6. TRANSMISSION LINES AND OTHER COMPONENTS

Transmission lines are conduits for transporting RF signals (and the energy contained in those signals) between elements of a communications system (fig. 1).

Transmission lines are not simply conductors that carry electrical current like the power cord for an electrical appliance does. Transmission line principles, derived from electromagnetic theory, must be used when the line exceeds a few tenths of a wavelength.

On a transmission line, not only do currents flow within and on the surfaces of the conductors, but traveling electromagnetic fields are also "guided" by the conductors. Therefore, the geometry of the transmission line is fundamental to its electrical characteristics.

6.1 Transmission Line Types

Figure 28 shows the arrangement of conductors for several common types of transmission lines. The open, two-wire line, shown in figure 28(a), is easy to construct and its characteristics are readily adjusted by changing the diameter and spacing of the wires. However, the electromagnetic field created between and around the conductor extends far beyond the line, so radiation losses become excessive at high frequencies. For this reason, it is only practical for use below several hundred megahertz. This line is also called "ribbon," "parallel," or "twin-lead" cable and was used extensively, from the 1950s to the 1970s, to connect a home television set to its antenna.

The most common transmission line in use today is *coaxial cable*, which gets its name from the coaxial arrangement of its conductors, as shown in figure 28(b). The center conductor may be held in position with periodically-spaced dielectric (insulating) beads or with a continuous,

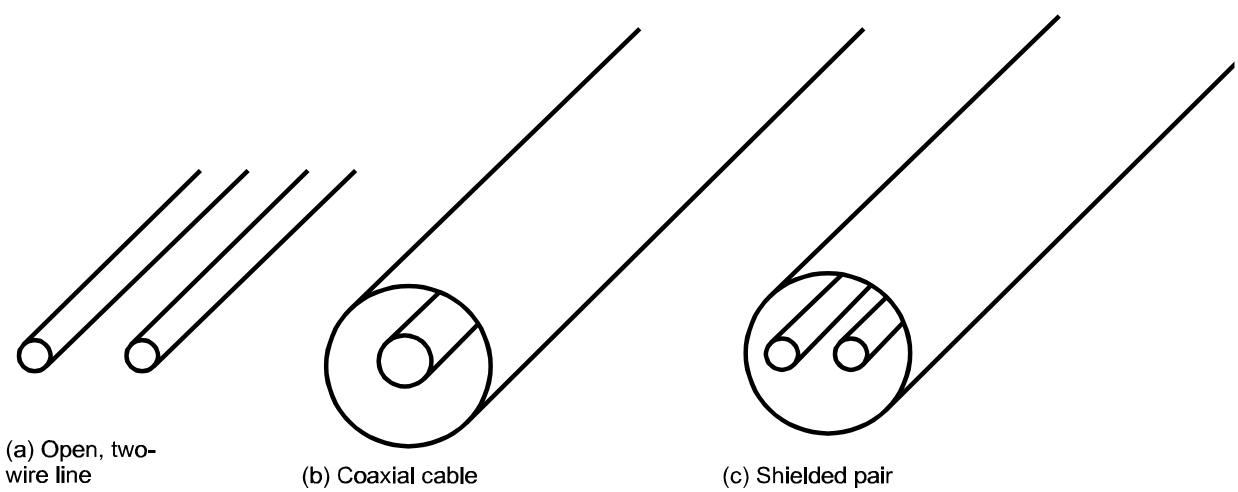

Figure 28. Common types of transmission lines

solid dielectric that fills the space between the conductors. The outer conductor can be either solid or braided; the latter making a more flexible cable. The coaxial cable is effectively self-shielded and has no external fields. For this reason, its losses are low and it is useful for frequencies as high as 3 GHz. Since the outer conductor of a coaxial line is usually grounded, it is not a balanced line. In other words, both conductors are not equally isolated from ground as is the case with the open, two-wire line. This distinction is an important factor at the connection to the antenna. A *balun* (see sec. 6.2) may be needed at that point to “match” the unbalanced line to an antenna.

