SEMINAR SUBJECTS

T-PASS ® EXPANDABLE MULTICOUPLERS: PRINCIPLES AND APPLICATIONS

by
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Model 73-38-05-2D-12 or 73-67-05-2D-12
12-Channel *T-Pass* Transmitter Multicoupler

Introduction

Thousands of TX RX Systems' *T-Pass*® multicouplers are in use today, in applications ranging from two-repeater sites to very complex transmitter/receiver multicouplers in multiband radio sites. The benefits of *T-Pass* multicoupler technology have been proven for over a decade in the toughest operating environments in the world. Unsurpassed ease of expansion, reliable performance and superior system design flexibility have made *T-Pass* multicouplers the preferred choice of radio site owners.

This Seminar Subjects explains how *T-Pass* multicouplers provide benefits beyond those of ordinary cavity and cavity/ferrite multicouplers, with none of their electrical or mechanical limitations. It outlines a variety of *T-Pass* system design techniques that have proven to be of practical interest in radio system design work.

T-Pass ®Filter Operating Principles

The heart of a *T-Pass* multicoupler is an innovative, patented three-port cavity filter that provides two distinct, isolated signal paths. One path, from a primary input/output port to a common antenna port, exhibits a high-selectivity bandpass characteristic centered at the resonant frequency of the cavity. A second path, from a secondary input/output port to the antenna port, behaves as a low-loss, 50-ohm transmission line at frequencies other than the resonant frequency of the cavity filter.

Figure 1 shows a typical *T-Pass* transmitter multicoupler channel. The assembly consists of a *T-Pass* cavity filter and a dual ferrite isolator. The *T-Pass* filter, shown in diagram form in **Figure 2**, consists of a tunable coaxial cavity filter, a bandpass coupling loop and a two-port, *T-Pass* coupling loop. The single-port bandpass loop is the primary input/output port. The two-port *T-Pass* coupling loop has the common antenna port (top) and the secondary input/output port (bottom).

Figure 1 - Typical *T-Pass* Transmitter Multicoupler Channel Assembly

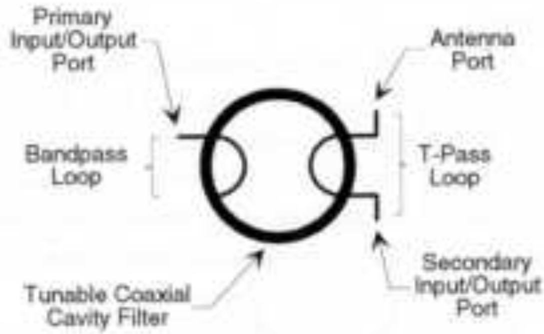

Figure 2 - T-Pass Cavity Filter

When the secondary input/output port of the *T-Pass* loop is short-circuited as shown in **Figure 3**, the path from primary input/output to antenna behaves as a bandpass filter whose response characteristics are a function of loop coupling, cavity design and tuning.

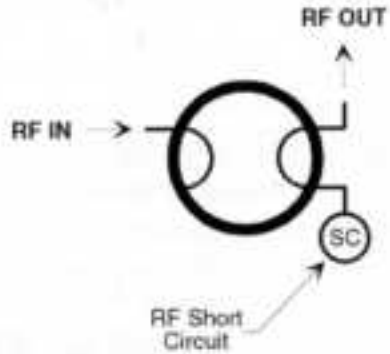

Figure 3 - *T-Pass* Bandpass Response Test Setup

The RF short circuit can be either a low-reactance metallic short between coaxial connector contacts or a 1/4-wave open coaxial stub, the former being preferred for broadband operation.

The short circuit does not need to be directly connected to the secondary input/output port as shown in **Figure 3**: it can be physically separated from the port by a transmission line of length equal to a multiple of a half wavelength at the cavity resonant frequency. The half-wave transmission line "repeats" the short at the secondary input/output port. In conjunction with the dual-path design of the *T-Pass* cavity filter, this important property provides the basis for *T-Pass* multicoupler design and its inherent benefits.

Figure 4 shows the bandpass response of a typical 10-inch, quarterwave 132-174 MHz *T-Pass* cavity filter at center insertion loss settings of -1.5 and -2.5 dB. The response is essentially the same as that of a 10-inch bandpass filter. Selectivity is greater at higher cavity insertion loss settings, as it should be.

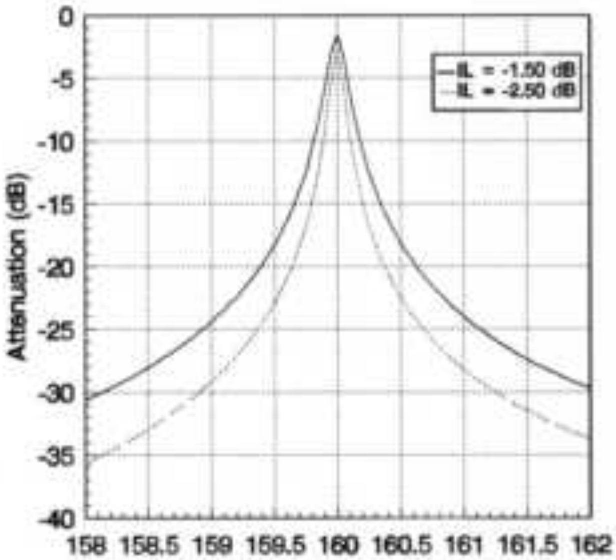

Figure 4 - Bandpass Response
10" 1/4-Wave VHF *T-Pass* Filter

If the primary input/output port of the *T-Pass* filter is terminated with a 50-ohm resistive load, and a signal is applied to the secondary input/output port as in **Figure 5**, a low-loss broadband response is attained between the secondary input port and the antenna port.

The loss through this path is referred to as *T-Pass bridging loss*. At frequencies well above and below the resonant frequency of the cavity, *T-Pass* bridging loss is in the order of -0.01 to -0.03 dB, depending on frequency range, cavity size and loop construction. Bridging loss is higher near the resonant frequency of the cavity, due to increasing coupling of RF energy from the T-Pass loop assembly into the cavity and the load on its primary input/output.

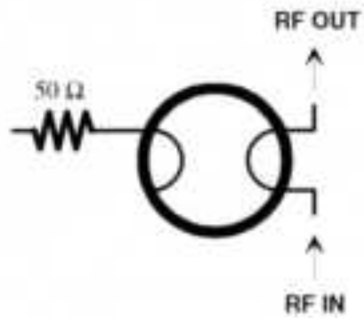

Figure 5 - *T-Pass* Bridging Loss Test Setup

Unlike bridging loss in ordinary cavity/ferrite combiners, *T-Pass* bridging loss is a well-defined, predictable function of offset from cavity resonant frequency for each type of cavity. The bridging loss curves in **Figure 6** are typical of 10-inch, quarterwave VHF *T-Pass* filters. See **Tech-Aid No. 92002** for normalized bridging loss curves for all *T-Pass* cavity filters from 66 to 960 MHz.

