

*We use them and talk about them, but rarely get involved with them. WA2YSJ presents an over-view on duplexers and repeaters and how they work.*

# Duplexers and Repeaters

## Some Basic Information

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All across the country there are many amateur repeater stations operating on 2 meters, 220 and 440 MHz, and to some extent on 1.2 GHz. Several modes of operating such as FM, ATV, and packet (digital) have also become very popular. Many amateur radio operators use these repeaters but do not really understand the basics of duplexers or the role a duplexer plays in repeater operation.

### Basic Repeaters

It is common knowledge that if you "hit" a repeater with low-level signal such as a mobile or handheld radio transmits, the repeater retransmits the information at a higher power level over a greater area. This is commonly referred to as the range of the repeater, the area within which you can activate the repeater with the transmitted signal. Antenna patterns can be adjusted so that a repeater range can cover a certain area or direction only, but a majority of repeater ranges are intended to be omnidirectional (see fig. 1).

The repeater does this receiving on one frequency and retransmitting on another frequency. This occurs simultaneously and is called **duplex** operation. The frequency separation between the TX

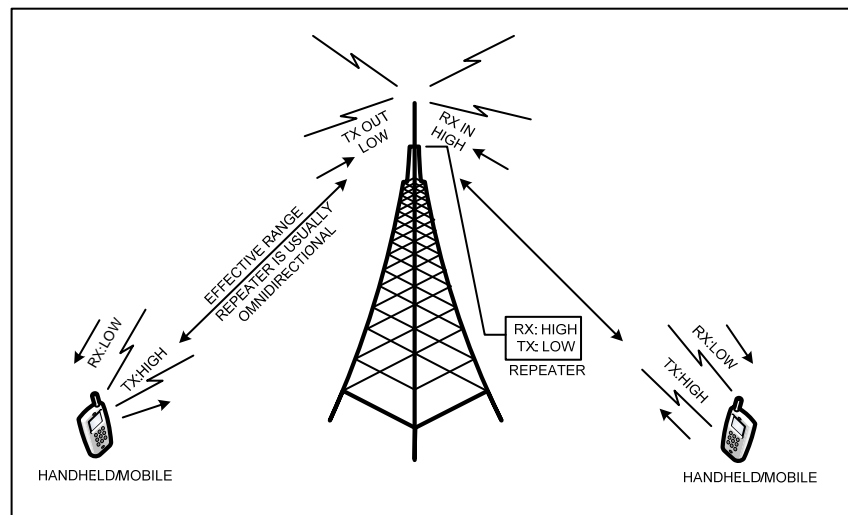


Fig. 1-Typical omnidirectional repeater installation.

(transmit) and the RX (receive) is sometimes referred to as the **split** or **repeater pair** of frequencies. For example, on 2 meters the split is .6 MHz (600 kHz). The TX can be the low frequency and the RX the high, or vice versa. At 220 MHz the split is 1.6 MHz, and at 440 MHz it is 5.0 MHz. At 1.2 GHz the frequency separation can be 12 MHz or 20 MHz, depending on the area of the country where the repeater will be in operation. Therefore, it follows that if the repeater receives on a high frequency and transmits on a low frequency, the mobile or handheld radio will conversely transmit high and receive low. If you reverse the repeater, then the mobile or

handheld radios must also be reversed to match it.

Many repeaters both receive and transmit with a single antenna rather than operating with separate TX and RX antennas (see fig. 2). This is where the duplexer is employed.

The duplexer enables the repeater to transmit and receive simultaneously on a single antenna and feedline without interference to each function by providing the necessary "isolation" between the TX and the RX frequencies. This isolation is measured in decibels (dB). If separate TX and RX antennas were to be used, they would have to be physically spaced a certain

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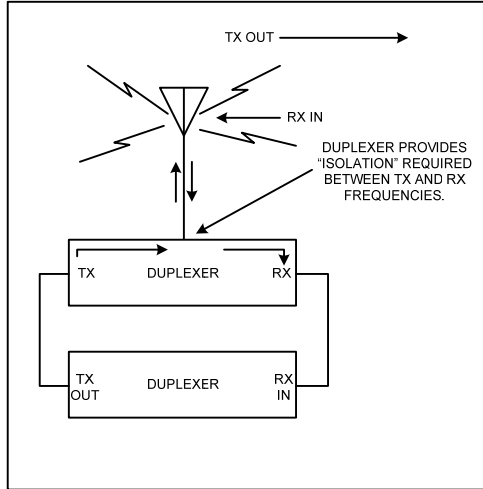


Fig. 2-A duplexer provides isolation between receive and transmit frequencies so that a single antenna and feedline can be used.

