

# DUPLEXERS

W2MIL

ORMOND BEACH RADIO CLUB

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## **WHY ARE DUPLEXERS USED?**

Radio receivers can be damaged if high level RF signals, like those directly from a transmitter output, is applied to the receiver antenna.

Additionally, receivers may become 'desensitized' (or 'de-sensed') and not receive weak signals when high noise levels or another signal near the receive frequency is present at the receivers antenna input.

Obviously, radio receivers and transmitters cannot be directly connected to the same antenna without some device being used to:

- (1) switch the antenna between the transmitter and receiver so that they are never connected to the same antenna at the same time.
  - (2) When the transmit and receive frequencies are different, filters may be used to reduce the transmit signal levels to an acceptable low level at the receivers antenna input. Naturally, you cannot filter out the transmitter signal when it is the same as the receiver frequency.
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## **Definition of a duplexer:**

A device which allows a transmitter operating on one frequency and a receiver operating on a different frequency to share one common antenna with a minimum of interaction and degradation of the different RF signals.

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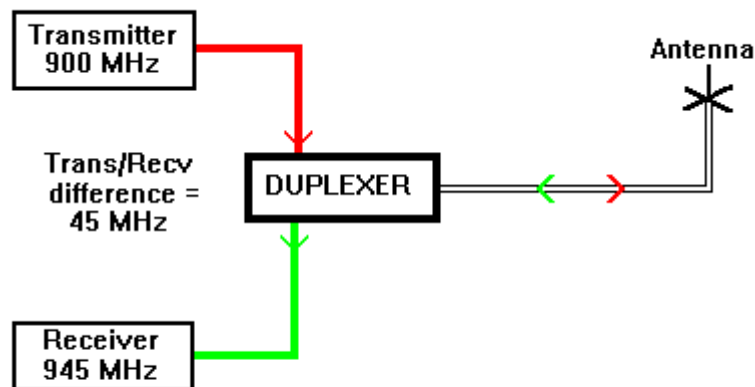
## **Duplex Operation**

Duplexers are often the key component that allows two way radios to operate in a full duplex manner. Full duplex means the transmitter and receiver can operate simultaneously as opposed to the 'push-to-talk' manner used in non-duplex (or 'simplex') operating modes.

Remember, the radio system must use two frequencies per 'channel' to use the kinds of duplexers we are discussing.

Recently, some very specialized digital radio systems that are under development are emulating duplex operation by switching the transmitter and receiver off and on extremely rapidly. This is not real full duplex operation but appears similar to the radio users. This discussion does not address this approach, but instead deals with more common accepted land mobile practices.

Duplexers are the devices that allow a mobile telephone to operate like a wired telephone, with either or both people speaking at any time without using a microphone switch to enable the radio transmitters.



