Coaxial Cable Shields

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Introduction

This article focuses on the coaxial cable shield, its effectiveness and what to look for when buying cable. The shield is easy to examine, which provides a lot of information about the cable quality. Of course, other parts of the cable are important, too, but they are not discussed here in any detail.

The basic components of a coaxial cable, from the inside out, are center conductor, dielectric, one or more shield layers and jacket (figure 1). A significant part of the cost to manufacturer coaxial cables is the outer conductor, or shield. Depending on the cable construction, the shield may use braided bare- or tinned-copper wires, a conductive foil tape such as aluminum, a corrugated or smooth solid copper or aluminum tube outer conductor or some combination. It is intuitive that the more shield coverage, the better. Some shield types, such as a tubular or wrapped shield, completely enclose the dielectric and center conductor. As a practical matter, a single-braid shield alone cannot achieve 100% coverage. The best individual braids achieve 95%. Many low-quality cables have around 50~60% coverage, or even less.

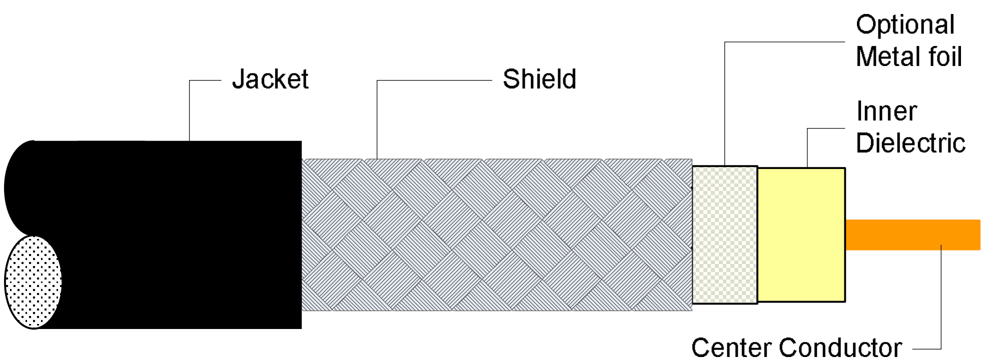


Figure 1 – Coaxial cable components

Shield purpose

The shield serves four basic purposes. The first is to keep the desired electrical currents inside, and the second is to keep the undesired currents outside. In radio astronomy, the desired currents are from celestial radio waves coupled by the radio telescope antenna into the coaxial cable transmission line. Undesired currents are those from terrestrial transmitters and other radio frequency interference (RFI) sources that are coupled to the cable from the outside. In all practical cables some undesired RFI energy can leak into the cable and some of the desired energy can leak out. The basic leakage mechanisms are radio currents diffusing through the shield materials, inductive coupling via the magnetic fields setup as the currents flow in the cable and by capacitive (electrostatic) coupling through holes or gaps in the shield, such as in the weave of a braided shield. The third purpose of the cable shield is to provide a return path for currents used to power tower-mounted electronics such as a preamplifier through the coax center conductor. Finally, the fourth purpose is to provide a path to earth ground for foreign voltages and currents on the coaxial cable due to lightning events, accidental power cross and static build-up (for additional details, see [1]). The last two purposes are beyond the scope of this article.

Shield coverage and shielding effectiveness

The use of *shield coverage* in advertising literature and datasheets is a marketing gimmick. It is the percentage of actual metal surface area to the total surface area of the cylinder underneath the shield. Shield coverage can be calculated from the geometry and dimensions of the cable components (figure 2) [2], but it provides only a rough indication of performance or effectiveness. While it is true that cables with higher coverage may provide better shielding than cables with lower coverage, shield coverage as a percentage is a physical quantity with an ambiguous relationship to effectiveness and says nothing about frequency effects. Technically appropriate terms that describe shield effectiveness are *screening* *efficiency*, *screening factor* and *transfer impedance*. It is very difficult to accurately calculate shield effectiveness, but it can be measured.