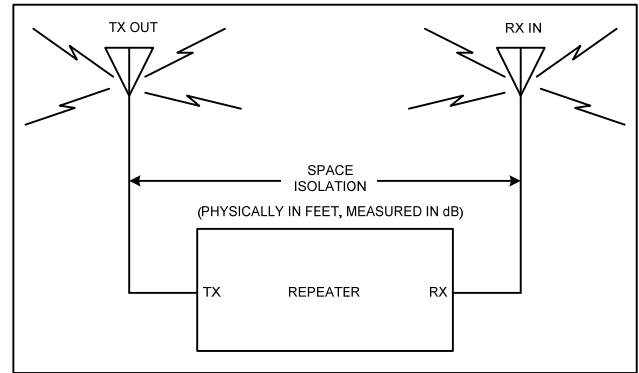


Fig. 3-Without the use of a duplexer, separate antennas for transmit and receive would be required. These antennas would have to be spaced far enough apart so as to provide suitable space isolation.

distance apart, either vertically or horizontally, to provide the necessary isolation (see figs. 3 and 4). This is usually referred to as **space isolation**.

For example, a 2 meter repeater using separate TX and RX antennas would require about 10 feet of vertical space isolation as compared to about 30 feet of horizontal space isolation to gain 30 dB of isolation between the transmit and the receive. Most repeaters require more isolation than this, so it is apparent that more space isolation would be required for the two-antenna approach. Two antennas take up valuable space on a tower, space that may not be available, and require two feedlines. A single antenna and feedline for a repeater is much more economical and saves tower space, particularly at a crowded antenna site. Antenna sites are generally located at the highest point of terrain in a given area and are usually shared by several radio services and users. Some duplexer designs can provide the repeater with protection from interference from other radios at the site and

protect other radios at the site from its own transmitter.

This filtering action of the cavities in the duplexer can also be used to control receiver desensitization (**desense**), which is one of the common problems that can be encountered on a repeater. Receiver desense can be defined as on-channel noise or a strong off-channel signal that degrades the receiver sensitivity. On-channel noise can be coming from the repeater or passing through the duplexer from some other source. An off-channel signal can be close in frequency and physically located somewhere else (another site), or it can be located in close physical proximity to the receiver, but not necessarily close in frequency. Either situation will restrict the receiver's capability to detect (pick up) a weak signal, such as a low-level signal from a mobile or handheld radio.

### How Does A Duplexer Work?

There are several duplexer designs being used in repeaters today, but by far the most common is the **pass/reject** or "pseudo-bandpass" type of duplexer. For this reason

we will consider the pass/reject type of duplexer in this description of duplexer operation.

Imagine, if you will, a transmitted signal being received by a repeater antenna (see fig. 5). This signal travels down the feedline to the duplexer and looks at the cavities. The cavities tuned to the TX side of the repeater are set to block, or reject, this received signal. Therefore, the signal will pass through the cavities on the RX side of the duplexer which are tuned to accept, or pass, the RX frequency of the repeater. They will pass this frequency and tend to reject, or attenuate, most everything else.

At the same time the repeater transmitter is retransmitting the information on another frequency on the same feedline and antenna. This transmitted signal leaves the repeater transmitter and then travels along the interconnecting cable to the duplexer. This signal will look at the cavities and pass through the cavities tuned to pass the TX frequency of the repeater. The cavities on the RX side of the duplexer are set to block, or

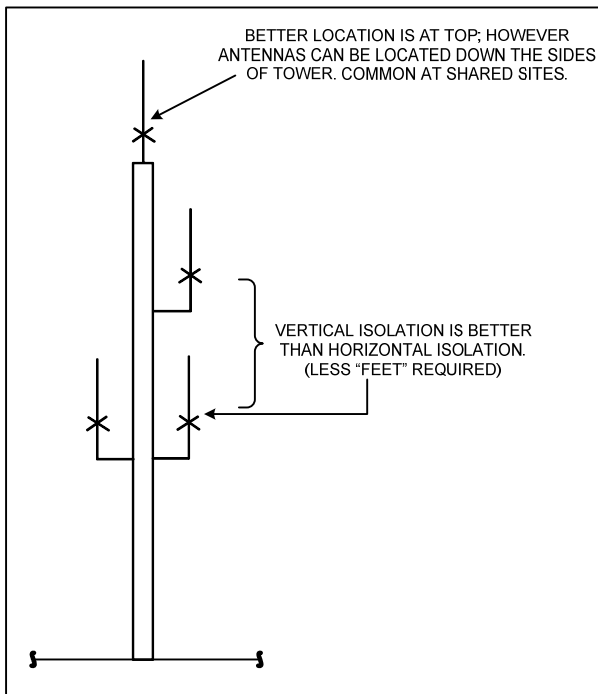


Fig. 4-At shared or crowded sites some space isolation may be required between the antenna of one repeater and the antenna of another.