**SIMULTANEOUS SIGNAL FLOW THROUGH A DUPLEXER**

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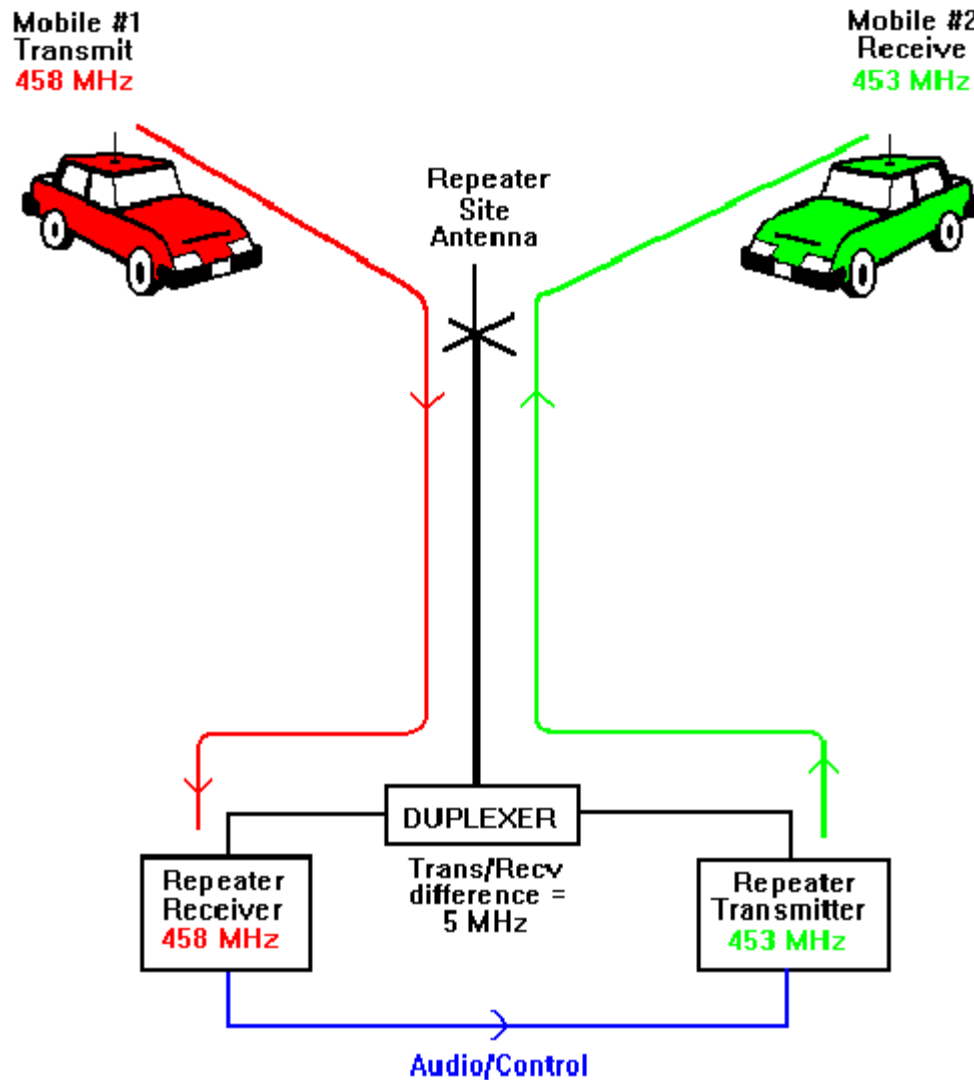
## **REPEATERS**

Most radio systems today use repeaters located on top of buildings, towers or on hill tops. These repeaters use two frequencies in a duplex fashion to extend the range of the radio system and make signals much stronger. In most cases, a duplexer is used as part of the repeater station.

The duplexers at repeaters may serve several objectives:

- Reduce the number of antennas required due to cost or space limits.
- Reduce the transmission line costs or allow a better and more expensive single cable to be used instead of two.
- Reduce the potential of intermodulation generated from the transmitter.
- Reduce the nearby broadband noise generated from the transmitter.

- Improve the receiver 'front-end' rejection of off-frequency interference.



RADIO SIGNAL FLOW THROUGH A TYPICAL REPEATER

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### WHY NOT USE TWO ANTENNAS?

Two antennas may be used instead of a duplexer, provided the antennas are placed far enough apart that the transmitter signals do not interfere with the receiver. Two transmission lines will also be required.

The isolation required between the transmitter and receiver is a complex issue and influenced greatly by the specific transmitter and frequencies used, the bandwidth of the channel, the difference in frequencies of the two frequencies to be used and the minimum amount of receiver degradation that is acceptable to the user.

It is not unusual to have a radio system require as much as 80 to 100 dB isolation between the transmitter output and the receiver input.

When two antennas are used, the type of antennas, the physical spacing and the orientation of the antennas to one another are also major concerns.

The antenna-to-antenna isolation can also be influenced by the presence of other antennas on the same tower as well as other nearby transmitters and mechanical structures. These factors may change over time and be out of the control of the repeater operator.

Antenna separation designs should also consider any additional receiver protection that may be required for other transmitters that may be present on the same tower.

In some extreme cases, duplex filters AND antenna separations may both be required to obtain satisfactory operation. This generally only occurs at lower frequencies with small differences between the transmit and receive frequencies or when closely spaced channels are combined.

Typical Antenna Spacing Isolation Values: (In dB) (Based on vertically polarized half-wave dipoles. Actual experience will vary due to local conditions, antenna variations, etc.)