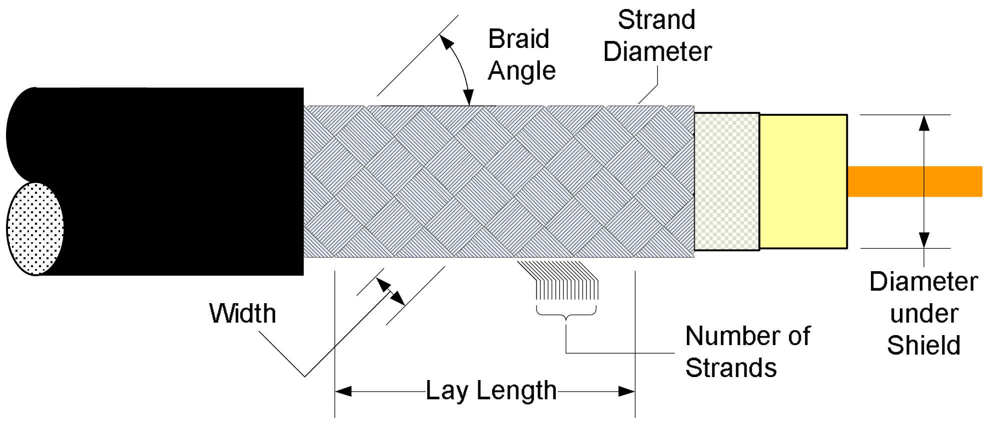


Figure 2 – Parameters required for calculation of braid coverage

Screening efficiency is a measure of the current transfer ratio and screening factor is a measure of the voltage transfer ratio, where *transfer ratio* means from inside to outside or outside to inside. Both can be expressed as a linear ratio or logarithmic in dB. *Transfer impedance* is the quantity most commonly used to describe shield effectiveness [2,3]. Impedance is the ratio of voltage to current in a circuit. For cable shields the transfer impedance is the ratio of the voltage setup in a disturbed circuit by current flowing in the disturbing circuit. In a receiving system, such as a radio telescope, the disturbed circuit is that of the coaxial cable transmission line and the disturbing circuit is the electrical environment surrounding the cable.

A cable shield with lower transfer impedance is better than one with higher transfer impedance – that is, a given disturbing current causes a smaller voltage disturbance in a cable with low transfer impedance than a cable with high transfer impedance. Transfer impedance measurements require complicated setups because isolating the cable under test from the environment is difficult [2]. An article in QST magazine years ago described a measurement method and showed the benefits of a double-braid shield (figure 3) [4].

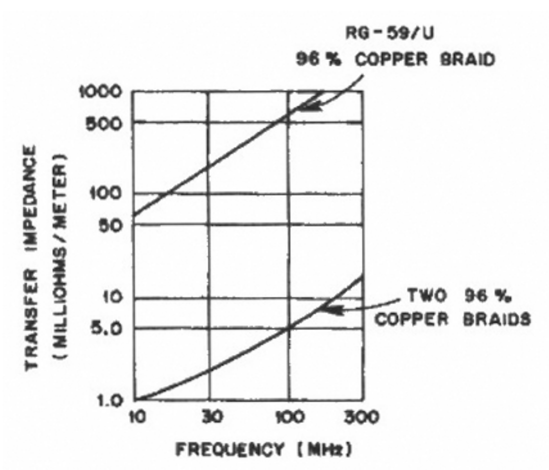
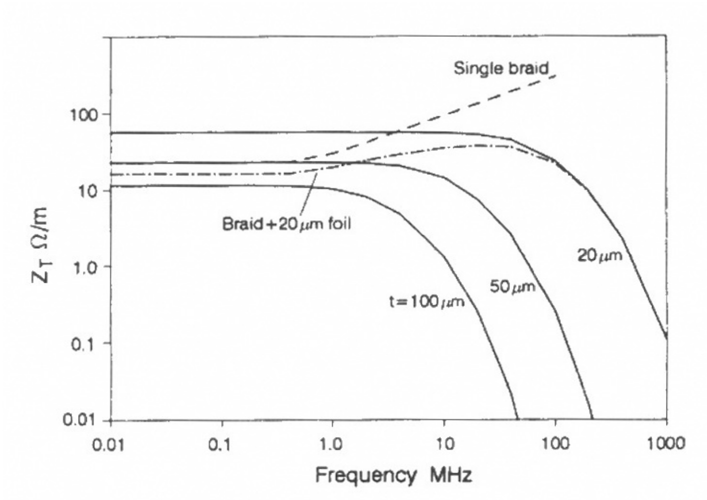