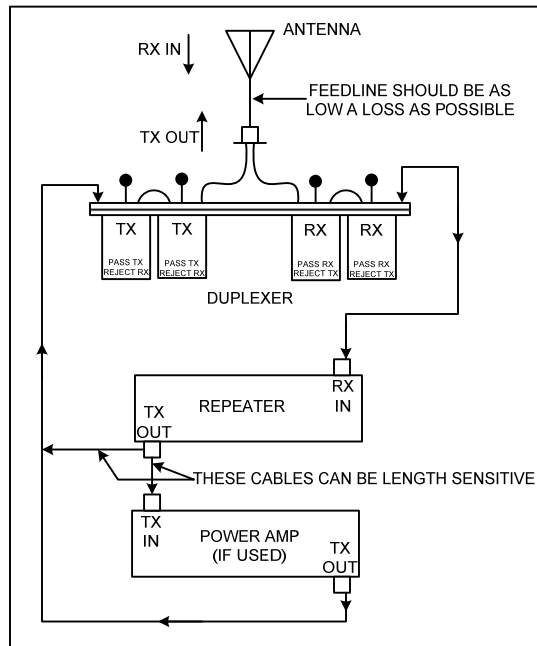


Fig. 5-Flow diagram showing the use of a duplexer and repeater at a typical site.

reject, this transmitted signal. The signal passes through the TX cavities, travels up the feedline, and is radiated by the antenna. Thus, the duplexer "isolates" the TX from the RX and vice versa, enabling the repeater to receive and transmit simultaneously without interference to each function. Resonant cavities which are used in the pass/reject type of duplexer can be a valuable tool in controlling spurious emissions, desense, and other problems that a repeater can experience.

Quality duplexers are designed and built to perform within certain ranges of power, temperature, and frequency separation. The materials used in the manufacture of duplexers usually control the power rating and temperature range of the duplexer. The physical size of a duplexer is most often determined by the frequency at which the duplexer is to be used. Temperature stability

is a very important factor to be considered. The frequencies to which the TX and RX sides of the duplexer are tuned cannot change due to something moving when it heats up and expands or cools down and shrinks. Detuning of a duplexer in this manner, in the worse case, can render a repeater inoperative. Materials with a low coefficient of thermal expansion are therefore used in critical areas such as the cavity main tuning control.

The components used in the RF circuits of the duplexers--such as capacitors, coupling loops, connectors, and cable--also have to stand up to the amount of power going through the duplexer. This is another source of heat.

The reverse side of the temperature stability problem is seen when the duplexer and repeater are housed in an unheated shack during

the winter months. The duplexer must be stable in the cold also. Most manufacturers will usually provide the necessary data and specifications to enable the proper duplexer to be chosen for the particular application.

### Some Common Sense

There seems to be a common misconception that a duplexer can be the cause or source of all the many problems that can plague a repeater. In reality there are things that can affect the operation of a repeater. Granted, there can be troubles with a duplexer, such as detuning during shipment or damage due to lightning or vandalism, but accidental detuning is perhaps the most common problem. There have been many instances of noise passing through a duplexer, making it appear that the duplexer is at fault. A majority of the time, however, problems usually can be

traced to some other source. A duplexer is not an active device and does not require much maintenance once it is installed and in operation.

There exists, the world over, a strong urge to "tweak" a duplexer after it is installed and the repeater is up and running. This "tweaking" can be the cause of some of the problems a repeater can experience. "Tweaking" can be equated with "detuning" if it is "tweaked" far enough. There usually will be some initial adjustment when the duplexer is first installed. However, once this is done and the repeater is operational, "tweaking" should be kept to a minimum or discouraged altogether.