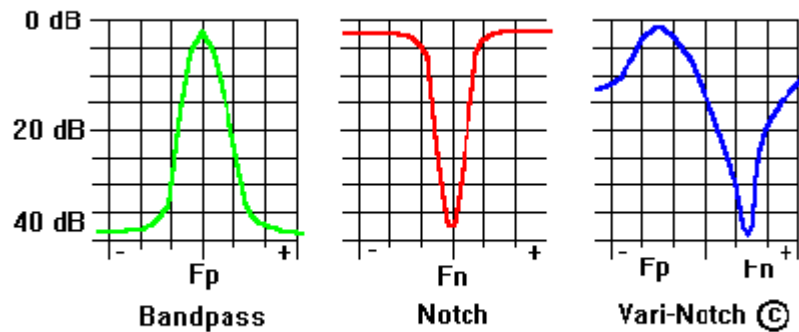
Frequency Band	Vertical Spacing			Horizontal Spacing		
	5'	10'	20'	25'	50'	100'
45 MHz	—	—	28	—	25	32
150 MHz	22	36	48	28	35	42
450 MHz	36	48	62	40	46	52
850 MHz	38	57	66	47	52	57

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## TYPES OF FILTERS USED IN DUPLEXERS

There are several ways to implement a duplexer, but all rely upon the characteristics of different types of RF filters. Specifically:

- Bandpass filters which allow a specific range of frequencies to pass through them. The filters are designed and tuned to a specific 'center frequency' and 'pass band' with relatively low losses to desired frequencies and higher losses that increase as the deviation from the center frequency increases.
- Reject or Notch filters which operate opposite of a bandpass filter. These are designed to cause high losses at the center frequency and lesser losses as the frequencies increase from the center frequency.
- Specialized filters such as TX RX Systems "Vari-Notch" (c) filter, which has characteristics of both a bandpass and notch filter in one device.



The filters are usually tubular or square cavity type filters but other types of construction such as combiner, ceramic, etc. may also be used in some cases.

Cavity type filters offer the best overall balance of performance, simplicity, and costs.

Combiners and ceramic filters have some space and size advantages at higher frequencies.

Ceramic filters may have power limitations and higher cost.

Although this discussion centers on the more commonly used cavity type filters, the basic principles will apply to any type of filter used in duplexers.

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## **DUPLEXER AND FILTER TERMINOLOGY**

### **Decibel (dB):**

A decibel is a logarithmic scaling value that is used in most RF engineering work because of its universal acceptance and simple manipulation in calculating signal and power levels. A decibel is a relative number, not an absolute value.

For example, a +20 dB difference in a power level is the same as saying the level change is 100 times the starting value. If the change was -20 dB, the change would be 1/100th the original level.

### **Decibel/one milliwatt (dBm):**

This signifies an absolute (real) value, with 0 dBm being one milliwatt of power.

TX RX Systems provides a dB chart in their engineering catalogs.

### **Selectivity:**

Selectivity is a measurement of the ability of the filter to pass or reject specific frequencies relative to the center frequency of the filter. Selectivity is usually stated as the loss through a filter that occurs at some specified difference from the center frequency of the filter.

For example, "- 3 dB bandwidth is +/- 250 KHz." means the output level of a signal frequency at + or - 250 KHz from the center (tuned) frequency of the filter will be at least 3 dB less than the level of the same signal IF it was at the center frequency.

The greater the selectivity the greater the attenuation of frequencies other than the center frequency.

The greater the selectivity the narrower the lowest loss 'window' of the filter and the need for good temperature and mechanical tuning stability in the filter design.

The larger the diameter of a cavity filter the greater the selectivity, assuming similar materials and construction of the filters being compared.

### **Tuning Stability:**

Tuning stability is the ability of the filter to remain at tuned at the desired frequency over time and variations in temperature, orientation, and vibration. Many aspects of filters are designed to overcome these variables, such as the use of temperature compensating metals, elimination of threaded tuning rods which can store mechanical torque stresses, added cooling, fine tuning adjustments, etc.