A very wide variety of coaxial cable (often called “coax”) is available to meet different requirements. Generally available in only two values of characteristic impedance—50 Ω and 75 Ω—coaxial cable is made in many sizes of various materials.

Figure 29 shows two common coax types. The cable shown in figure 29(a) has a semi-rigid, helical outer conductor, so it is less flexible. This cable is commonly used for base-station applications. The cable shown in figure 29(b) has a braided outer conductor. This type of cable is commonly used in mobile applications and for less-demanding base-station applications.

Figure 29. Coaxial cables commonly used for LMR — (a) base-station applications and (b) mobile applications

Coaxial cable is described by nomenclature derived from military standards [15]. The “JAN type” or “RG-“ number assigned to a coaxial cable defines specific values for a wide range of physical and electrical characteristics. Selected characteristics for a few of the several hundred types of cables are given in table 1. Not shown in this table are other physical and electrical characteristics such as weight, tensile strength, materials used for the dielectric and sheath, maximum voltage, and attenuation.

There are many other transmission line geometries. The *shielded pair*, shown in figure 28(c), is not uncommon. It offers the fully shielded characteristic of a coaxial line and the balanced nature of a two-wire, parallel line.

6.2 Baluns

Since the outer conductor of a coaxial line is grounded, it is not a balanced line. In other words, the voltage potential difference between the inner conductor and ground is different from the voltage potential difference between the outer conductor and ground. This distinction is an important factor at the connection to the antenna. Antennas such as dipoles are balanced. A *balun* will be needed at the antenna terminals to connect the unbalanced coaxial transmission line to the antenna.

A balun is a device for transforming a load on an unbalanced transmission line (coaxial) or system to a balanced line or system. The name *balun* is a contraction of the terms *balanced* and *unbalanced*.

Table 1. Characteristics of selected coaxial cable

Type	Impe-dance	Inner Conductor	Outer Conductor	Diameter	Max. Power	Notes
RG-58/U	50 Ω	19×0.0071 in (19×0.018 cm) stranded (tinned copper)	braid (tinned copper)	0.195 in (0.49 cm)	200 W	small, flexible, low loss
RG-55/U	50 Ω	0.032 in (0.08 cm) solid (silvered copper)	double braid (silvered copper)	0.206 in (0.52 cm)	200 W	small, flexible, low loss
RG-11/U	75 Ω	7× #26 AWG (tinned copper)	braid (copper)	0.412 in (1.05 cm)	750 W	medium sized, flexible

6.3 Duplexers

In order for transmitters and receivers to share a single antenna, a *duplexer* must be used. The duplexer acts as two parallel, frequency selective filters, directing transmitted signals to the antenna, preventing those signals from reaching and overloading collocated receivers, and routing all of the received signals from the antenna to the receivers. Duplexers used in the VHF and UHF bands are typically constructed from mechanically tunable, highly selective cavity filters, as depicted in figure 30.

