight. If degradation disappears when the transmitter is keyed into the dummy load, check for bad joints in transmission line and/or antenna system. Interaction with another transmitter that is close in frequency and has its antenna a few feet away horizontally, is also a possibility.



TEST FOR INADEQUATE DUPLEX ISOLATION  
(Using Bandpass or band reject filters)



The bandpass filter test is illustrated, as it is the easiest to perform. Reduction in receiver degradation in position 1 indicates lack of TX noise filtering, and in position 2, TX carrier suppression. In extreme cases, both positions may require extra filtering. Band reject filters may be necessary in this test when T-R frequency separation is very narrow, and bandpass skirt selectivity is inadequate.

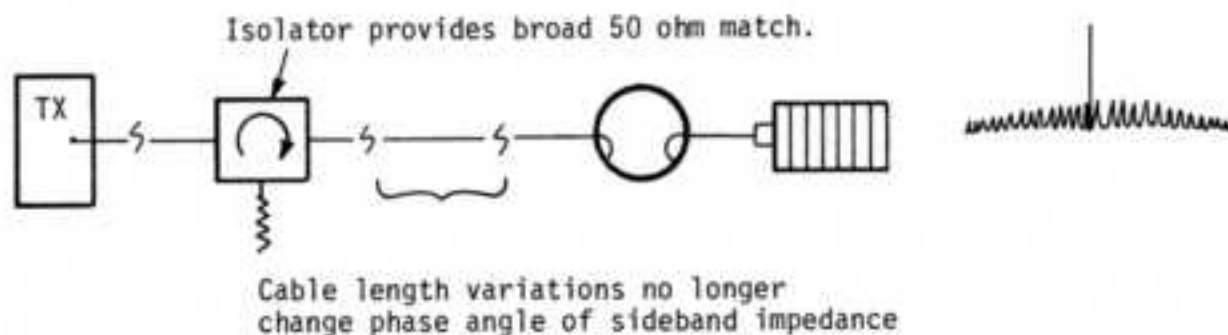
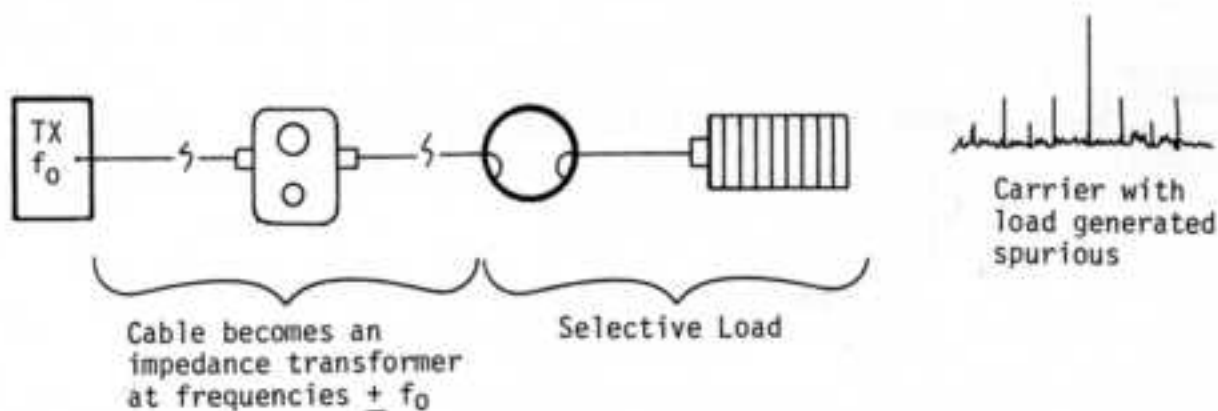
## DETECTING TRANSMITTER SENSITIVITY TO SELECTIVE LOAD IMPEDANCE

### Symptoms:

1. Poor loading and forward power.
2. Reflected power changes when cable length varied between Transmitter and filter input.
3. Installing isolator reduces reflected power at filter input, restores forward power, and eliminates change in reflected power when varying cable length between isolator and filter input.

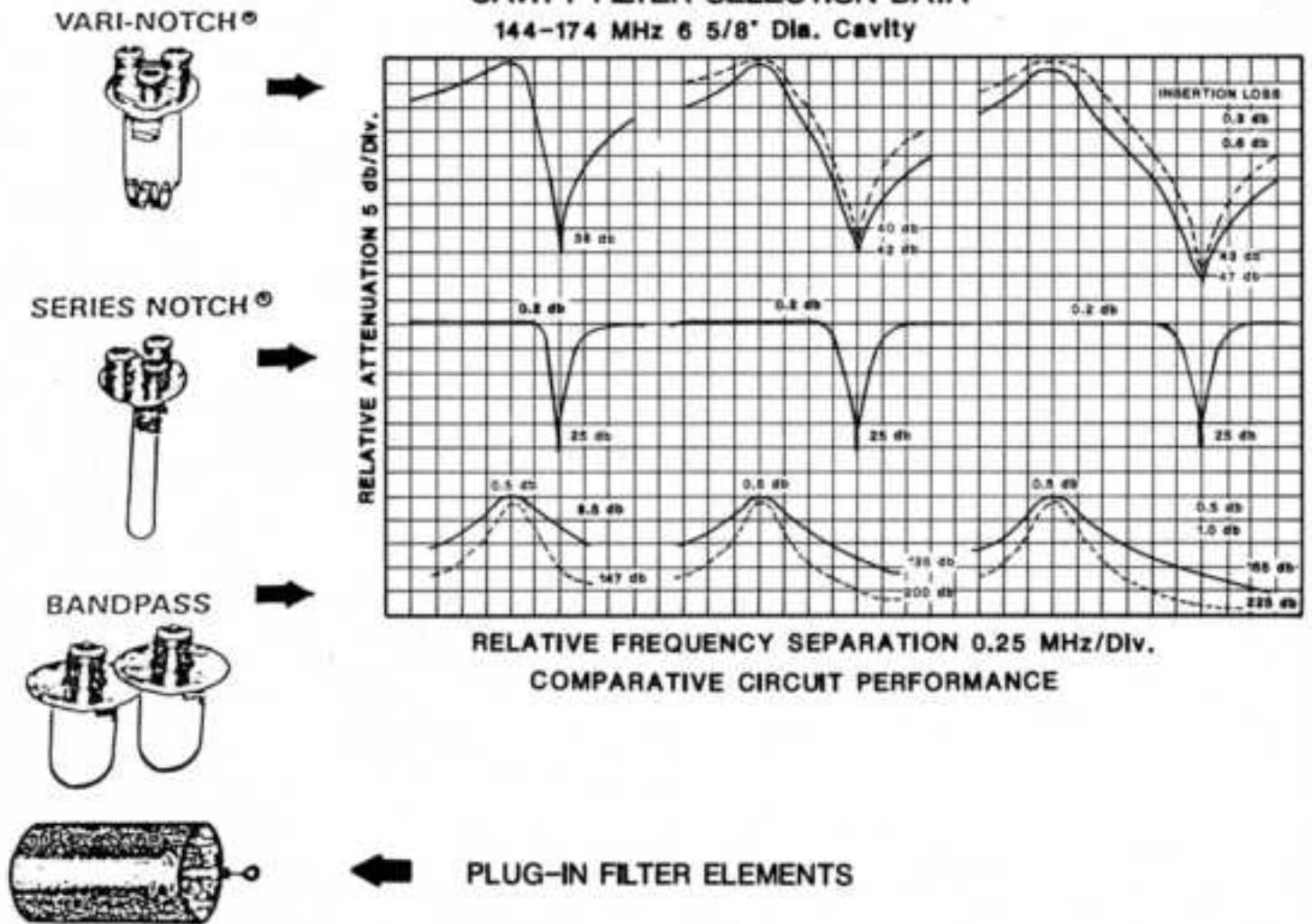
### Cure:

Hunt cable length between transmitter and filter which provides acceptable performance. Make changes no larger than one eighth wavelength.  
Install isolator, if all else fails.



## CAVITY FILTER SELECTION DATA

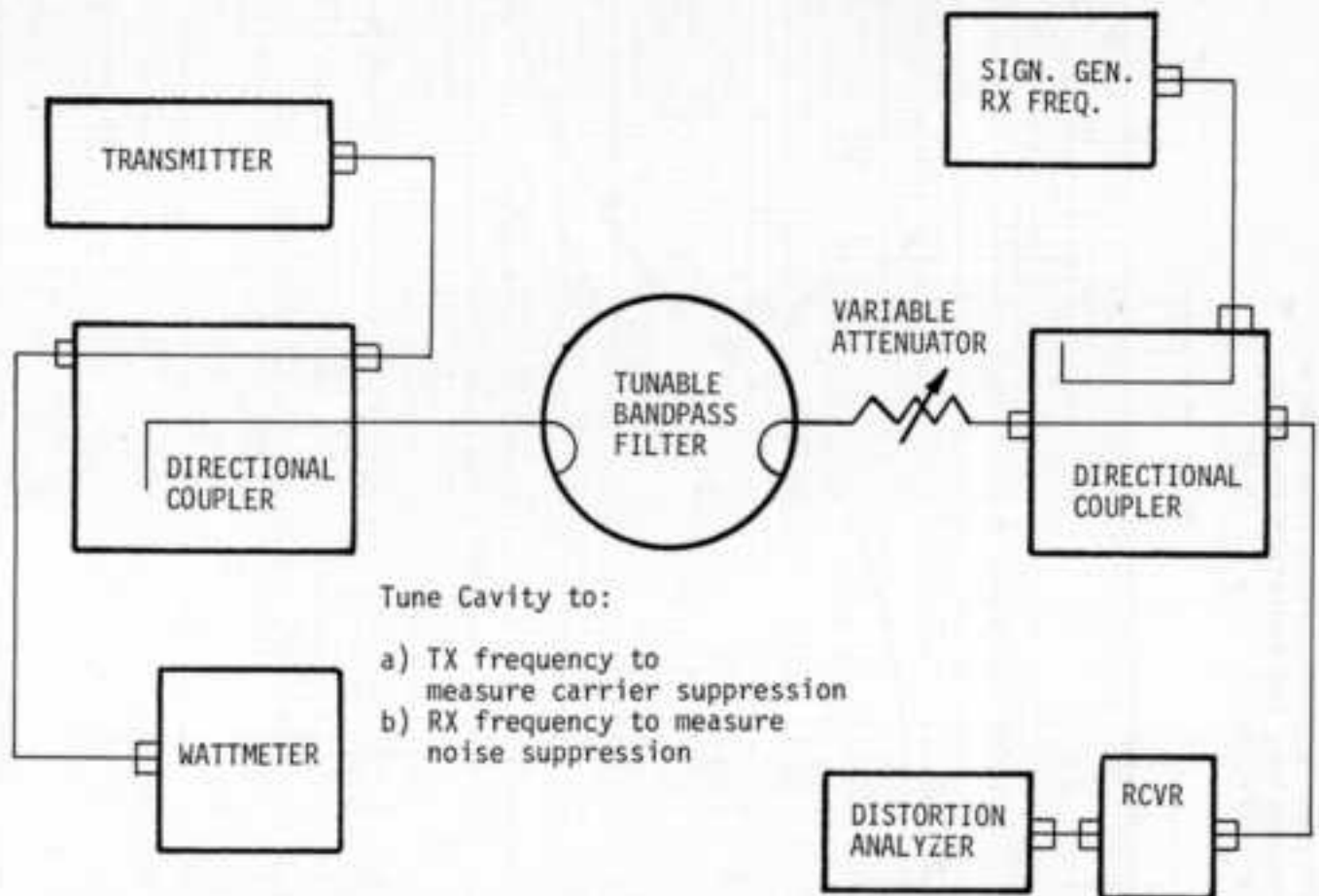
144-174 MHz 6 5/8" Dia. Cavity



## SPECIFIC FILTER APPLICATIONS AND SELECTION

1. **BANDPASS CAVITY FILTER**-Passes one narrow band of frequencies and attenuates all others with increasing attenuation above and below the pass frequency. A great filter for general transmitter spurious clean up and sharpening of receiver front end selectivity. TX RX bandpass cavities (4", 6", and 10") have adjustable selectivity characteristics (rotatable loops) to allow a trade-off between insertion loss (0.5-3.0 db) and selectivity. Maximum power handling is determined by insertion loss setting (see available Tech-Aids). This filter is the best choice when interfering frequencies are not known to any degree of accuracy or when very broad band filtering is needed.
2. **SERIES NOTCH® (NOTCH)**-Passes a relatively wide band of frequencies while rejecting a very narrow band of frequencies. Notch depth is variable from 15-25 db. Both pass and notch frequencies must be known. Best filter for very close separations (70 KHz and greater in low band, 70 KHz to 200 KHz in highband, and 200-400 KHz in the UHF band). The wide passband can be an advantage when filtering multiple channel transmitters and receivers.
3. **VARI-NOTCH®**-Passes a relatively narrow band of frequencies and rejects (notches out) a relatively wide frequency band. This filter has the greatest notch depth when compared to other types. Notch depth is adjustable but is referenced to a passband insertion loss (0.3 db or 0.6 db typical). Best filter type for moderately close to wide separations (200 KHz and greater in highband, 400 KHz and greater in UHF).

