Duplexers, Diplexers and Circulators
By Don Steinbach, AE6PM

Duplexers, Diplexers and Circulators are passive devices that are connected between a transmitter, a receiver and an antenna to perform various functions like radio-frequency signal combining, separating, or isolation. They are typically designed for use at vhf frequencies and higher.

Duplexers

The duplexer is a passive frequency-selective three-port device designed specifically to allow simultaneous transmission and reception on adjacent frequencies on the same antenna. They have separate transmitter and receiver ports (connectors) and a common (shared) antenna port. Obviously, the transmitter and receiver cannot operate on the same frequency, but they can be very close to the same frequency. This is accomplished by using highly frequency-selective band-pass and band-reject filters in the two independent transmit and receive channels. Duplexers are carefully tuned to the specific transmit and receive frequencies being used. The primary duplexer attribute for each channel is low insertion loss through the channel and high isolation between the channels. The duplexer protects the receiver from overload and desensitization while the transmitter is operating at full power, or from other strong signals in the immediate area. It also protects the transmitter from "receiving" strong local signals that might result in spurious signals being produced in the transmitter final amplifier. Typical duplexer specifications might be insertion loss of less than 1 dB and isolation greater than 75 dB.

Duplexers are based on very high-Q tuned circuits that often take the form of cavity resonators. Some cable lengths need to be exact quarter- or half-wavelengths, the resonators themselves are sometimes silver plated internally, and mechanical adjusting rods might be made from Invar for dimensional stability over temperature changes. A duplexer 'set' typically consists of 4 or 5 resonators such as shown in Figure 1. Typically, two of the resonators (also called "cavities") would be in the receiver path and pass the receive frequency and notch the transmit frequency. The other two resonators would be in the transmit path and pass the transmit frequency and notch the receive frequency.

Diplexers

The diplexer is similar in function to the duplexer in that it combines two (or more) ports into a single port. Like the duplexer, the diplexer is frequency selective, but typically broadband. A typical application for a diplexer is to allow two transceivers on two different bands to share a common transmission line. For example, a 2-meter transceiver and a 70-cm transceiver might each be connected a single diplexer which is connected to a single coax. On the other end of the coax might be a dual-band antenna, or another diplexer that separates the signals for connection to two separate antennas.

Remember the splitter we used to separate the VHF and UHF TV signals from the single 300 ohm twinlead from the antenna so we could get the signal to the separate VHF and UHF tuner inputs at the TV set? That's functionally equivalent to a diplexer consisting

of a low-pass filter for the VHF channels (54-216 MHz) and a high-pass filter for the UHF channels (470-890 MHz).

The diplexer concept can be expanded to more ports, such as three inputs for a triplexer. Gary Gordon, K6KV, described a triplexer to connect 10- 15- and 20-meter field day stations to a single triband beam. See QST magazine for June 2010.

Circulators

The circulator is a 3-port ferromagnetic-based device that allows rf energy to to be coupled only from port A to port B, from port B to port C, and from port C to port A. The isolation between the ports is such that almost no rf energy can flow in the reverse direction. If port A is connected to a transmitter, and port B is connected to an antenna, the forward power will pass from port A to port B and any reflected power back from the antenna will pass to port C. An isolator is a special case of a circulator with the third port (port C) terminated by a dummy load equal to the system characteristic impedance in which case any power from port C will be dissipated as heat.

In another application, a transmitter could be connected to port A, an antenna to port B and a receiver to port C, similar to a duplexer connection. Energy from the transmitter (the transmitted signal) would flow to the antenna, and energy from the antenna (the received signal) would flow to the receiver. Unfortunately, any reflected energy from the transmitted signal due to mismatch at the antenna would also flow back to the receiver connection at port C possibly damaging or desensitizing the receiver. Circulators are somewhat frequency dependant and also require exact impedance matching to be fully effective. The reverse isolation between ports is typically 20 to 25 dB.

Fig.1. A 4-resonator duplexer similar to the one used on the W6UU 70-cm repeater. A unit like this costs about $1,800, has an insertion loss of 1.0 dB or less and isolation of 90 dB. A set for 2-meters is much larger than this. A resonator for 6-meters approaches the size of a trash can. The panel in this photo is 19” wide.