Another area where problems can exist or be created is in the coaxial cable and connectors used to interconnect the antenna, duplexer, and repeater. It doesn't pay to scrimp on cable and connectors. Quality cable, hardline or whatever, is expensive. But when you consider repeater "down time" due to connector or cable problems, it pays in the long run. Cheap connectors and cheap cable make for cheap performance and reliability. Since connector joints are a prime source for noise on a repeater, quality connectors properly assembled onto quality cable can minimize this possibility.

Keeping this in mind, the interconnecting "patch" cables are another important factor to be considered in the operation of a repeater. Specific cables for interconnecting the duplexer, the repeater, power amp, etc., should be made with quality connectors and cable that is of the specified impedance of the repeater system. Some of these cables may be length sensitive, such as the cable running from the repeater transmitter to the duplexer. You can't just plug in a random length

of 75 ohm cable into a 50 ohm system and expect that system to work properly. The use of connector adaptors and splices in the cable are not considered "good practice" either. Double-shielded (double-braid) coaxial cable is a recommended choice when considering interconnecting cables and, in some cases, even the feedline.

Some thought is also required when routing cables at a repeater site. If cables are run close together—i.e., in a "bundle"—coupling may occur between cables. For example, the cable that connects the antenna to the duplexer is run parallel to, and in the same "bundle" with, the cable connecting the duplexer and the receiver in the repeater. When the transmitter is keyed, "desense" occurs in the receiver. This is caused by a strong RF field being generated by the transmitter coupling into the cable running to the receiver and overloading the receiver. This is a good argument favoring double-shielded cable.

Crowding at repeater sites is sometimes unavoidable and special care should be taken in the routing of the cables under such circumstances. Even the routing of feedlines or placement of the antenna on the tower can cause problems. At shared or crowded sites some "space isolation" may be required between the antenna of one repeater and the antenna of another (see fig. 5). In some adverse cases a little extra filtering may be required on a receiver or offending transmitter. Each case is usually unique, and sometimes they can drive a person crazy trying to analyze the problem and formulate a cure.

Once the repeater is up and operational, drawing up and sticking to a monthly or quarterly inspection schedule is a very good idea. Periodic inspection of the site can provide valuable

information on equipment status. Inspection of the cable, the tower and antenna, and the grounding system can usually detect potential problems. This can provide enough time to prevent a major problem with the repeater, causing it to provide poor or inadequate coverage, or even to be off the air for an extended period of time. Brief, intermittent periods of "down time" for inspection and repair are much more acceptable than days, weeks, or even months on end! Co-ordination and co-operation with other services at a site can also go a long way to help prevent or resolve any problems that may arise. As the old saying goes, "An ounce of prevention is worth a pound of cure."

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### **Lightning Protection**

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It cannot be stressed enough that a good grounding and lightning-protection system should be employed for just about any amateur installation, including a repeater.

Most repeater sites are located at higher elevations that are more prone to being struck by lightning. A tower or antenna, reaching into the sky, on top of a mountain, hill, or house, makes an excellent lightning rod. Lightning can damage or destroy just about anything at a repeater site, including towers, buildings, and equipment. A duplexer doesn't have many parts, but it is just as susceptible to lightning damage as anything else at the site.

A good electrical ground is the basic requirement, and grounding the tower and equipment is the first place to start. Tower manufacturers can usually provide suggested grounding schemes for towers and equipment shelters. There may be local building and zoning codes that have to be followed. There are several manufacturers of lightning

protection equipment who can provide a wealth of information about lightning protection. Lightning protection cannot stop a lightning strike, but it can usually minimize the amount of damage that can result from one. Nature can be very unpredictable and sometimes any measure taken can be almost useless. It is best to provide some form of lightning protection even if the possibility of a lightning strike doesn't exist or is minimal. Some protection is better than none for any installation, if only for peace of mind.

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### **In Closing**

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There are several manufacturers and quite a few varieties of duplexers and repeaters available on the market today for amateur use. Most offer excellent warranty and repair/retuning services for their products.

A good rule of thumb is to choose a duplexer that has specifications of power, frequency separation, and temperature range. Isolation requirements between the TX and RX frequencies are an important factor to weigh. Some duplexer designs provide more isolation than others. Some duplexer designs also suffer more insertion loss than others. Sufficient research and question asking can usually result in getting the right equipment for the job.

The same thinking should be applied to the antenna and feedline system to be used with the repeater. A good quality duplexer, connected to a good repeater and antenna, installed and maintained properly can provide many amateurs with reliable communications and enjoyment of their hobby over long periods of time with little or no aggravation and a minimum of down time.

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### **Acknowledgements**

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