## DUPLEX ISOLATION MEASUREMENT SYSTEM



The isolation required for duplex operation is normally specified at two frequencies, the TX frequency (carrier suppression), and the RX frequency, (transmitter noise suppression). The filters for the former will appear in the receiver section of the duplexer, and for the latter, in the transmitter section.

The circuit used to determine the isolation at the TX and RX frequency is shown above. The tunable bandpass cavity acts as a frequency "window", allowing isolation measurements at essentially discrete frequencies.

A predetermined level of receiver degradation is usually assumed when making these measurements, and this level must be known for the duplex isolation data to be meaningful. A certain db degradation of the 20 db quieting sensitivity or the 12 db SINAD sensitivity is usually referenced.

Due to normal manufacturing variations, reliable isolation values should be determined from a number of measurements on like models under similar conditions.

It should also be noted that the isolation values so determined will only be directly applicable to duplexers having filter response curves similar to the bandpass filter "window". Notch filter duplexers having narrow isolation bands and large "acceptance" bands may require 20-30 db more isolation than the above circuit would indicate, due to the added mixing of broadband noise in the receiver or antenna line components.



TYPICAL DUPLEX ISOLATION CURVE, 450-470 MHz

Since this data is determined using a laboratory measurement system providing a 50 ohm match at carrier and sideband noise frequencies, and therefore does not exactly duplicate practical duplex impedance characteristics, a 10-15 db safety margin is usually added to the below values.

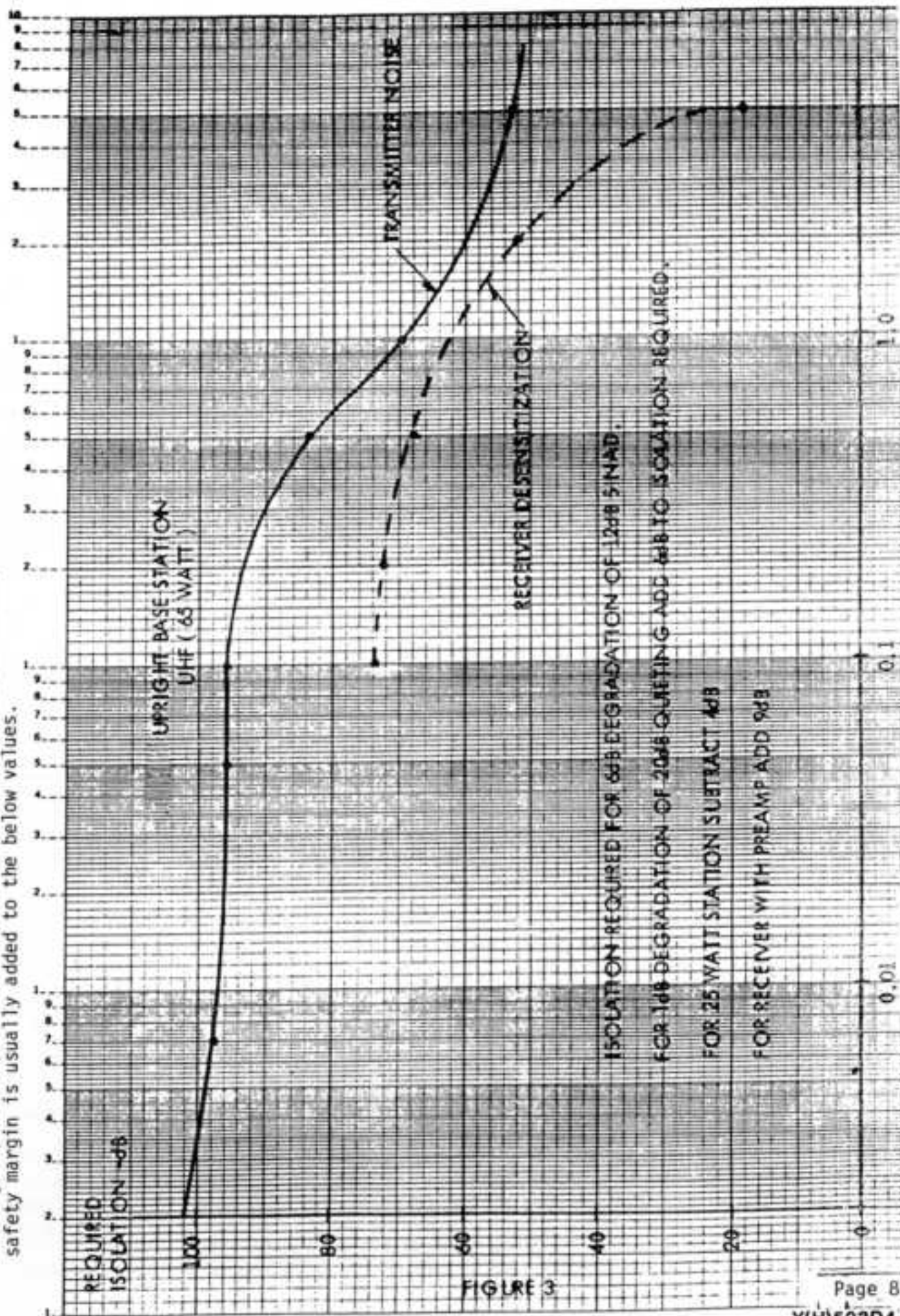


FIGURE 3

**ESTIMATING CHANGES IN I.M. LEVELS  
FOR EFFECTED CHANGES IN FUNDAMENTAL LEVELS**

The power of an I.M. product is a function of the power in the fundamental frequencies, the order of the I.M., and a very illusive quantity called the mixing efficiency constant.