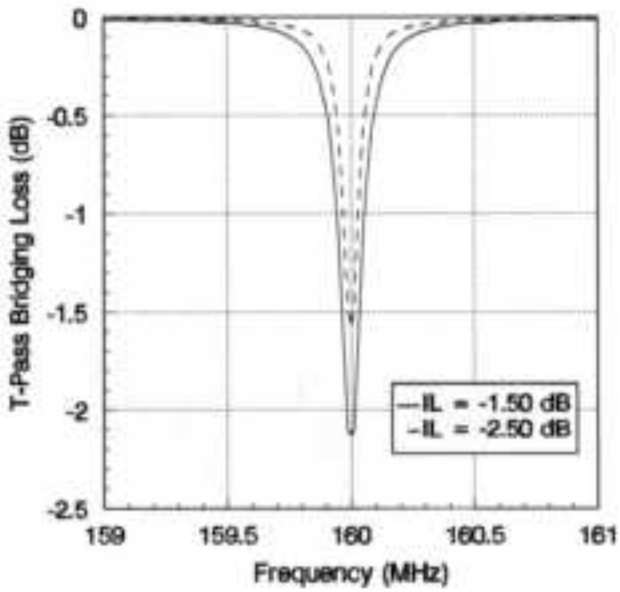

Figure 6 - *T-Pass* Bridging Loss
10" 1/4-Wave Cavity @ -1.5 & -2.5 dB Loss

Building a T-Pass ® Multicoupler

Let us now apply the principles outlined above to the construction of a simple three-channel *T-Pass* transmitter multicoupler.

Figure 7 shows two separate *T-Pass* cavity filters, C1 and C2. An RF short circuit has been connected to the secondary input port of each filter, and the coupling loops have been set to provide an insertion loss of -1.5 dB at the filter resonant frequencies of 160.000 and 161.000 MHz.

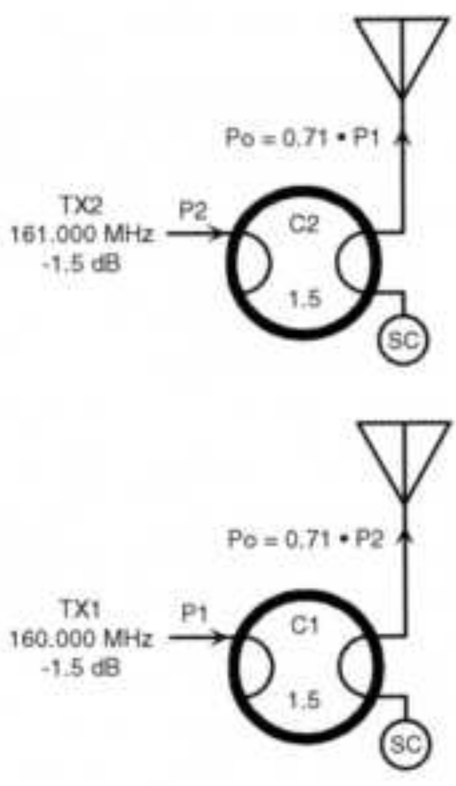

Figure 7 - 160 and 161 MHz *T-Pass* Filters

When transmitters TX1 and TX2 operating on 160.000 and 161.000 MHz are connected to the primary inputs of C1 and C2, respectively, 71% of carrier power P1 and P2 passes to the antennas, due to the cavity insertion loss of -1.5 dB. Transmitter broadband noise and spuria, as well as unwanted signals entering each antenna, are attenuated in the cavity filters in accordance with the bandpass response curve for -1.5 dB loss shown in **Figure 4**.

To construct a two-channel *T-Pass* transmitter multicoupler with these cavities, we first remove the RF short circuit from the secondary input of C2, and then connect the antenna port of C1 to the secondary input of C2 through a length of coaxial cable L2, as in **Figure 8**. If we cut L2 to a length such that the total transmission line length between the secondary input port of C2 and the RF short circuit on C1 is one half-wavelength at 161.000 MHz, the short circuit on C1 is "repeated" at the secondary input port of C2. In this case, 19.1 inches of teflon-dielectric coaxial cable are required.

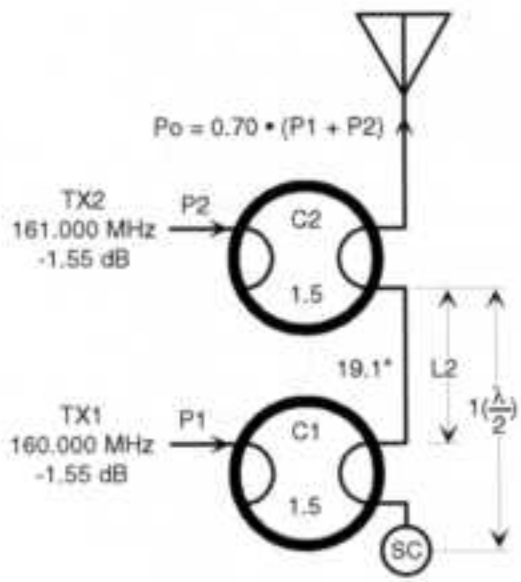

Figure 8 - Two-Channel *T-Pass* Transmitter Multicoupler

When transmitter TX2 operates, C2 behaves as an ordinary bandpass filter. 70% of carrier power P2 is transferred to the antenna port, in the same manner as if the short circuit on C1 were connected directly to the secondary input of C2. When transmitter TX1 operates, C1 also behaves as an ordinary bandpass filter and 70% of carrier power P1 is transferred to the antenna via C1, thruline cable L2 and the T-Pass coupling loop on C2.

Channel insertion loss is the sum of cavity insertion loss at resonance, thruline cable loss and *T-Pass* bridging loss. *T-Pass* channel loss in this particular case is -1.55 dB with 10-inch cavities at 1.0 MHz separation. This is only -0.05 dB more than individual cavity insertion loss.

The order in which *T-Pass* channels are chained together is unimportant, as it is always possible to cut thruline cables of lengths that produce the required multiple of a half wavelength. If the position of C1 and C2 were reversed in the preceding example, L2 would be 19.3 inches long instead of 19.1 inches. All other system characteristics would remain the same.