Figure 3 – Measured transfer impedance of single- and double-braid shield (Illustration from fig. 3 in [4], reprinted with permission of ARRL. Copyright ARRL)

High-quality cables usually use double-shield construction in which one shield is a braid and the other is a thin, coated aluminum foil underneath the braid (the aluminum foil requires a coating, often Mylar, to keep it from cracking when flexed). In many cables, the aluminum is bonded to the dielectric. The foil screen reduces the transfer impedance at higher frequencies. For example, the measured transfer impedance of a single-braid shield with the same dc resistance as a 0.05 mil (0.00005 inch) thick copper foil screen is constant up to about 1 MHz and then rises in proportion to the square root of frequency (figure 4). As the frequency increases, the inside current is brought to the outside surface by the braid weave. The voltage developed on the surface increases as the braid resistance increases due to skin effect, thus raising the transfer impedance. A significant improvement at frequencies above 1 MHz is readily apparent when the braid is combined with a thin foil.



Coaxial cables often used for home distribution of cable television and satellite television, and by radio astronomers as well, have four shields, two foil and two braid in alternate layers – the so-called "quad cable". The additional shields presumably improve performance at higher frequencies. The braided shields in low-cost versions of these cables generally are very thin and have few strands.

Figure 4 – Transfer impedance of a shielded cable with a single braid (dashed line) , braid in combination with a thin inner foil (dotted-dashed line) and foil alone (solid lines). Foil thicknesses are given in micrometers. The improvements at higher frequencies provided by a foil in addition to a braid are readily apparent. (Illustration from fig. 10.9 in [2])

As more components are added to a cable to improve its performance, the cable becomes costlier, heavier and harder to install. Such cables are not as flexible as simple single-braid cables and, generally, the allowable bend radius is larger to prevent crushing of the dielectrics and ruining its transmission performance. Another common type of high-quality coaxial cable is the semi-flexible type. It often is called "hard-line" because it has a solid corrugated copper or aluminum outer conductor (shield) and is comparatively stiff. The corrugation helps reduce both the stiffness and allowable bend radius and helps prevent distortion of the cable cross-section. A familiar type of semi-flexible cable goes by the trademark *Heliax* and is made by Andrew (CommScope). At ultra-high frequencies (UHF, 300 MHz~3 GHz) and super-high frequencies (SHF, 3~30 GHz), semi-rigid cable types are common, but their lengths are necessarily short and they are used only within equipment assemblies to couple modular components. Shields in semi-rigid cables commonly are smooth tin-plated copper or tin-plated aluminum tubes.

It is interesting to compare shields that are used with cables including those discussed above and conduits (table 1). One of the best sources for such information is [3].

Table 1 – Comparison of cable shields (from Table 8-17, Vol. 1 in [3])

	Single-layer braid +	**Multiple layered braid +**	**Foil ++**	**Conduit ++**	**Flexible conduit**
Shield effectiveness * at audio frequencies	Good	Good	Excellent	Excellent	Good
Shield effectiveness * at radio frequencies	Good	Excellent	Excellent	Excellent	Poor
Shield coverage	60~95%	95~97%	100%	100%	90~97%
Fatigue life	Good	Good	Fair	Poor	Fair
Tensile strength	Excellent	Excellent	Poor	Excellent	Fair

Table 1 notes:
* Poor: < 20 dB; Fair: 20~40 dB; Good: 40~60 dB; Excellent: > 60 dB
\+ Effectiveness against magnetic fields is poor
++ For effective magnetic shield, high permeability material must be used

Common coaxial cables with braided shields

Amateur radio astronomers often use RG-6/U, RG-58/U, RG-59/U, RG-213/U and RG-8/U type cables, among others. These are basic designations and variations exist such as RG-58A/U, RG-58C/U and so on. For any given basic designation, the outer dimensions of the cable are nominally the same, but there may be significant differences in the shield, center conductor, dielectrics, jacket materials and transmission performance. In addition to the familiar "RG" designations, cable manufacturers usually have their own designs. Three common examples are Times Microwave LMR-400, Terrawave TWS-400 and Andrew CNT-400. These are equivalent 50 ohm cables with a braided outer shield, aluminum foil tape inner shield, nominal outside diameter of 0.405 inches and a foam polyethylene (PE) dielectric. Other commonly available sizes with the same basic construction are 0.100 inch, 0.195 inch, and 0.240 inch overall diameters. Larger diameters also are available.