Assuming a constant mixing efficiency (which probably is rarely the case) we can determine the effective change in I.M. level for various changes in fundamental levels reaching the mixing point.

For a two frequency third order product:

$$\text{Power of } \mathbf{IM}_3 = K \left[ P_{f_A}^2 P_{f_B} \right] \text{ where } K = \text{mixing efficiency constant}$$

$P_{f_A}$  = Power in freq. A in watts  
 $P_{f_B}$  = Power in freq. B in watts

Logging the above expressions to the base 10 and evaluating a difference relationship, we can obtain an expression easily worked in db levels:

$$\Delta P_{I.M.} = 2\Delta P_{f_A} + \Delta P_{f_B} \text{ for a } 2A-B \text{ product.}$$

This says for a 10 db power change in  $f_A$  and also in  $f_B$ , the total level change,  $P_{I.M.}$  will be:

$$\Delta P_{I.M.} = 2(10 \text{ db}) + (10 \text{ db}) = 30 \text{ db}$$

Similar relationships can be formed for higher order products and three frequency mixes. The value of K usually decreases as the I.M. order increases.

The above illustration shows the importance of maintaining adequate T-R antenna space isolation.

For Tx's mixing in a common transmit antenna, the product level radiated to the RX antenna will decrease by an amount equal to the increased space isolation. When mixing is occurring in the RX antenna or in components of the RX system, the I.M. level will drop by (3) three times the increased space isolation.

TODAYS DATE IS: 2/2/83

SITE NAME OR REFERENCE# : SIMULATION RUN

TX 1 = 462.125  
 TX 2 = 461.475  
 TX 3 = 464.3  
 TX 4 = 464.8  
 TX 5 = 463.3  
 TX 6 = 461.975

RX 1 = 467.125  
 RX 2 = 466.475  
 RX 3 = 469.3  
 RX 4 = 469.8  
 RX 5 = 468.3  
 RX 6 = 466.975

\*\*\* THE EQUATIONS SOLVED WILL BE INDICATED BY THE FOLLOWING \*\*\*-----\*\*\* HITS HAVE BEEN FOUND PRINT HEADING

\*\*\* NO ENTRIES UNDER THE PRINT HEADING INDICATES THAT NO! HITS WERE FOUND FOR THAT EQUATION

.....  
 THE FOLLOWING \*\*\* 2A-B \*\*\* HITS HAVE BEEN FOUND---

FREQ A (MHZ)	FREQ B (MHZ)	FREQ IM (MHZ)	FREQ RX (MHZ)	TEST WINDOW (+/-MHZ)
464.3000	461.4750	467.1250	467.1250	0.0150
464.3000	462.1250	466.4750	466.4750	0.0150

.....  
 THE FOLLOWING \*\*\* A+B-C \*\*\* HITS HAVE BEEN FOUND---

FREQ A (MHZ)	FREQ B (MHZ)	FREQ C (MHZ)	FREQ IM (MHZ)	FREQ RX (MHZ)	TEST WINDOW (+/-MHZ)
464.3000	464.8000	461.9750	467.1250	467.1250	0.0150
464.3000	464.8000	462.1250	466.9750	466.9750	0.0150

.....  
 THE FOLLOWING \*\*\* 3A-2B \*\*\* HITS HAVE BEEN FOUND---

FREQ A (MHZ)	FREQ B (MHZ)	FREQ IM (MHZ)	FREQ RX (MHZ)	TEST WINDOW (+/-MHZ)
463.3000	461.4750	466.9500	466.9750	0.0250

.....  
 THE FOLLOWING \*\*\* 4A-3B \*\*\* HITS HAVE BEEN FOUND---

FREQ A (MHZ)	FREQ B (MHZ)	FREQ IM (MHZ)	FREQ RX (MHZ)	TEST WINDOW (+/-MHZ)
464.8000	463.3000	469.3000	469.3000	0.0350

# ANTENNA INTERMOD

## Single TX & RX Antenna

I.M. levels shown based on the following assumptions:

1. Mixing is occurring only in TX antenna
2. I.M. specifications on antennas for 2A-B products is 100 db below +47 dbm levels of A and B.

I.M. levels at Receiver Antenna  
2A-B = -108 dbm  
2B-A = -108 dbm  
(-108 dbm = .87 uv)

2A-B and 2B-A I.M. levels generated in RX antenna are usually undetectable if the change in I.M. level, per the power formula in Figure 1, applies.

Radiated I.M. levels:  
2A-B = -53 dbm  
2B-A = -53 dbm

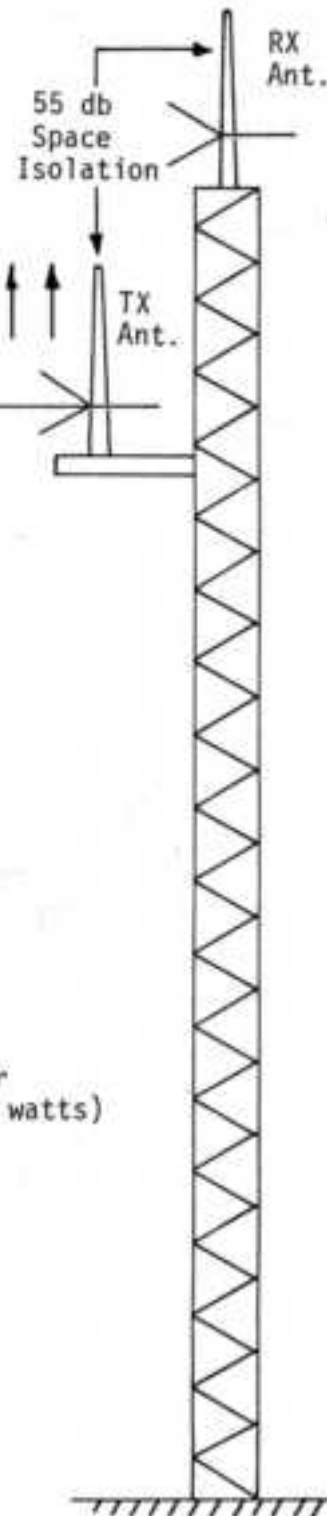
Tx 'A' power = +47 dbm  
Tx 'B' power = +47 dbm  
(+47 dbm = 50 watts)

TWO CHANNEL  
TRANSMITTER  
MULTICOUPLER

TX  
'A'

TX  
'B'

Tx A and Tx B power  
equal +50 dbm (100 watts)  
each.