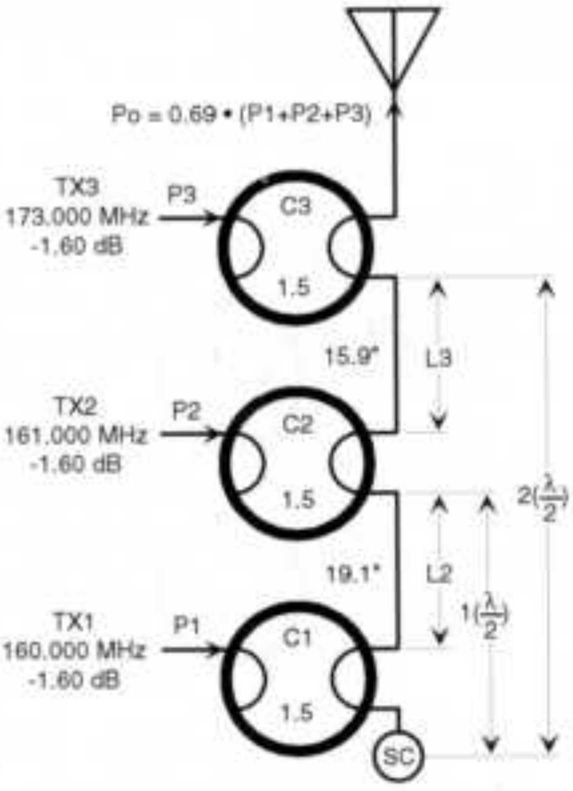

Figure 9 - Three-Channel *T-Pass* Multicoupler

A third channel can be easily added for transmitter TX3 operating on 173.000 MHz, as shown in **Figure 9**. *T-Pass* cavity C3 is tuned to 173.000 MHz and connected to the antenna port of C2. The length of thruline cable L3 is such that the total electrical length between the secondary input of C3 and the RF short on C1 is two half-wavelengths at 173.000 MHz. 15.9 inches of teflon-dielectric cable are required in this case. The RF short on C1 is now repeated at C3, and power from TX3 can pass to the antenna as if the RF short circuit were connected directly to the secondary input port of C3. The *T-Pass* loop on C3 behaves as a 50-ohm transmission line at the frequencies of TX1 and TX2. Power from TX1 and TX2 therefore passes through C1, C2, L2 and L3 to the system output. *T-Pass* channel loss increases from -1.60 to -1.65 dB, and 69% of transmitter carrier power is transferred to the antenna.

Many channels can be connected in this fashion, with practical limits on the number of channels that are dictated by site conditions, intermodulation considerations, mechanical assembly limits and maximum allowable insertion loss for each application. The majority of existing *T-Pass* multicoupler systems in commercial service today are from 4 to 20 channels.

T-Pass ®Channel-to-Channel Isolation

T-Pass channel-to-channel isolation, measured from one channel primary input/output port to another, is the sum of cavity insertion loss at resonance, adjacent cavity selectivity, and a thruline cable mismatch loss of -6 dB or more. In the case of the two-channel multicoupler described in **Figure 8**, ten-inch *T-Pass* cavities provide a total of -31 dB isolation at a cavity insertion loss of -1.5 dB and a channel separation of 1.0 MHz. **Figure 10** shows the corresponding selectivity and isolation curves.

Because it is determined primarily by cavity selectivity, channel-to-channel isolation de-

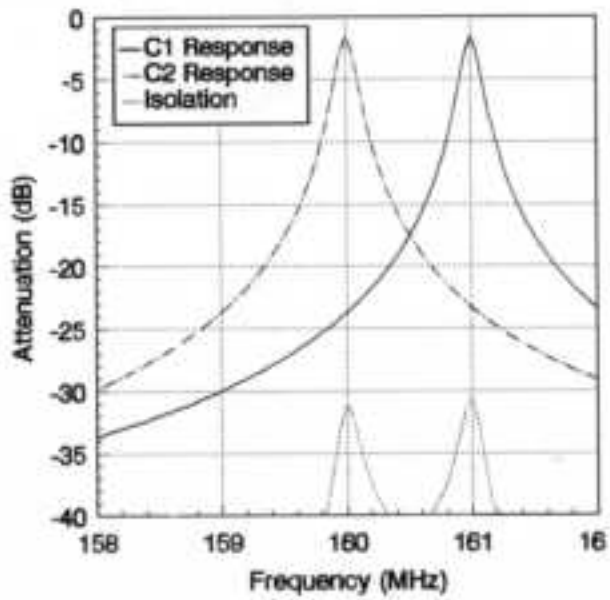

Figure 10 - 10" *T-Pass* Cavity Isolation
1 MHz Separation @ -1.50 dB Loss

creases rapidly at smaller channel frequency separations. **Figure 11** shows that isolation decreases to about -14 dB at the minimum recommended channel separation of 50 KHz for 10-inch VHF quarterwave *T-Pass* cavities set to a center loss of -2.50 dB.

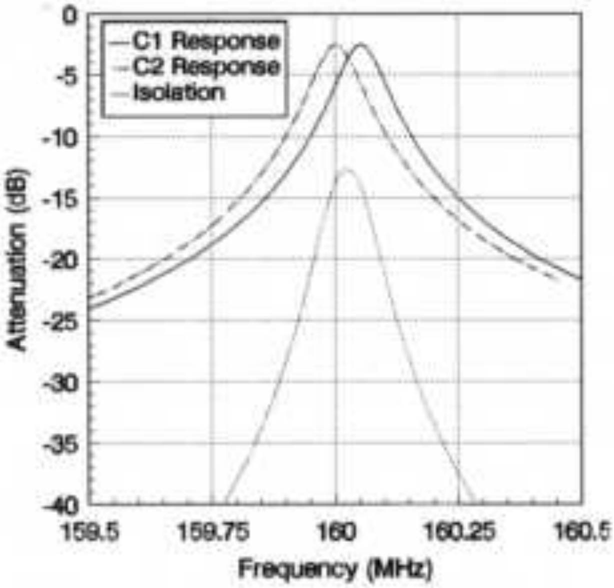

Figure 11 - 10" *T-Pass* Cavity Isolation
50 KHz Separation @ -2.50 dB Loss

Table 1 is a summary of minimum channel separation specifications for *T-Pass* multicouplers in the 66-960 MHz range using 6.625- and 10-inch T-Pass cavities. **Tech-Aid No. 92002**, "T-Pass Expandable System Design Data", provides a complete set of worst-case response curves for all 6.625-inch and 10-inch diameter *T-Pass* cavity filters for frequency ranges from 66 to 960 MHz. The curves are useful for estimating selectivity in *T-Pass* receiver multicoupler channels, noise suppression in transmitter multicoupler channels, and channel-to-channel isolation in all *T-Pass* multicouplers.

Isolators in T-Pass ®Tx Multicouplers

A single, dual or triple ferrite isolator may be added at the input of each *T-Pass* channel to increase transmitter multicoupler channel isolation. TX RX Systems' standard *T-Pass* transmitter multicouplers utilize dual ferrite isolators to provide a typical channel-to-channel isolation of 80 dB at minimum recommended channel separation. Isolation increases rapidly at greater frequency separations.