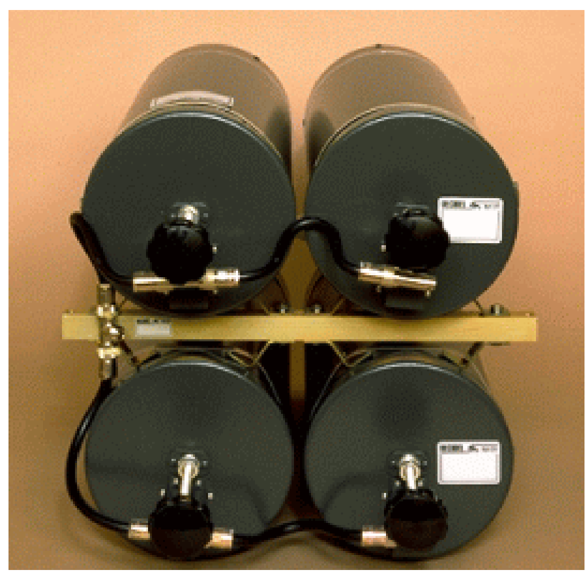

Figure 30. A VHF duplexer

6.4 Combiners

In order to combine more than one transmitter onto one antenna system, *combiners* are used. Two typical configurations, shown in figure 31, use either *hybrid combiners* (commonly called *hybrids*), or mechanically tuned, highly selective *cavity combiners* that use cavity filters quite similar to those used in duplexers. Depending on a number of factors, such as how close in frequency the transmitters are to one another and how many transmitters must be combined, one approach will offer superior performance over the others. Vendors and manufacturers should be able to explain why they selected one combining method as opposed to the other for their design.

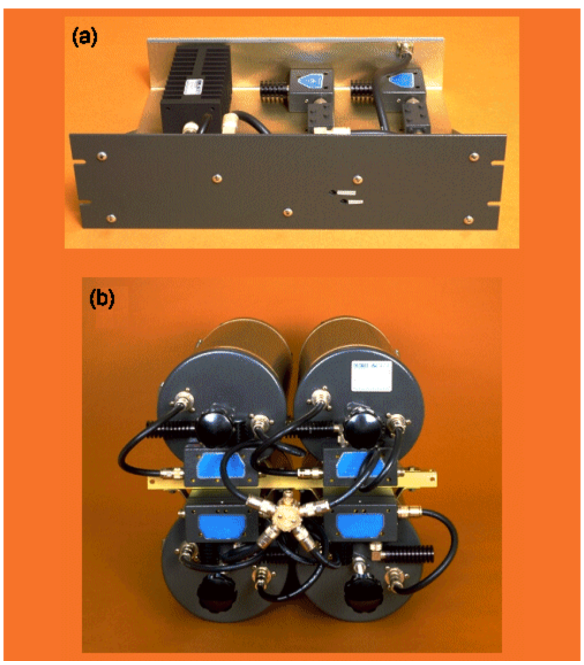

Figure 31. Typical types of combiners — (a) hybrid combiner and (b) cavity combiner

6.5 Intermodulation Suppression

Cavities and hybrids will likely not provide sufficient attenuation to RF signals (from other collocated transmitters) that could cause intermodulation interference. *Isolators* are used to provide additional protection against intermodulation interference. These devices provide very low attenuation to signals passing through them in one direction, while providing a high degree of attenuation to signals passing through them in the other direction. They are the principal components of *intermodulation suppression devices* (fig. 32).

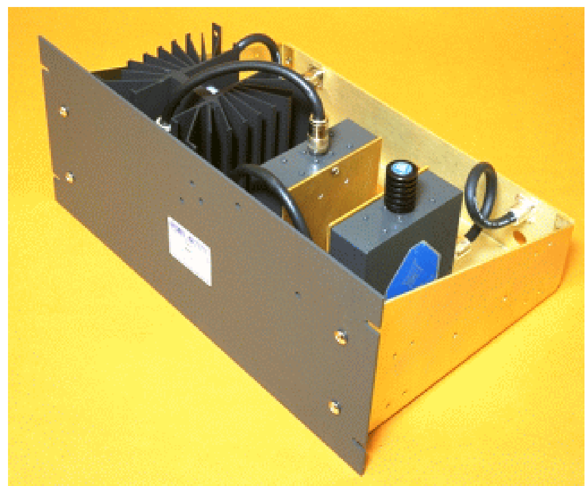

Figure 32. Intermodulation suppression device

6.6 Multicouplers

Just as multiple transmitters can share an antenna, so can multiple receivers. Inbound RF signals are "split" and routed to the appropriate receivers. Because RF splitters attenuate the signals passed through them, a preamplifier precedes the splitter. Its amplifier gain is carefully adjusted to compensate for the splitter loss, but is not set too high, as the resultant intermodulation interference signals would be detrimental to proper receiver performance. These preamplifiers and signal splitters are combined into a single assembly known as a *multicoupler* (fig. 33).

Figure 33. A multicoupler