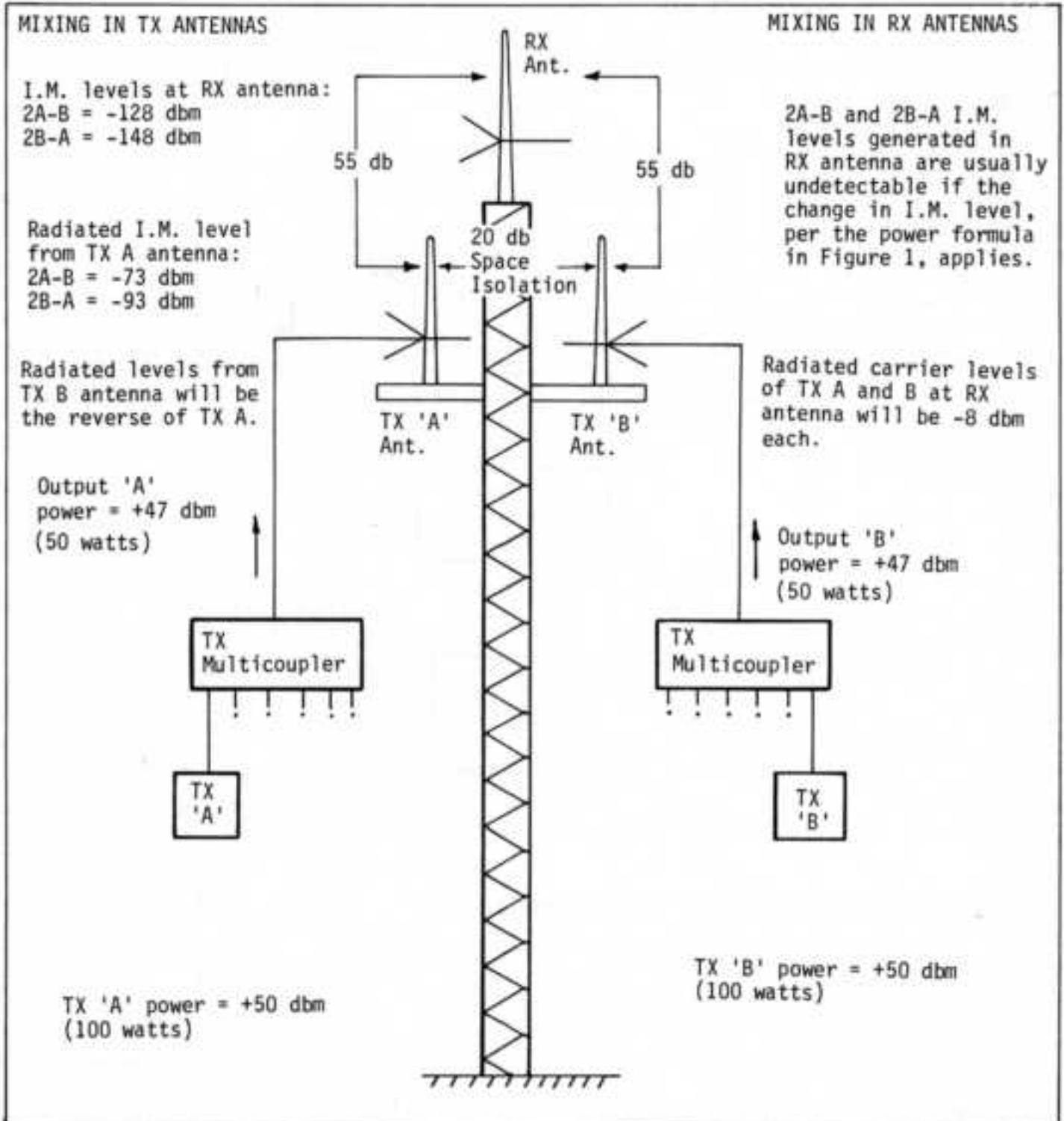
Options to eliminate this I.M. interference:

1. Change one of the TX frequencies by more than 15 KHz.
2. Use two TX antennas, as shown in Figure 4.
3. Move one TX to a different site.
4. Maybe a long shot, but try to obtain 70 db+ antenna isolation.

## ANTENNA INTERMOD Multiple TX Antennas

NOTE: Calculations are based on limited field tests and known I.M. power relationships. Individual systems may vary considerably in antenna I.N. mixing efficiency.

Assumption: I.M. specification on an antenna and 500' transmission line for 2A-B product level generation is 100 db below +47 dbm levels of A and B.



## TESTING FOR RECEIVER AND PREAMP I.M.

## Step 1.

Reduce gain of preamp and power divider portion of multicoupler to unity by pad or variable attenuator. Note level of Receiver I.M. (Note: for valid test, pad must be placed after preamp).

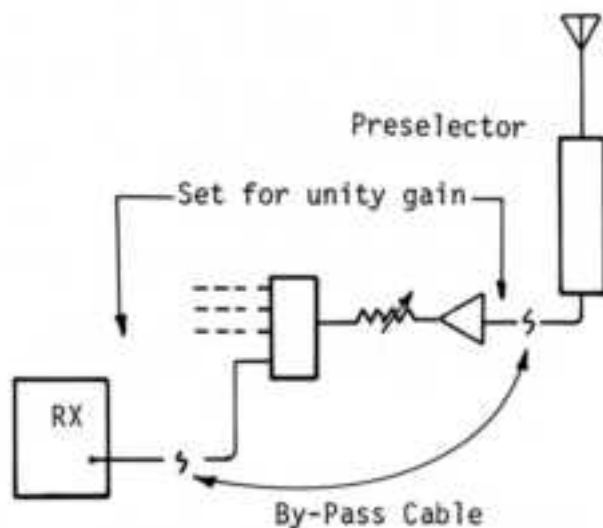
## Step 2

Substitute a by-pass cable for unity portion of multicoupler. If level of I.M. is unchanged, preamp is not a source. This test is valid only if levels of incoming signals to RX are kept about equal in steps 1 and 2. If I.M. level drops when by-pass cable is substituted, preamp is contributing I.M.