Ferrite isolators in *T-Pass* transmitter multicouplers provide three additional benefits:

1. They isolate the transmitter from unwanted signals that enter the system via the antenna. Typical antenna-to-transmitter isolation with dual isolators is -70 dB at the channel frequency. The combination of reverse isolation and *T-Pass* cavity attenuation produces even greater antenna-to-transmitter isolation at frequencies within the isolator operating bandwidth. This accounts for the superior intermodulation suppression that is characteristic of *T-Pass* transmitter multicouplers.

Frequency Range (MHz)	T-Pass Multicoupler Series	Minimum T-Pass Channel Separation (KHz) @ Specified Cavity Loss (dB)						
		-1.0 dB	-1.25 dB	-1.5 dB	-1.8 dB	-2.0 dB	-2.5 dB	-3.0 dB
66-88	**73-28-01** (6.625" 1/4-Wave)	135		90		60	45	40
	73-28-05 (10" 1/4-Wave)	95		65		50	35	30
118-136	**73-35A-01** (6.625" 1/4-Wave)	170		105		75	55	45
	73-35A-05 (10" 1/4-Wave)	120		80		60	45	35
132-174	**73-38-01** (6.625" 1/4-Wave)	200		140		95	70	N/A
	73-38-05 (10" 1/4-Wave)	150		95		70	50	40
215-300	**73-54A-01** (6.625" 1/4-Wave)	225		170		120	95	80
	73-54A-05 (10" 1/4-Wave)	185		140		105	75	60
400-530	**73-67-11** (6.625" 3/4-Wave)	325		215		150	115	90
	73-67-25 (10" 3/4-Wave)	240		150		110	85	70
800-1000	**73-90-11** (6.625" 3/4-Wave)		400		250			N/A
	73-90-31 (6.625" 5/4-Wave)		350		220			125

Table 1 - Minimum *T-Pass* Channel Separation

2. The transmitter "sees" an excellent impedance match on its output, because the isolator absorbs reflected power that would otherwise enter the transmitter output. This improves the stability, spectral purity and long-term reliability of the transmitter.
3. An RF sampler can be installed between the termination port of the isolator output stage and its 50-ohm load, to provide a convenient means of monitoring individual channel reflected power. The sampler also provides a test point for fine-tuning system channels with an inexpensive tuning meter, an RF millivoltmeter or a spectrum analyzer.

Figure 12 shows a complete 3-channel VHF *T-Pass* transmitter multicoupler. Isolation between channels is greater than 100 dB. Channel insertion loss is -2.6 dB on all channels, resulting in a transfer of 55% of transmitter power to the system antenna port.

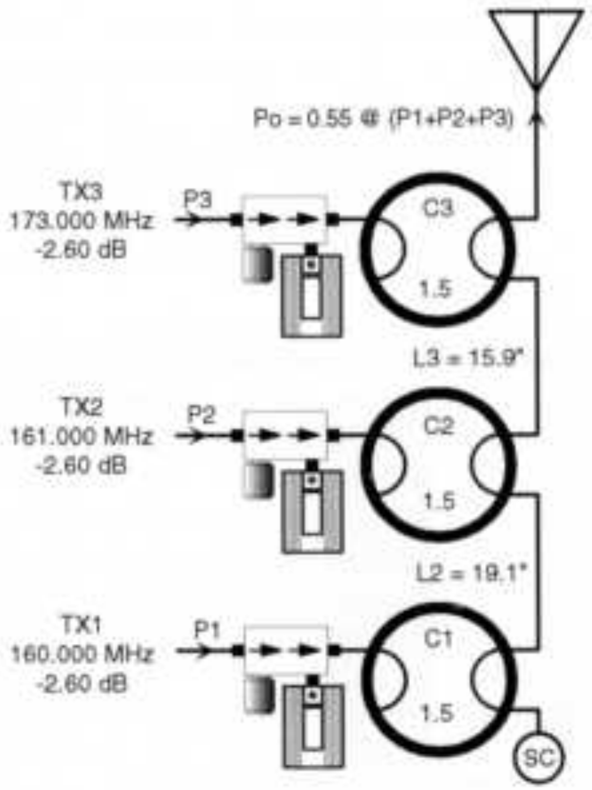

Figure 12 - Model 73-38-25-2C-03
T-Pass Expandable transmitter Multicoupler

Calculating T-Pass ®Thrulines

Thruline cable lengths for new systems or expansion channels are easily and accurately determined on the basis of channel frequencies. Cable length calculations can be performed with pencil, paper and a four-function calculator, using *Thruline Worksheets* and the simple procedure described in **Tech-Aid No. 93003**.

For those who have and prefer to use a personal computer, TX RX Systems' *T-Pass* system design software reduces the possibility of errors and eliminates guesswork about the performance of new or expanded *T-Pass* multicoupler systems. After entering channel frequencies, the software quickly calculates thruline cable lengths that satisfy the requirement of half-wave transmission line lengths at each channel frequency.

As an additional benefit, the software accurately estimates *T-Pass* channel insertion loss for the specified frequency plan and cavity loss settings. Channel loss estimates are typically pessimistic and within a fraction of a dB of measured insertion loss.

Figure 13 is a printout created with TX RX Sytems' *T-Pass* system design software for the 800-1000 MHz range. The excellent agreement between estimated and measured loss is typical of predictions made with the software.

In addition to making it easy to optimize multicoupler channel loss settings, the ability to predict multicoupler loss is very useful for purposes of communication system analysis. The software has provisions to specify channel gains or losses other than those associated *T-Pass* cavities, such as isolators, hybrid couplers, duplexers, power amplifiers, receive preamplifiers, antenna feedlines and other multicoupler system components. See **Tech-Aid No. 93004** for more information about the software.

TX RX Systems Inc. maintains extensive engineering files that allow customers to order expansion channels by simply specifying the new channel frequencies and the serial number of the existing system. This is quite convenient to customers who may no longer have records of what was originally installed many years ago.