**Insertion Loss:**

Insertion loss is the minimum amount of loss to the signal passing through a filter at a designated frequency. For example, a filter may have 1 dB insertion loss at its center frequency and if two filters are used in series in a duplexer, the duplexers insertion loss would be 2 dB.

Insertion losses occur in both the transmit and receive paths of a duplexer and they may be different amounts.

The greater the insertion loss, the less the output level.

Higher insertion losses generally increase the selectivity of cavity filters. (i.e. A filter bandpass might be +/- 200 KHz at 1.5 dB insertion loss and +/- 100 KHz at 2 dB insertion loss.

The greater the insertion loss, the greater the power dissipation and temperature rise of the filters. High insertion losses may reduce the power capacity of a filter.

**Receiver Desensitization:**

Receiver desensitization, commonly called 'receiver desense', is caused when high RF signal levels enter a receivers antenna input.

When desense occurs, the usual symptom is as though the desired signal was reduced; the signal becomes noisy or even fades out completely.

The frequency of the desensitizing signal can be considerably different than the frequency the receiver is tuned to. The interfering signal can be wideband noise and/or spurious emissions from the associated transmitter or other nearby transmitters.

The susceptibility of a specific receiver to off-frequency signals is dependent upon the receiver design and any external filtering added to the receiver.

**Transmitter Noise:**

Every transmitter emits signals other than those on the desired frequency. The frequencies and amplitudes of these undesired signals varies greatly and is dependent mainly upon the transmitter design and the modulation used. The amount of transmitter noise can be reduced by external filters and/or physical isolation between the transmitter and any receivers.

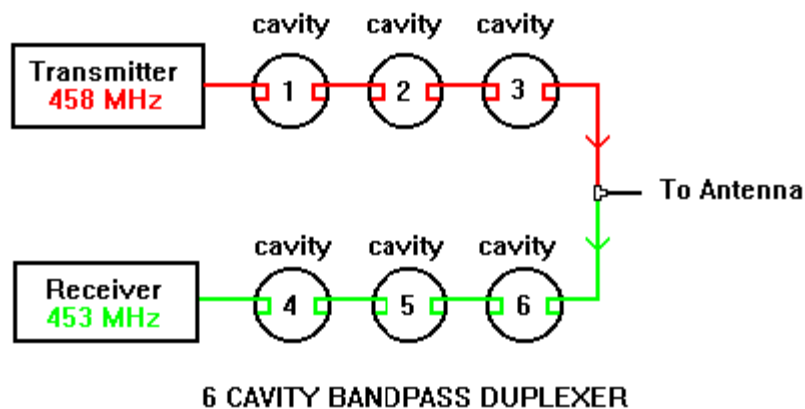
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## TYPES OF DUPLEXERS

There are many ways to combine filters to perform duplexer operations. The more common approaches are:

### Bandpass Duplexers:

Bandpass duplexers use several filters to reduce the bandwidths of the transmitter output and the receiver input frequency bands.



Cavities 1, 2 and 3 tuned to pass 458 MHz. 80 dB loss at 453 MHz.

Cavities 4, 5 and 6 tuned to pass 453 MHz. 80 dB loss at 458 MHz.

Cable lengths between cavity 3 and cavity 6 to "T" are tuned lengths.

The amount of isolation between the transmitter and receiver may be reduced or increased by changing the number of cavities and the size (efficiency) of the cavities. Note that since the transmitter output passes through bandpass filters, therefore transmitter noise and spurious emissions are also attenuated in a bandpass type duplexer, which can help reduce interference to other receivers at the same site.

Bandpass type duplexers are best suited for moderate to wide transmit/receive frequency separations. Close spaced frequencies may require additional notch filters and/or separate antennas.