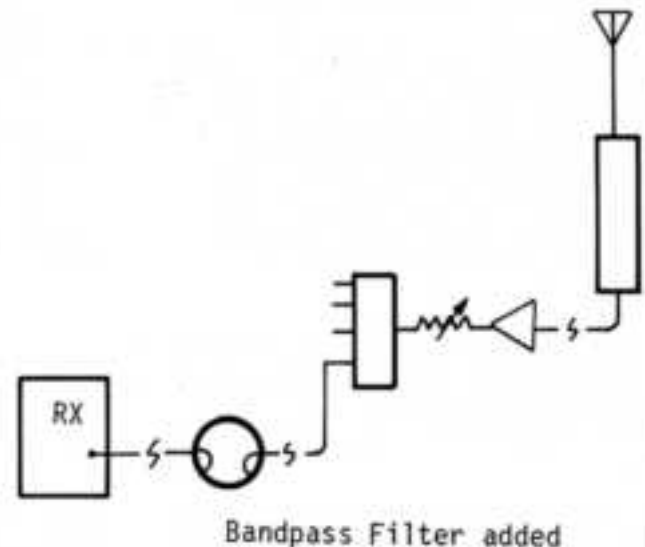
## Step 3

Add a selective bandpass filter ahead of the receiver. If the preamp is not a source of I.M., but the selective cavity reduces I.M. level, the receiver front end is a source. Add selectivity, as practical, to reduce level. Receive - to - transmit antenna isolations may need to be increased for improved overall performance. In Tower Mount receive systems, adding selective filters in conjunction with by-pass cable in Step 2 may reveal RX I.M.

Steps 1 &amp; 2



Step 3



## PREAMP INTERCEPT POINT AND THIRD ORDER INTERMODULATION

In a multicoupler system, a typical TX carrier input level to a Receive antenna is -8 dbm.

A receiver with an 80 db I.M. rejection specification will begin to suffer I.M. interference at -33 dbm input levels, assumed in the receiver RF passband.

Preselector filters ahead of RX multicouplers, designed to protect a receiver against TX carrier overload (desense) per duplex isolation curves, will generally be inadequate for I.M. protection.

Because of the large difference between multicoupler and receiver I.M. performance, additional selectivity added just ahead of the affected receiver is often sufficient.

To determine level of I.M. below Preamp output, a) read right along the selected output level to the fundamental diagonal, b) then down to the appropriate 2A-B line, c) and left to the vertical scale for the I.M. level.

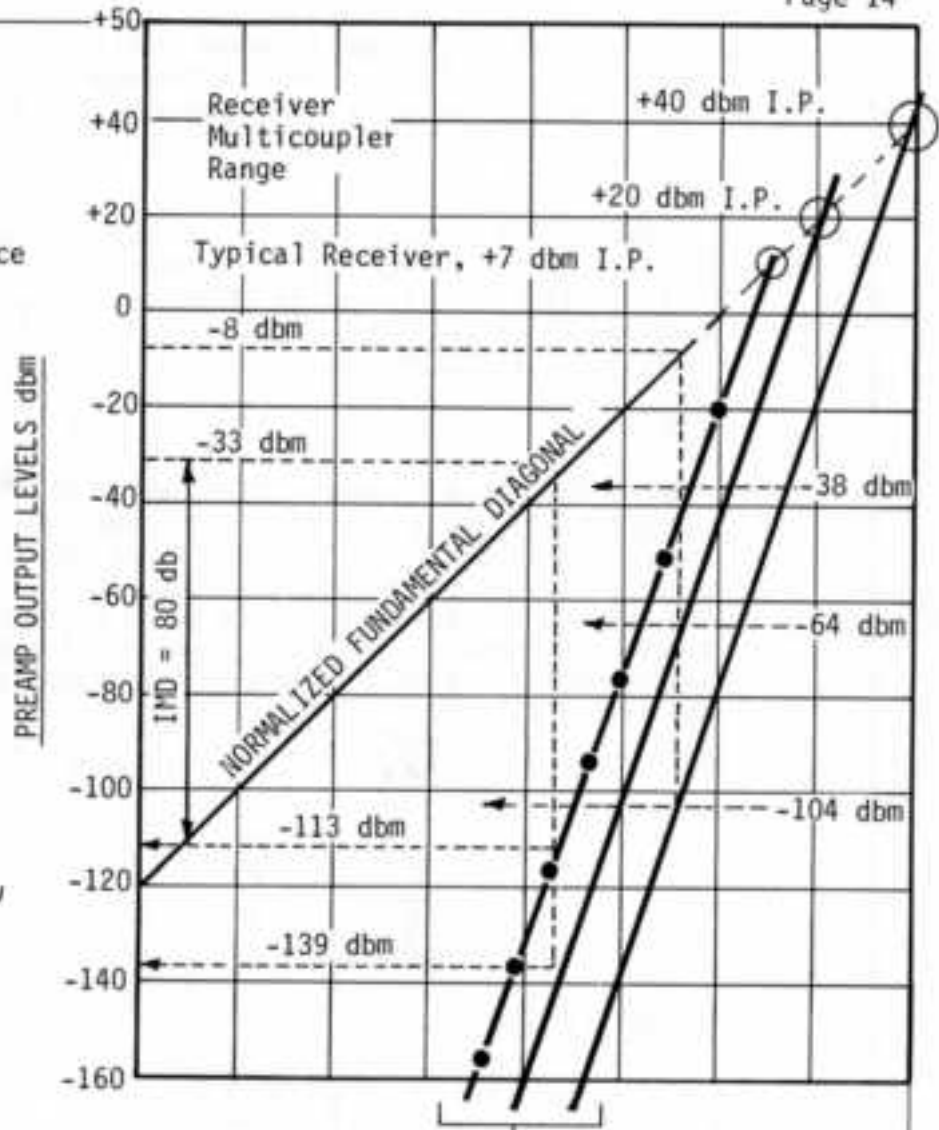
The following expressions can be used to determine exact levels on the above curve.

$$IMD = 2(I_p - P_o)$$

IMD = number of db the 3rd order product is below preamp output.