T-PASS CHANNEL DATA Ch Type/ID	Frequency	COMPONENT LOSS (dB) Cav.	Isol.	Other	CHANNEL LOSSES(dB) Estimated	Measured	Length Adjust	Old TL(in) New TL(in)	Cnnctr dL(in)	REMARKS
5 TX5 Model No.:	856.5625	-1.25	-0.70	-0.75	-3.24	-2.90	+0.00	11.92	3-1754 +0.000	
4 TX4 Model No.:	857.5625	-1.25	-0.70	-0.75	-3.34	-3.20	+0.00	11.88	3-1754 +0.000	
3 TX3 Model No.:	858.5625	-1.25	-0.70	-0.75	-3.35	-3.30	+0.00	11.85	3-1754 +0.000	
2 TX2 Model No.:	859.5625	-1.25	-0.70	-0.75	-3.34	-3.20	+0.00	11.56	3-1754 +0.000	
1 TX1 Model No.:	860.5625	-1.25	-0.70	-0.75	-3.24	-3.20	+0.00	Short Ckt 0.257		

T-Pass ®Peg Rack ™ Mounting System

The open, volumetrically efficient arrangement of the multicoupler on the inside front cover of this booklet is achieved with a patented cavity support frame (U.S. Patent number 4,493,422), known as a *Peg Rack* ™. It securely holds up to twelve 10-inch or fifteen 6.625-inch *T-Pass* channel assemblies, allowing unrestricted access to all system parts, tuning adjustments and test points.

T-Pass channel assemblies are attached with stainless steel clamps to four support "pegs" and become an integral part of the *Peg Rack* structure. Excellent mechanical strength is achieved with a minimum of support members. A typical *Peg Rack* is about 75% lighter than a 19" cabinet of equivalent capacity. This results in a large reduction of shipping cost.

More than one multicoupler system can be installed in one *Peg Rack*. For this reason, all standard transmitter and transmitter/receiver multicouplers manufactured by TX RX Systems Inc. can be ordered with or without a *Peg Rack*. Optional racks are available to accommodate up to twenty 6.625-inch channels.

T-Pass ®System Expansion

Electrical and mechanical expandability is an inherent characteristic of *T-Pass* multicoupler technology. *T-Pass* multicoupler expansion amounts to nothing more than installing an expansion channel assembly, or several, on top of an existing system. Each expansion channel assembly is factory-tuned to the new channel frequency and delivered with a thruline cable that satisfies the simple *T-Pass* cable length requirements described above. Nothing has to be changed in the existing system and, unless the frequency of a new channel is very close to an existing one, it is normally not necessary to retune channels after expansion.

Expansion channels for standard *T-Pass* transmitter multicouplers include factory-tuned ferrite isolators. Expansion channels for *T-Pass* receiver multicouplers are available with or without low-noise preamplifiers and RF splitters. See **Tech-Aid No. 93002** for a partial guide to available *T-Pass* expansion channels.

System performance after expansion can be predicted with TX RX Systems' *T-Pass* System Design Software.

T-Pass ®System Operating Bandwidth

Because the thruline associated with each *T-Pass* channel needs to be optimized only at its own operating frequency, individual channel frequencies can be anywhere in a very broad frequency range. It is quite easy to design *T-Pass* multicoupler systems with operating bandwidths that span or exceed an entire frequency band (66-88 MHz, 118-136 MHz, 132-174 MHz, 215-300 MHz, 400-530 MHz, 800-1000 MHz). **Figure 14** shows a *T-Pass* transmitter multicoupler system in which channel frequencies occupy an operating bandwidth of nearly 30% of center frequency.

Ordinary cavity/ferrite combiners utilize quarterwave or multiple-quarterwave cable transformers to couple cavities to a common output. Such cable transformers are frequency-sensitive and intrinsically narrowband. They restrict combiner operating bandwidth to no more than 3% to 6% of center frequency.

T-Pass multicouplers do not use narrowband cable transformers. *T-Pass* loops and their associated thrulines are designed to be a broadband transmission line, and system bandwidth is only limited in practice by antenna bandwidth and frequency allocation regulations.

Tailoring T-Pass ®Channel Selectivity

T-Pass channel selectivity can be easily tailored to meet specific duplex operation requirements. When simplex radios are multicoupled to a single antenna, for example, large amounts of transmitter noise suppresion may be required for desensitization-free operation. Furthermore, ferrite isolators cannot be used to provide transmitter isolation, due to the bidirectional nature of the simplex channels. In such cases, channel selectivity can be increased by adding cavities in series with the *T-Pass* channel filter.

When greater attenuation is required at one frequency only, *Series-Notch* ® and *Vari-Notch* ® cavity filters may be used to substantially increase *T-Pass* channel selectivity at the specified frequency, with an insertion loss penalty of no more than -0.25 to -0.60 dB per cavity.

In **Figure 14**, 4-inch *Vari-Notch* cavities are used in channel 2 Tx (455.800 MHz) and Rx (460.800 MHz) to obtain approximately 45 dB additional noise and carrier suppression at 5 MHz T-R separation. This allows operation with only 20 dB space isolation between antennas.

Bandpass cavities are best for providing additional selectivity over a broad range of frequencies. A channel consisting of one bandpass

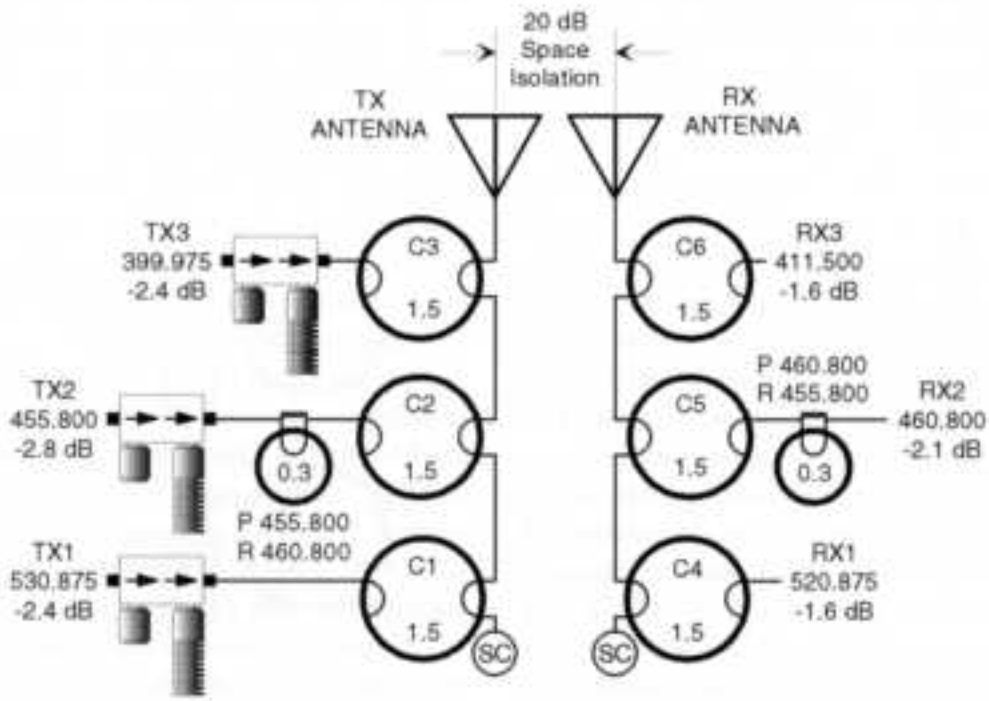

Figure 14 - Broadband UHF *T-Pass* Multicoupler System

cavity set to -0.5 dB loss and one *T-Pass* cavity set to -1.0 dB loss, for example, provides much greater selectivity than a single *T-Pass* cavity set to -1.5 dB loss, without a net increase in channel insertion loss. Multiple-frequency channels can be set up by adjusting the selectivity of a T-Pass cavity and one or more bandpass cavities to provide the required passband.

