The importance of coaxial cable to base station performance

Low-loss flexible cable provides an alternative to semi-rigid corrugated cable with advantages in loss, handling, ease of installation and ruggedness compensating for tradeoffs in shielding and intermod performance.

By Robert Perelman and Joe Lanoue

Coaxial cables are vital to the performance of mobile radio systems. Selecting the best coaxial cable for an application within a mobile radio base station has become more complicated over the past few years as more suppliers have offered a broader range of products.

The cable selected will affect the system's cost, coverage and reliability. The new choices that are available can frequently allow for better overall system performance at a lower price than the older alternatives.

Until recently, the choices were generally limited to corrugated copper cables, conventional braided cables and air dielectric braided cables. Generally, corrugated copper cables were chosen for applications requiring the lowest loss, such as antenna feeders. Braided coax or RG-type cables were used for applications requiring the greatest physical flexibility.

Air dielectric cables seemed to offer a compromise, with relatively low loss and good flexibility, but their construction leads to performance problems. These include moisture accumulation in the air space, radial movement of the center conductor at bends, resulting in VSWR degradation, and axial movement of the center conductor relative to the outer conductor, resulting in connector failures.

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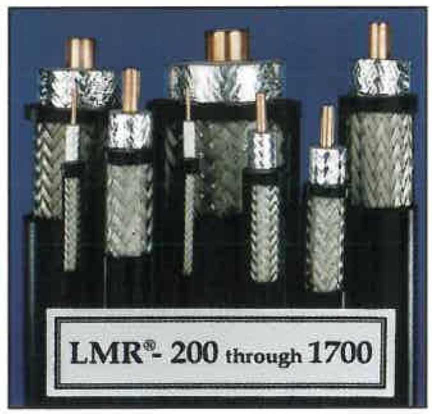


The flexible low-loss cables are available in a range of sizes from 0.195" to 1.70" diameters for a wide range of applications from mobile antenna feeders and system interconnects to base antenna feeders.

In recent years, several new types of cables have been introduced for communications applications. These include low-loss flexible cables, which offer loss comparable to corrugated copper cables, but with much better flexibility. In addition, several manufacturers have introduced new types of semi-rigid cables with smooth outer conductors.

New suppliers of corrugated copper cable have also entered the market. To select from this greatly expanded universe of choices, it is helpful to consider the most important characteristics of coaxial cable more carefully.

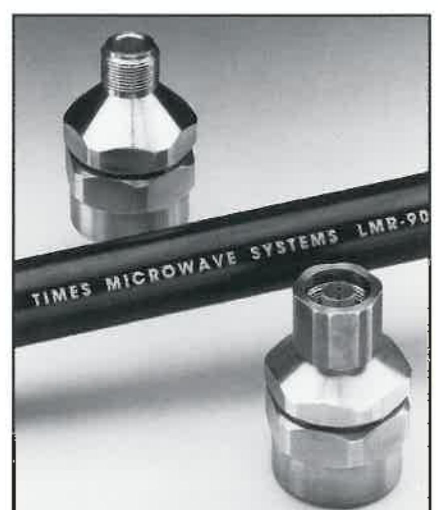
Signal Loss

Because the function of a coaxial cable is to transmit RF energy from one point in a system to another, efficiency is the most important factor in selecting a cable. The loss of a cable is measured in dB/100ft, which is a logarithmic expression of the ratio of the output power from the cable *to* the input power to the cable. The loss of a cable is determined by the conductor loss and the dielectric loss. Dielectric loss remains essentially constant as the size of the cable changes, whereas conductor loss decreases as cable size increases, much as the resistance of a wire decreases as the size of the wire increases. The need for low loss, rather than requirements for high power handling, dictates the size of large cables in mobile communications systems.

Table 1—Transmission performance comparison (dB per 100 feet).

Frequency (MHz)	Times LMR-1200 7/8"	Cablewave FLC78 7/8"	Eupen 5228 7/8"	Andrew LDF5 7/8"	CommScope CR501070 7/8"	Times LMR-900 5/8"
450	0.86	0.850	0.810	0.834	0.790	1.15
900	1.26	1.25	1.21	1.23	1.21	1.67
2000	1.99	2.10	1.94	1.97	1.97	2.59

Source: Manufacturers' published data.



The 5/8" low-loss cable eliminates the need for jumper cables in base antenna feeder applications resulting in comparable loss to 7/8" cable with jumber cables.

Table 2—Assumptions: jumpers are 6 feet in length, the operating frequency = 2,000MHz and there is a 0.06dB loss per connector.