Comparisons

The main concern in this article is the cable shield, so in this section I will examine the various types I have in my shop and lab (table 2 and figure 5). I always try to use the best cable available and was surprised to find some low-quality types while preparing this article. All low-quality types were for cable television applications and suffered from poor shield construction. One in particular, the Jasco "RG-59U" had wide gaps in the braid (figure 6). The copper strands in the shields of some cables are not tinned. Without tin plating, the strand surfaces will oxidize more rapidly than tinned strands, thus causing degradation in shield performance.

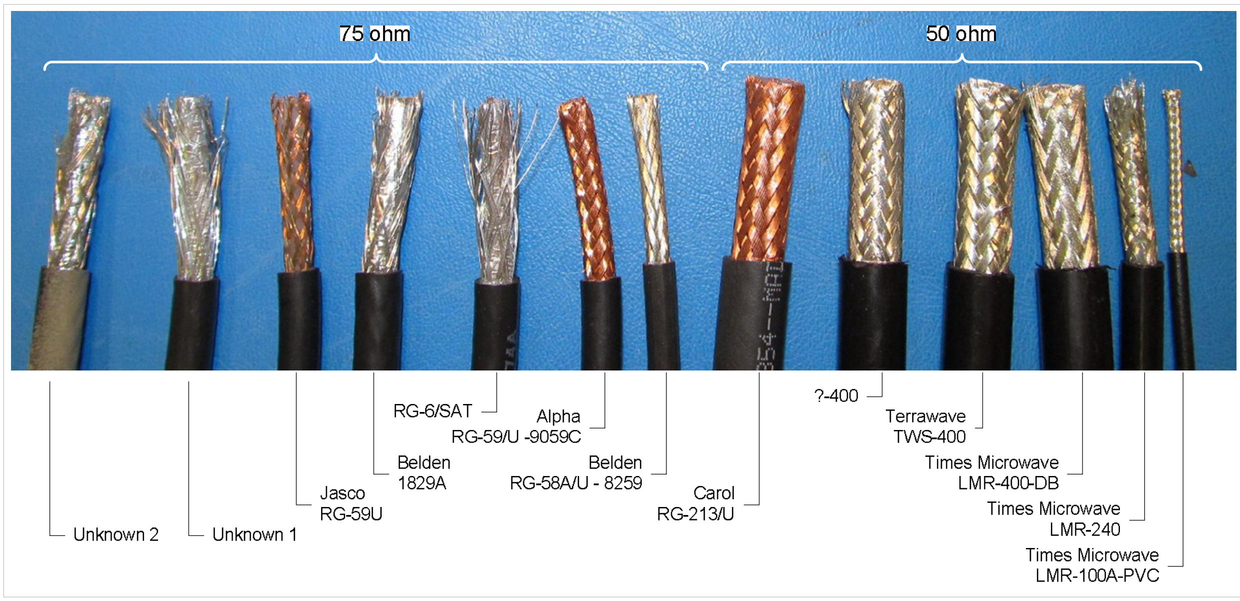


Figure 5 – Coaxial cables stripped 25 mm to reveal the shields. The five cables on the left have very few strands in the shield and the strands are very loosely braided. All cables except the RG-213/U, RG-58A/U, RG-59/U and Jasco "RG-59U" have a foil shield under the braid. The 75 ohm cables shown here are for in-home cable television and satellite television distribution. The LMR-400-DB cable is designed for direct burial applications – the interstitial spaces are filled with a waterproofing compound.


Figure 6 – Jasco "RG-59U" coaxial cable. This cable is very poorly constructed. It has only a few shield strands and there are wide gaps in the braid. The dielectric is clearly visible through the gaps.

A good quality coaxial cable has a tight and dense braid, and some effort is required to unravel it or comb it out. The shield in a poor quality cable is loose and will practically unravel itself when the jacket is removed. Most coaxial cable connectors require that the shield be left undisturbed after the jacket is stripped off, so you should not routinely comb the braid. The exception is with some connectors that are assembled with a wrench, in which case the strands are combed and then bent back over the braid clamp before assembly.