The possibility of enhancing *T-Pass* channel selectivity with any combination of bandpass, *Vari-Notch* and *Series-Notch* filters allows the system designer to satisfy difficult duplex operation requirements, without losing the benefits of superior *T-Pass* system expandability.

T-Pass ®System Design Showcase

The two-port, dual-window *T-Pass* filter shown in **Figure 15** is ideal as a multichannel transmit/receive filter for simplex or semiduplex transceivers, or as a dual-window receive preselector for operation on wide-spaced discrete channel frequencies. In the case illustrated, TR1 is a simplex base station transceiver operating on 155.310 MHz on channel 1 and 155.910 MHz on channel 2. Signals to and from the transceiver are routed through the set of cavities on the corresponding transmit or receive frequency. Typical channel insertion loss is only -2.5 dB, and channel selectivity is in the order of -48 dB at 1 MHz from the center of each passband. Antenna-to-transmitter isolation can be provided by inserting a ferrite isolator between the transmitter power amplifier and the antenna relay in the transceiver. Several *T-Pass* channels may be stacked in this fashion to configure two-port, multiple-window filters. If channel selectivity requirements can be met with a single cavity, each channel may consist of only one cavity with two *T-Pass* loops.

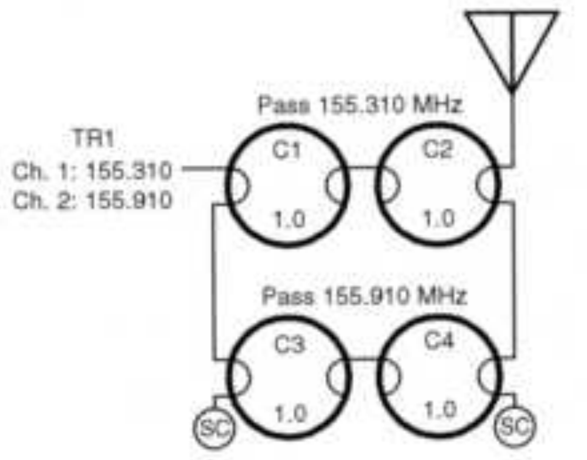

Figure 15 - Two-Frequency *T-Pass* Comb Filter

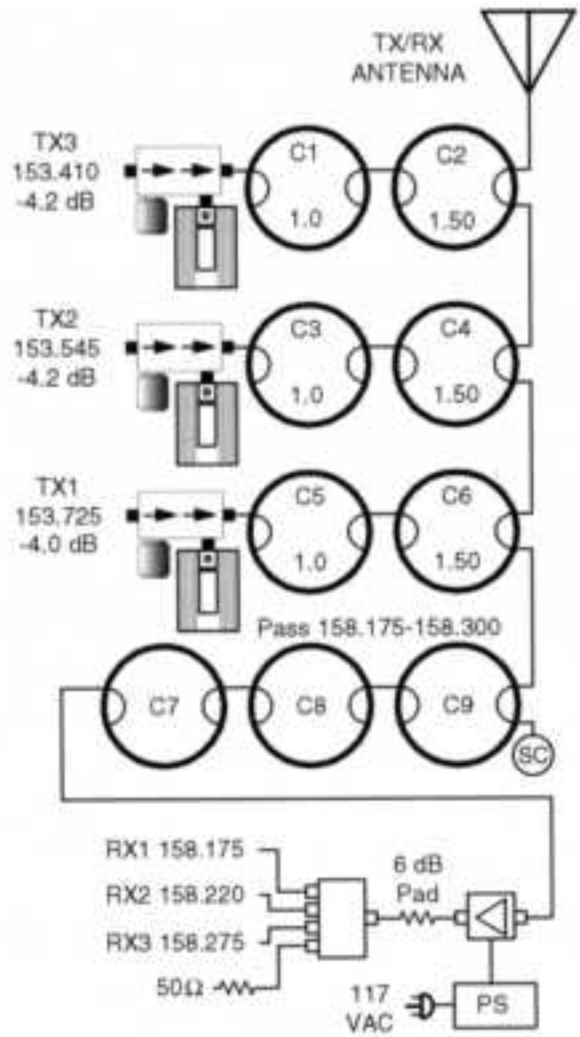

Figure 16 - *T-Pass* Transmitter/Receiver Multicoupler with Broadband Rx Channel

The *T-Pass* transmitter/receiver multicoupler system in **Figure 16** incorporates a multi-frequency receive channel. *T-Pass* filter C9 and bandpass filters C7 and C8 are tuned as a high-selectivity preselector, with a response that provides more than 80 dB carrier suppression and a pass bandwidth of approximately 125 KHz. A low-noise receiver multicoupler provides signal for up to 4 receivers in the preselector frequency range. With 0.25-uV receivers and -2.5 dB antenna feedline loss, typical system noise figure is 8 dB, equivalent to 0.22 uV SINAD sensitivity. The dual-cavity transmitter multicoupler channels provide more than 85 dB isolation between transmitters and more than 80 dB noise suppression at frequencies within the receive passband.

Figure 17 shows a single-antenna 800-MHz trunking multicoupler system for operation on transmit 851-866 MHz, receive 806-821 MHz. This particular system configuration is very popular among trunking system operators in the U.S. and abroad, because of its excellent system performance in congested operating environments. The system consists of a five-channel, 73-90-11-Series *T-Pass* transmitter multicoupler (C1 to C5 in the diagram), a high-performance combline bandpass duplexer, and a low-noise receiver multicoupler system.

T-Pass cavity filter selectivity and a four-section transmit combline filter provide more than -90 dB transmitter noise suppression at 821 MHz, the nearest receive frequency. A high-selectivity, 6-section combline preselector provides -80 dB carrier suppression. The expandable, low-noise receiver multicoupler provides excellent system sensitivity and a large spurious-free dynamic range.

Systems are also available for the expanded trunking frequency range (transmit 851-869 MHz and receive 806-824 MHz.) When congested site conditions require it, high-selectivity preselectors are available to provide more than 100 dB carrier suppression .