$I_p$  = Preamp 3rd order intercept point in dbm.

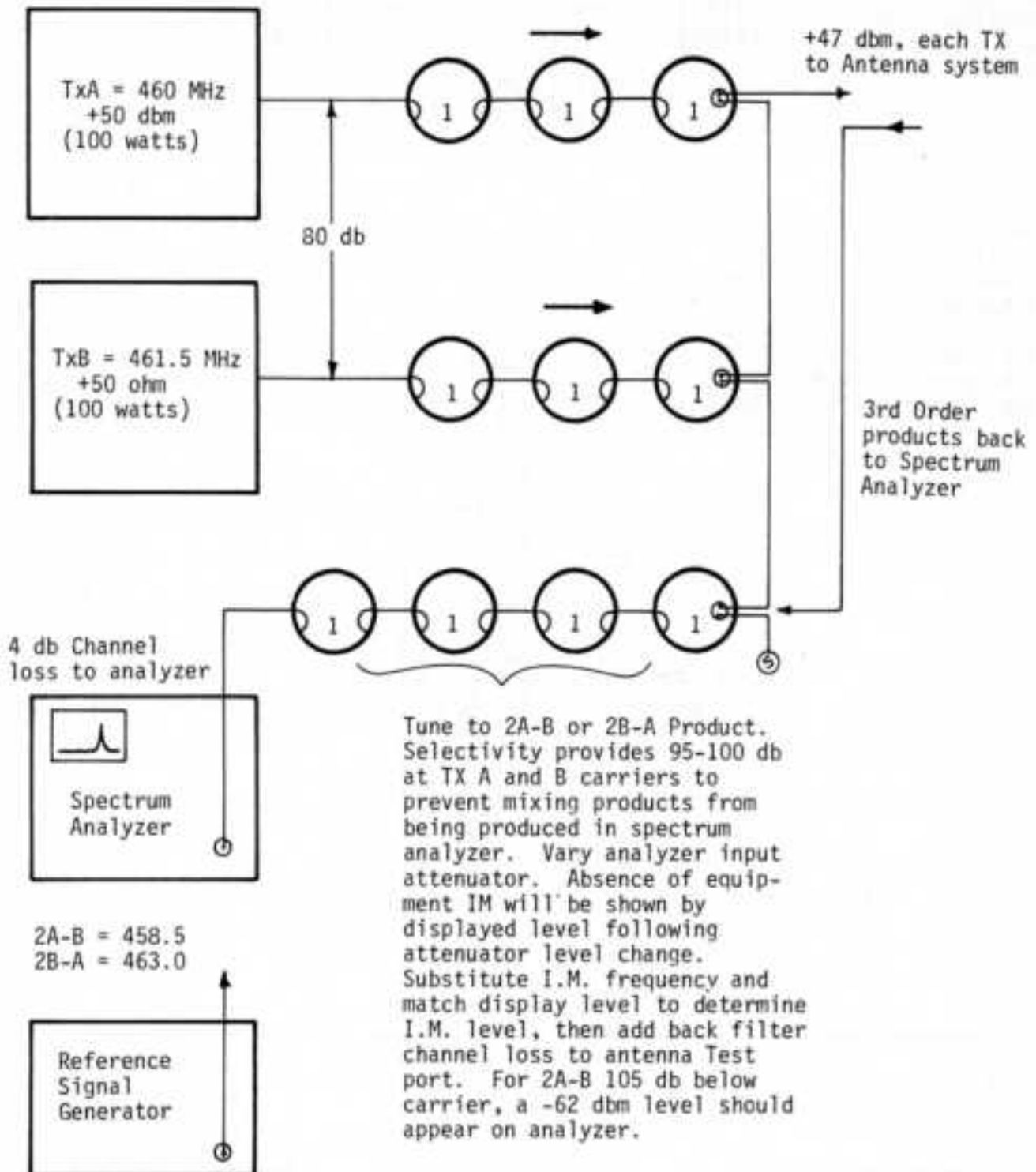
$P_o$  = Preamp output power in dbm.