### Notch Type Duplexers:

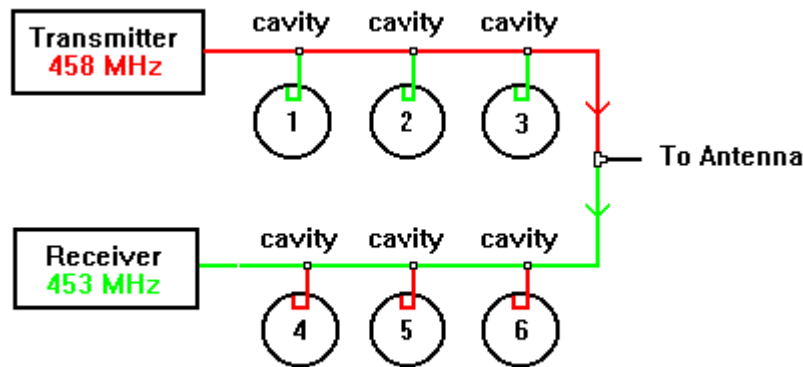
Notch type duplexers may appear physically similar to bandpass duplexers but their operation and tuning is very different.

There are two types of notch filters that may be used in a notch type duplexer:

- The series notch filter, which has two ports (in and out).



- The shunt (or common) notch filter which has one port and is linked to the other filter sections by a "T" connector. NOTE: Do not confuse this with the TX RX Systems "T-Pass" filter which is a specialized bandpass filter.



**NOTCH TYPE DUPLEXER [shunt type cavities]**

Cavities 1, 2 and 3 are tuned to notch out 453 MHz.  
Less than 1 dB loss near and at 458 MHz.

Cavities 4, 5 and 6 are tuned to notch out 458 MHz.  
Less than 1 dB loss near and at 453 MHz.

Cable lengths between cavity 3 and cavity 6 to "T" are tuned lengths.

Note that since the transmitter output passes directly to the antenna, therefore transmitter carrier and noise is only attenuated near the 453-notch frequency.

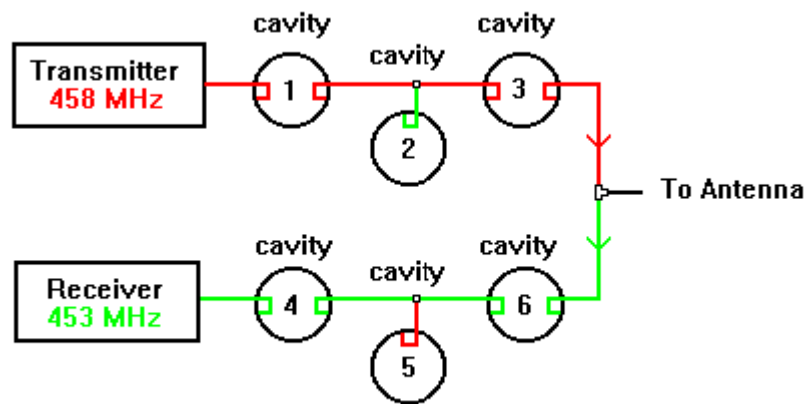
This offers minimal reduction of interference to other receivers at the same site.

Notch type duplexers are cost effective and operate at much closer transmit/ receive frequency separations than bandpass type duplexers.

Shared sites may require additional bandpass filters and/or separate antennas.

### **Bandpass/Band Reject (BP/BR) type duplexers:**

These types of duplexers are combinations of the two preceding duplexer types, having many of the benefits of both and usually at some increase in cost. A bandpass/band reject example; (Actual combinations vary widely)



**BANDPASS/BAND REJECT (BP/BR) DUPLEXER**

Cavity 1 and 3 tuned to pass 458 MHz

Cavity 2 tuned to notch (reject) 453 MHz.

Cavity 4 and 6 tuned to pass 453 MHz.

Cavity 5 tuned to notch (reject) 458 MHz.

Cable lengths between cavity 3 and cavity 6 to "T" are tuned lengths.

### **The TX RX Vari-Notch (c) type Duplexer:**

The Vari-Notch type duplexer is a very popular, low cost and small size duplexer that is only available from TX RX Systems. It is very similar to a bandpass/ band reject type duplexer in operation and tuning.

The major difference is the use of TX RX Systems exclusive "Vari-Notch" (c) filter designs which incorporate the equivalents of a broad bandpass filter and a notch filter within the same cavity.

The result is the elimination of separate bandpass sections in most duplexer requirements and an inherent increase in the number of notch filters for a given number of cavities. It is important to remember that there can be interaction between the bandpass and notch frequency tuning of any combination duplexer, especially when the duplex frequencies are close spaced.

**73s**

**W2MIL**

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