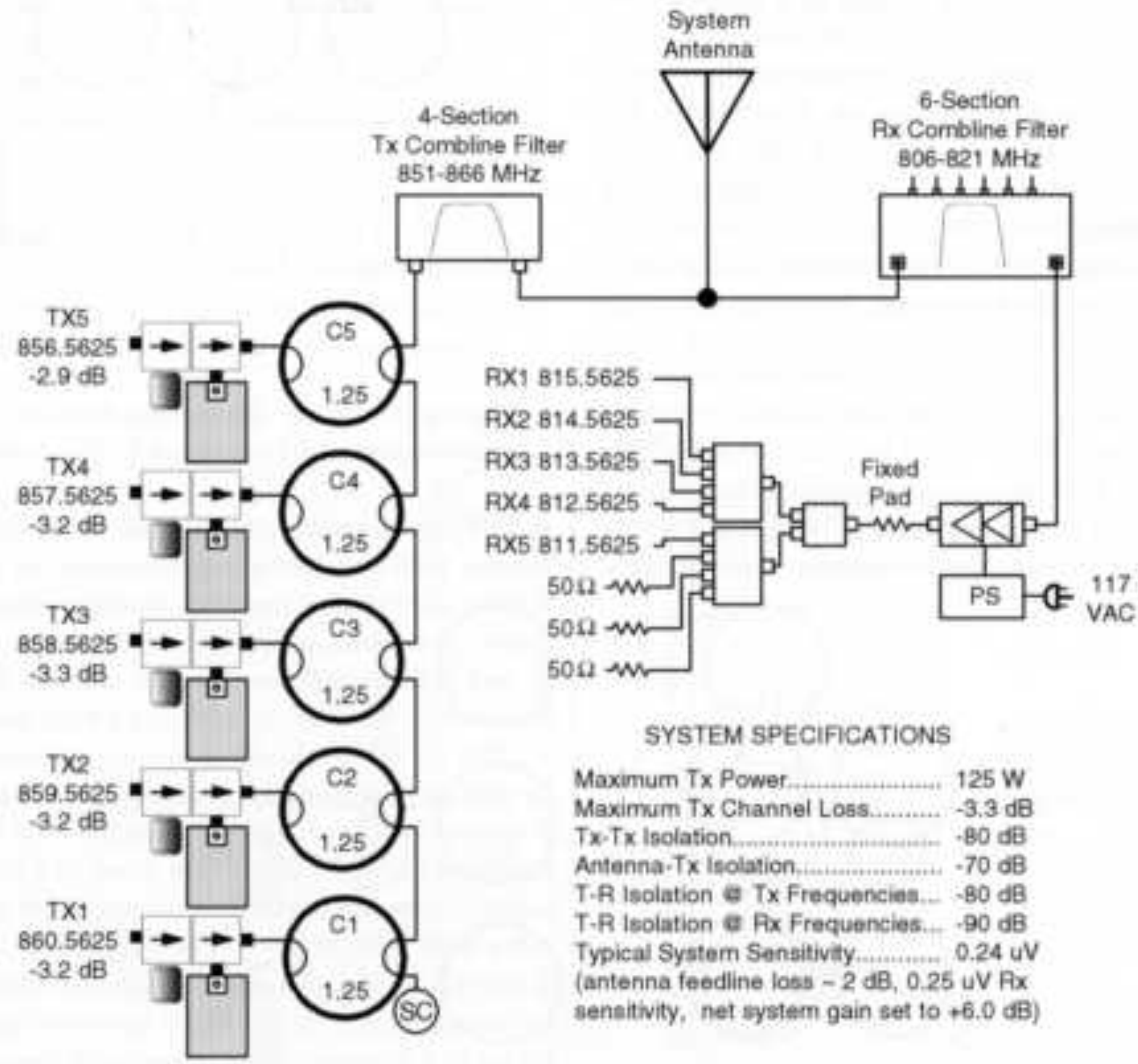

Figure 17 - Single-Antenna 800 MHz Trunking Multicoupler (Model 74-89-03-2D-05)

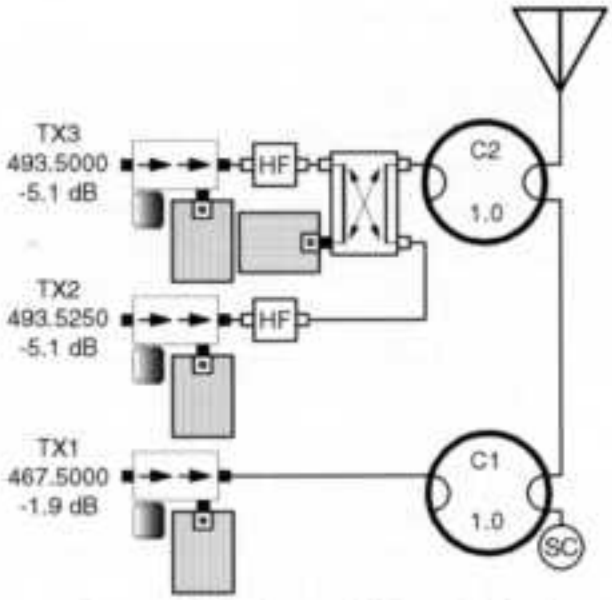

Figure 18 - 3-Channel *T-Pass*/Hybrid Transmitter Multicoupler

In **Figure 18**, close-spaced transmitters TX2 and TX3 are coupled into *T-Pass* cavity C2 through a hybrid combiner. TX1 is combined with TX2 and TX3 via T-Pass cavity C1. The system shown provides more than 90 dB isolation among transmitters, in addition to excellent noise and intermodulation suppression by C1 and C2. Insertion loss for TX2 and TX3 is -3.2 dB higher due to hybrid loss. The system can be expanded by adding either dual-frequency assemblies similar to C2 and associated hybrid combiner, or standard single-frequency expansion assemblies.

The transmitter/receiver multicoupler system in **Figure 19** meets the duplex operating requirements of U.S.-standard amplitude-compandored, narrowband 220-MHz trunking systems.

The system consists of a 5-channel *T-Pass* transmitter multicoupler, a 10-cavity, 4-inch *Vari-Notch* ® duplexer, and an 8-channel receiver multicoupler. Ten-inch *T-Pass* cavities and dual ferrite isolators provide more than 100 dB Tx-Tx isolation at 150 KHz channel separation. Total transmitter noise suppression is greater than 110 dB at 400 KHz T-R separation. Carrier suppression is greater than 80 dB over the 600-KHz receive bandwidth.

If the system were operated with an antenna feedline loss of -2.5 dB and 0.25-microvolt receivers, overall system noise figure would be 8.5 dB, equivalent to a sensitivity of 0.23 microvolt for 12 dB SINAD.