2A-B Product Response Curves for  
Various Output Intercept Points

# CAVITY FILTER TEST BED FOR FIELD MEASUREMENT OF ANTENNA INTERMOD

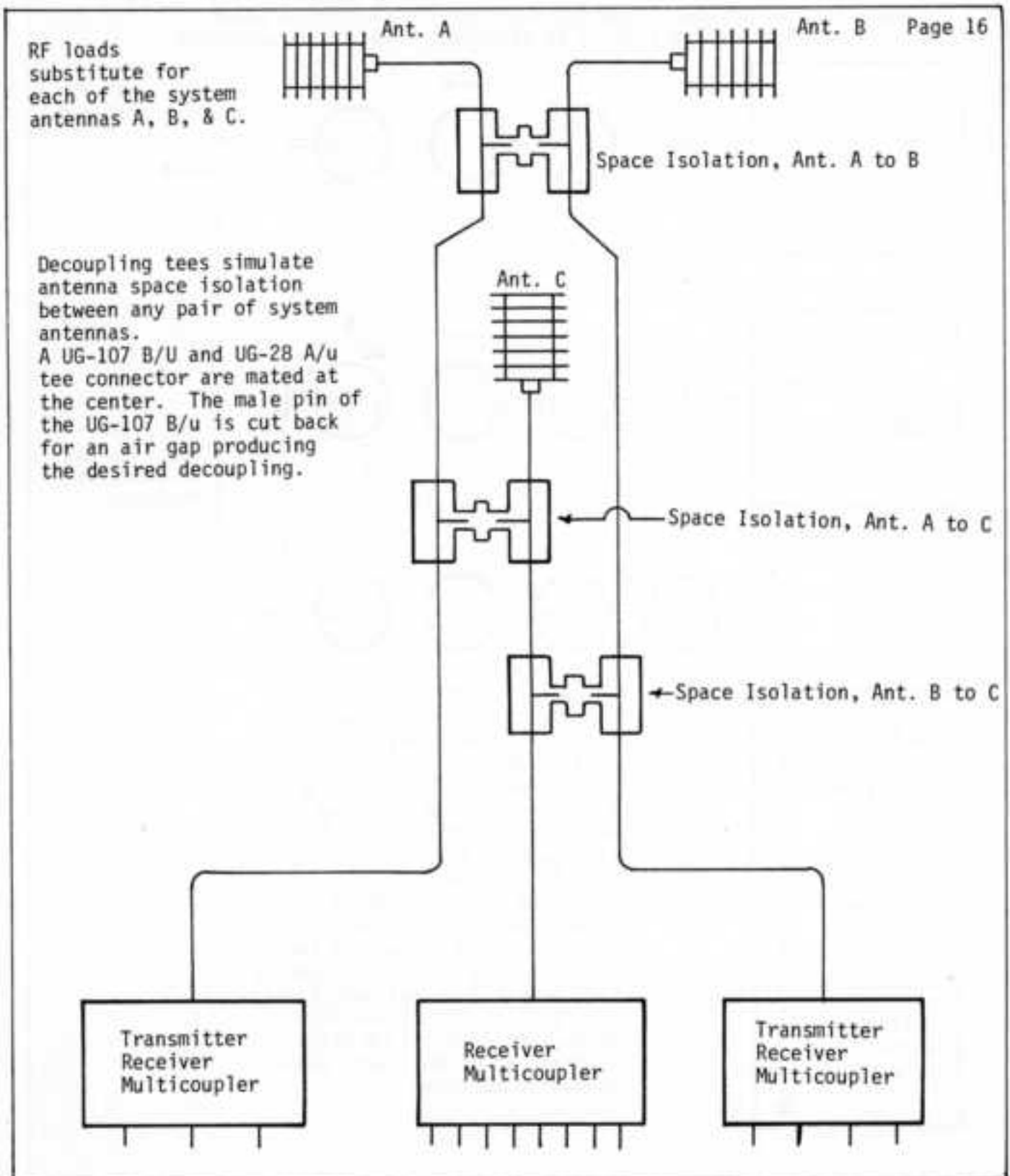
NOTE: 80 db between TX bandpass channels will produce about 160 db suppression of IM generated in either transmitter.



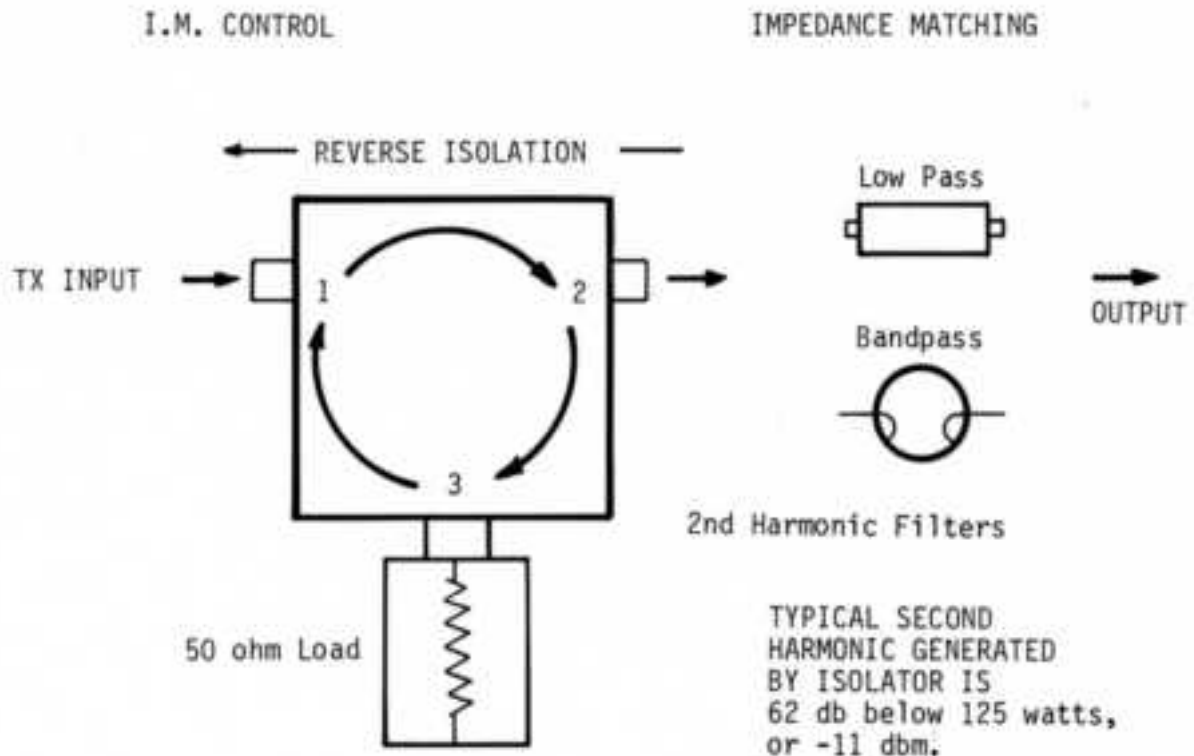


## AN ANTENNA SYSTEM SUBSTITUTION TEST FOR POSSIBLE SEPARATION OF ANTENNA SYSTEM I.M. FROM MULTICOUPLER I.M.

Elimination of I.M. products when this test is made indicates source is exterior to multicoupler system.



## FERRITE ISOLATOR



- PORTS 1 - 2 LOW LOSS, NON-SELECTIVE PASS BAND, WITH INPUT IMPEDANCE NOT A FUNCTION OF OUTPUT IMPEDANCE
- PORTS 2 - 3 REFLECTED POWER, OR OTHER INCOMING SIGNALS TERMINATE IN PORT 3 LOAD
- PORTS 3 - 1 LEAKAGE PATH. ENERGY NOT ABSORBED BY LOAD ON PORT 3, TRAVELS TO PORT 1.
- PORTS 2 - 1 DESIRED REVERSE ISOLATION, NON-SELECTIVE IN CHARACTER. POOR MATCH OF LOAD TO PORT 3 WILL CAUSE 3 - 1 LEAKAGE AND REDUCE ISOLATION.

When TX antennas are horizontally spaced and deficient in space isolation, radiation of Isolator second harmonic into an adjacent isolator may create a readable 2A - B product.