The question often asked about cables with a bonded aluminum foil shield is, should the foil be removed from the dielectric or left in place when the cable is connectorized? The datasheet for the connector defines the action to take with respect to the foil. If the datasheet is silent, the foil is left in place, and this usually is the case for most connectors. However, care must be taken that bits or shavings of the foil do not short the shield to the inner conductor. This is a common problem with small diameter cables (particularly 0.100 and 0.195 in diameter cables), and a loupe or magnifying glass is required to examine the interfaces between the center conductor, dielectric and shield. Further comment on connectorization is beyond the scope of this article.

Table 2 - Cable types examined. All were found in my shop in various lengths and are shown right-to-left in the next figure.

Item	Marking or Type	Mfr	Remarks
1	LMR-100A-PVC	Times Microwave	Indoor only
2	LMR-240	Times Microwave	
3	LMR-400-DB	Times Microwave	Direct buried
4	TWS-400	Terrawave	
5	?-400	Unknown	Probably Terrawave TWS-400
6	RG-213/U	Carol	Untinned shield strands
7	RG-58A/U : 8259	Belden	
8	RG-59/U : 9059C	Alpha Wire	Untinned shield strands
9	RG-6/SAT Foam 18 AWG	Radio Shack	
10	1829A 3 GHz	Belden	
11	RG-59U	Jasco	See figure 6
12	Unknown 1	Unknown	Probably Radio Shack RG-6/SAT
13	Unknown 2	Unknown	Probably Radio Shack RG-6/SAT

Things to remember

1) Never buy coaxial cable based on cost alone. Cable costs are all over the map. It is easy to pay high prices for low-quality cable, and sometimes high-quality cables are comparatively cheap. The cable type, manufacturer, brand, distributor, retailer, and shipping all affect cable costs. There are many more brand names than cable manufacturers. Manufacturers build cables to order using a specification. Brand X cable may be made by a manufacturer according to the Brand X specification, but it could be much lower quality than Brand Y cable made by the same manufacturer to the Brand Y specification.
2) Buy only known brand names such as Allied Wire & Cable, Alpha Wire, Andrew (CommScope), Belden, Consolidated, Southwire, Terrawave, and Times Microwave. There are other reputable brands. It is tempting but perilous to buy very cheap, unbranded and unmarked cables. You get what you pay for....
3) Do not buy cable unless you can physically examine it first. Of course, an exception is made when you buy from a source you can trust. This includes authorized distributors such as Allied Electronics, Mouser, Digi-Key, Tessco, Talley and Hutton (although even these companies are not completely immune from counterfeit products). There possibly are others, including local sources.

4) Be sure you are buying new cable and not old stock or used cable. Old stock and used can be recognized by stripping a few cm of jacket and examining the shield. If necessary, use a loupe or magnifying glass. If the shield braid wires are oxidized or corroded, have a dull color or are spotted, or the cable jacket is scuffed and scratched, do not buy the cable. If you buy from established distributors, you generally do not have to worry about this.
5) Do not buy cable that has been stored outdoors or in a humid environment. This is easily recognized by examining the jacket for moisture and mildew stains and the shield for corrosion.

6) After stripping the jacket, look again at the shield. If it contains only a few strands or the strands are loosely braided or not braided at all, the cable is low-quality and should not be used.
7) Examine the dielectric and center conductor. If the dielectric does not have a uniform color or is hard or brittle, do not buy the cable. Also examine the cable cross-section. It should be circular and not elliptical.
8) Some vendors that sell cable in small quantities, hand coils or cut-to-order have transferred the cable from a large reel to smaller reels. If this has been done improperly, the cable will be crushed and will have an oblong (elliptical) cross-section. Do not buy this cable.
9) Beware of coaxial cable purchased through online auction websites unless from a vendor you trust. You cannot examine the cable before purchase and it may not be returnable. Even if it is returnable, the costs of sending it back may negate any savings you thought you were getting. On the other hand, it may be worthwhile to purchase a small amount so you can examine and test it before purchasing a larger quantity. However, unless the seller can provide a bonafide name-brand datasheet, one not written with Chinese language characters, stay away from this type of merchandise.

Conclusions

Coaxial cables are important to the proper operation of a radio telescope. You do not save any money by buying cheap cable, but you do save money by being careful and knowing what to look for. Coaxial cables have many important components, including the shield, and simply looking at them closely often will tell you if they are any good.

References

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For further reading

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