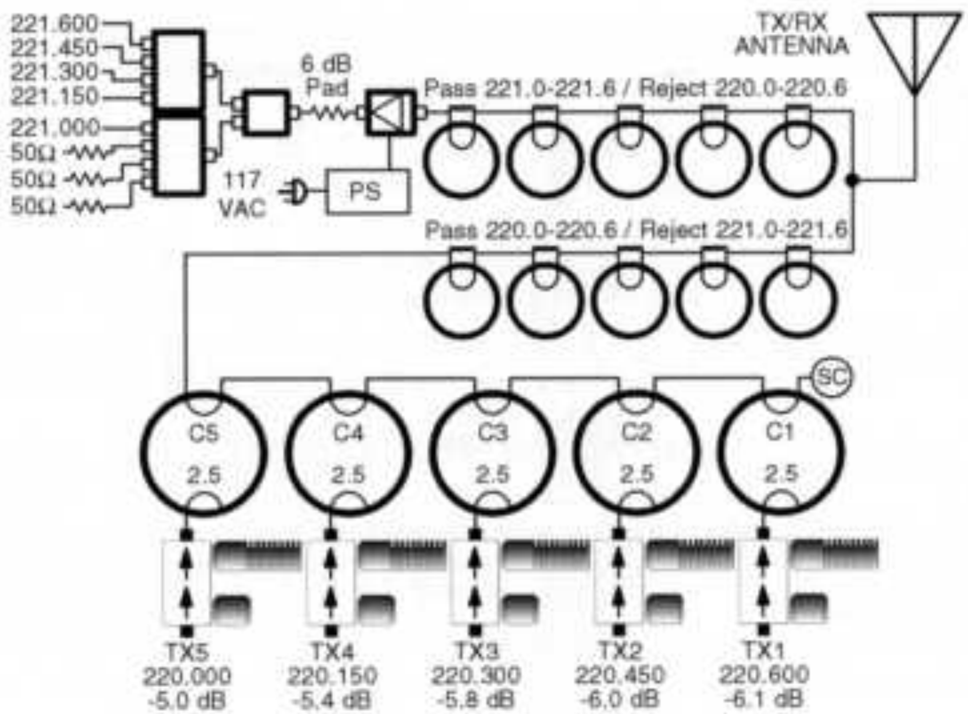

Figure 19 - Single-Antenna 220-MHz Trunking Multicoupler

A Word About System Design

The long-term success of *T-Pass* technology lies both in the elegant design of the hardware and in the judicious way that it has been applied over the years. Whether the situation requires just a standard *T-Pass* multicoupler straight from our catalog or a complex custom system design, the same principles should be applied every time:

1. ***Leave nothing to chance:***

- *Always do a comprehensive intermodulation analysis involving all known transmitter and receiver frequencies in the site and its vicinity.* This allows you to intelligently decide how to set up equipment and antennas in ways that minimize the potential for interference.
- *Always do a duplex isolation analysis,* to determine how much carrier and noise suppression are required for every transmitter/receiver pair in the system.
- *Always measure antenna isolation before installing the system.* Antenna isolation tables and charts should be used as guidelines only. Allow for possible reductions of isolation due to environmental effects (wind, rain, snow, ice, trees, etc.).

2. ***Be conservative:***

- *Do not use a single-antenna system if the intermodulation analysis indicates possible products on your receive frequencies.*
- *Do not assign transmitters to the same antenna when they may produce low-order intermodulation products:* your multicoupler may provide -140 dB of intermodulation suppression, but your antenna, feedline or connectors may not.
- *Be generous with your design margins.* Environmental conditions and equipment will change over the years. 6 to 10 dB of additional isolation may be the difference between satisfactory and unsatisfactory long-term system performance.
- *Above all, do not save money in places where you should not.* A cheap antenna that may be adequate for an isolated repeater may be a total disaster in a multicoupled radio site. Cheap connectors with nickel-plated contacts frequently become sources of noise and intermodulation problems. Operating unprotected transmitters and receivers on separate antennas is a sure way to guarantee interference problems.

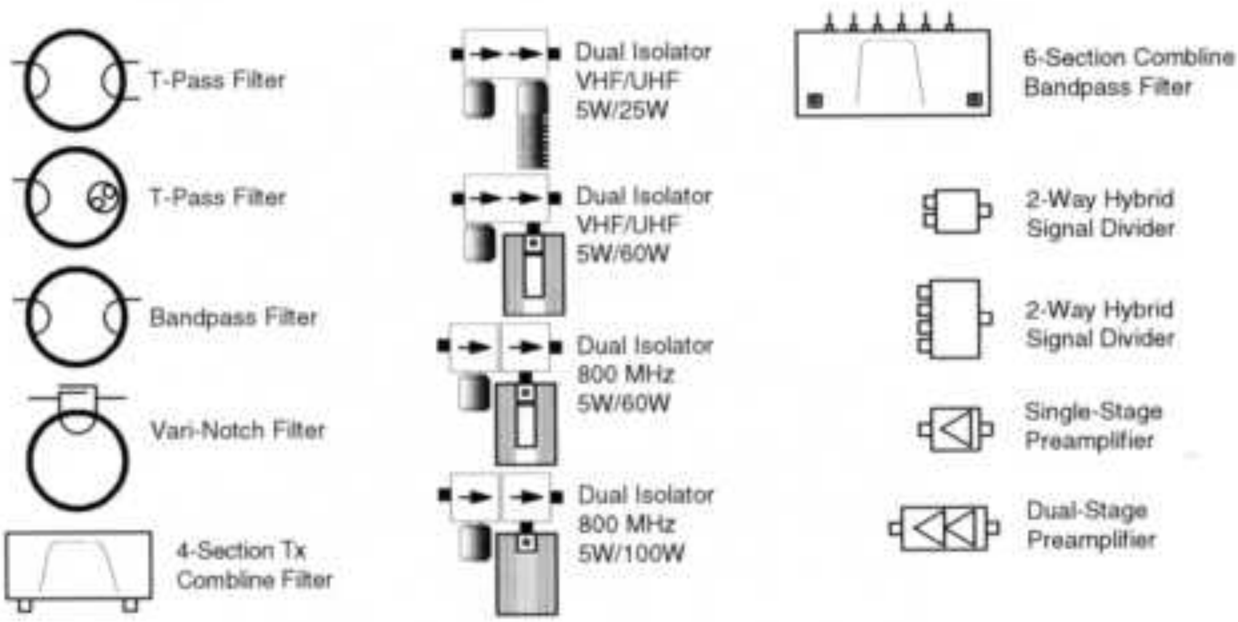

Figure 20 - System Diagram Nomenclature

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FOR ADDITIONAL INFORMATION

TX RX Systems Inc. provides an unusually broad range of technical support services to its customers, including extensive assistance in the selection of products for specific customer applications and/or system design services.

Contact **TX RX Systems Inc.** for additional information on transmitter and receiver multicouplers, cavity filters, duplexers, signal boosters (repeater amplifiers), ferrite circulators and isolators, RF loads and an extensive line of RF system products.