Performance Details:

Flexible 5/8" low-loss cable (LMR9-900) —jumpers not required
Transmission line loss = (2 × 0.06dB) + (150 × 0.026) = 4.02dB
List price = 150 feet × $3.70/ft + $45/connector = $645

Flexible 7/8" low-loss cable (LMR-1200) —jumpers not required
Transmission line loss = (2 × 0.06dB) + (150 × 0.02) = 3.12dB
List price = 150 feet × $4.85/ft + $65/connector = $857.50

Semi-rigid 7/8" corrugated copper cable LDF5 —with ½" (LDF4) jumpers
Transmission line loss = (2 × 0.06dB) + (2 × 0.4) + (138 × 0.02) = 3.68dB
List price = 138 feet × $6.18/ft + $96/connector) + $110/jumper = $1,264.84

Flexible 1¼" low-loss cable (LMR1700) —with LMR-900 jumpers
Transmission line loss = (2 × 0.06dB) + (2 × 0.28) + (138 × 0.015) = 2.75dB
List price = 138 feet × $7.80/ft + $110/connector + $142/jumper = $1,580.40

Semi-rigid 1¼" corrugated copper cable LDF6 —with ½" (LDF4) jumpers
Transmission line loss = (2 × 0.06dB) + (2 × 0.4) + (138 × 0.015) = 2.99dB
List price = 138 feet × $10.94/ft + $150/connector + $110/jumper = $2,029.72

Because all of the cable types being compared use low-loss dielectrics and high-conductivity conductors, the losses of similar size cables are close, as can be seen in Table 1. This is not the entire story with regard to total signal loss, because the semi-rigid cables generally require the use of jumper cables at each end in order to be routed to the radio equipment and the antenna.

These jumper cables add loss to the feeder run. Flexible cables generally can be run without jumper cables, lowering total signal loss, or alternatively, allowing the use of a smaller cable to achieve the same loss.

Table 2 above left shows a performance comparison of 150-foot feeder runs of flexible and semi-rigid cables.

By eliminating jumper cables with the 5/8" and 7/8" flexible low-loss cables, performance similar to the next-larger-size corrugated copper cables can be achieved with substantial cost savings.

The elimination of four connector junctions—two on each of the jumper cables—greatly increases the reliability of the system while simplifying and speeding installation. These savings are being realized by system operators who have chosen the 5/8" flexible cable to replace 7/8" corrugated copper cables. The difference in total signal loss is only a few tenths of a decibel for lengths as long as 200 feet, an insignificant difference in system performance.

The cost savings are about 50% in materials and a substantial savings in labor. An additional savings may result from the reduction in tower loading with the use of smaller cable.

Shielding

Another important characteristic of a coaxial cable is shielding effectiveness. This is a measure of the ability of the cable to keep signals in the cable from leaking out and signals outside the cable from leaking into the cable.

A transmit cable with poor shielding may allow RF energy to leak out and interfere with nearby receive cables. Conversely, a poorly shielded receive cable will allow RF energy from the environment into the system and may cause interference. Typically for antenna feeders, shielding is not an important issue because the antennas allow a large range of RF signals into the system, which must be filtered out before the receiver.

Semi-rigid cables with solid outer conductors provide the best shielding, typically better than 120dB. Flexible, low-loss cables have bonded metal tape outer conductors with braided overshields. This construction provides better than 90dB shielding. With either semi-rigid or flexible cables, the weak point in shielding is the interface between the cable and the connector, which will typically limit shielding to about 90dB.

Because the concern is typically the leakage of signal from a transmit cable into a receive cable, the effective shielding provided is the sum of the shielding of the two cables—better than 240dB in the case of semi-rigid cables or 180dB in the case of flexible cables. These levels result in signals that are far below the receiver sensitivities of any practical mobile radio system. In any case, these cables are being used to feed antennas.

Typically, the isolation between receive and transmit antennas will be far less than the isolation between the cables; therefore, cable shielding is not the limiting factor in these applications.

Intermodulation distortion

Intermodulation distortion or passive intermodulation distortion (PIM) has been a topic of much discussion in recent years as a contributor to performance degradation in mobile radio systems.

When two high-power signals are present in a device with a non-linear junction (such as a semiconductor or ferromagnetic material), a third signal is generated at a frequency equal to two times one of the frequencies minus the other frequency (sometimes referred to as 2A−B). Actually, a whole series of additional frequencies will be created, with the 2A−B frequency being referred to as the third-order intermod product.

In high-power systems, such as broadcast, the power levels of the intermod signals can be quite high relative to receive signals and can cause major problems with other co-located systems. Within mobile communications systems, the power levels are relatively low, and the frequencies that are used are usually selected to minimize the probability of within-system interference from intermodulation. The primary concern is active devices that usually produce intermodulation products at levels much higher than passive devices, such as cables.

PIM levels are typically expressed in dBc (decibels below the carrier level). The following estimated values are based on two carrier tests with carriers in the 900MHz range at +43dBm (20W)

Semi-rigid cables with properly designed and attached connectors can provide PIM levels of −160dBc and better. Flexible low-loss cables, with properly designed and attached connectors, provide PIM levels of −130dBc or better. The limitation in both cases is the connector-to-cable interface and the design of the connector.

These levels are far better than the levels provided by typical active components, such as power amplifiers, and are more-than-adequate for most system applications. In the most-common system configuration, additional protection for the receiver is provided by the use of separate receive and transmit antennas. The separation of the antennas results in at least 60dB of path loss, which reduces the level of the intermod products in the receive path. In systems using the same antenna and transmission line for transmitting and receiving, the additional path loss is not available, and the immunity of the system to intermod is decreased.