# Brass Tacks

***An in-depth look at a radio-related topic***

## Selecting your feed line

Unless you're brand new to the craft, sooner or later you'll want to connect your radio to an antenna that's not rigidly attached to your radio. You'll need to use a ***feed line*** to make that connection, and typically the type of feed line you'll use is *coax* (coaxial cable). A feed line is any pair of conductors (technically known as a *transmission line*) that carries a signal from your transceiver to your antenna. This article addresses three major concerns regarding feed lines: impedance, power-handling, and a particular focus on attenuation, or *loss*. There are other concerns, such as materials, construction, capacitance, cost, and velocity factor, and this article will touch on some of them lightly.

Let me first mention that there are many more conventional feed line types that amateurs use besides coax, such as ladder line, window line, and twin-lead. Even twisted pair, a differential set, and other kinds of conductors have been used successfully as types of feed lines. The fact is, what sets coax apart from other feed line types are lower cost, ease of use, and its ability to present a relatively consistent impedance regardless of frequency. On the other hand, a significant characteristic that sets coax apart from other transmission line types is ***loss***, and that factor can't be ignored.

## Loss is wasted power

Because all feed lines are constructed with real-world materials, they also exhibit some resistive and reactive properties, which oppose an electrical current passing through them. When your transceiver sends a signal through your feed line to your antenna (or other object, such as a meter, an amplifier, a tuner, or dummy load), the signal suffers some degradation of signal strength (power) due to the resistive and other (such as dielectric) properties of your feed line.

This degradation of signal power in your feed line is something that you must consider, if you plan to purchase any that's longer than, say, fifteen feet. Furthermore, the loss in coaxial cable differs between models and frequency. Fortunately, you can easily calculate feed line loss for a given coax model at a given frequency by simply knowing the length you require.

For example, from the table on the next page, you can see that coaxial cable model RG-213 used at 2 meters (say, 146.560 MHz) near room temperature exhibits 2.4 dB of signal loss per 100 feet of cable length. So, if know that you're going to need to run a 42-foot length of RG-213, your loss will be (42 feet / 100 feet) X 2.4 dB = 1.0 dB loss, which amounts to

$$-1.0\ \text{dB} = 10\log_{10}(1 - x) \gg x = 1 - (10^{-0.1}) \approx 20.6\ \%$$

which means that, if your transmitter outputs 50 watts, about 39.7 watts will actually reach your antenna, the remaining 10.3 watts leaving your coax as heat and radiation. If you're willing to live with that loss, then you've reached a compromise that should work well for your station. But if you find that loss excessive, you'll need to either shorten your cable or use another model. If you choose LMR-400, for example, then your loss will be (42 feet / 100 feet) x 1.5 dB = 0.63 dB loss, which amounts to

$$-0.63\ \text{dB} \approx 13.5\ \%$$

which will allow more than 43 watts to reach your antenna.

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The following table lists different coax models and their losses in dB at particular amateur bands per 100 feet of cable length (taken from my online PDF) :

| Model | Ohms | 80 m | 40 m | 20 m | 10 m | 6 m | 2 m | 70 cm |
|---|---|---|---|---|---|---|---|---|
| RG-58 | 50 | 0.9 | 1.2 | 1.7 | 2.5 | 3.3 | 5.6 | 10.0 |
| RG-8X | 50 | 0.7 | 1.0 | 1.3 | 1.9 | 2.7 | 4.5 | 8.2 |
| RG-59 | 75 | 0.6 | 0.9 | 1.2 | 1.8 | 2.4 | 4.1 | 7.4 |
| RG-6 | 75 | 0.5 | 0.7 | 1.0 | 1.4 | 1.9 | 3.3 | 6.0 |
| LMR-240 | 50 | 0.5 | 0.7 | 0.9 | 1.3 | 1.8 | 3.0 | 5.3 |
| RG-213 | 50 | 0.4 | 0.5 | 0.7 | 1.0 | 1.4 | 2.4 | 4.5 |
| RG-8 | 50 | 0.4 | 0.5 | 0.7 | 1.0 | 1.4 | 2.4 | 4.5 |
| LMR-400 | 50 | 0.2 | 0.3 | 0.5 | 0.7 | 0.9 | 1.5 | 2.7 |

These values will differ slightly between manufacturers of the same model of coaxial cable, so this table is only a approximate guide. Also, suffixes to coax model numbers, such as RG-58U or RG-8/U or LMR-400UF do not modify the cable loss appreciably, but only describe other characteristics, such as flexibility and jacket material. As a side note, the above table does not list the coaxial cable diameters, but suffice it to say that, *in general*, the larger the coax diameter, the lower loss it exhibits, and the greater its power-handling capability.

Notice in the above table that each coax model is listed alongside its *characteristic impedance* (**Ohms**). This value does not change (much) with length, for a given frequency, one of the hallmarks of this type of feed line. Coaxial cable was invented in 1880 by Oliver Heaviside, to solve the problem of reliance on a uniform feed line impedance at a given frequency, regardless of length, to minimize loss.

I listed a couple of examples of 75-ohm feed lines In the above table because a few hams get hung up worrying about whether their RG-6 coax will work with their ham radio (50-ohm) set up. The simple answer is Yes, it will. It's true that the 75-ohm feed line does not match the impedance of your rig, but that difference will result in an SWR of

75 ohms / 50 ohms = 1.5:1

which, in my book, is pretty good, because that results in a reflection of only

$$P_{REFLECTED} = P_{FORWARD} \times [(SWR - 1) / (SWR + 1)]^2 = 100\,\% \times [0.5 / 2.5]^2 = 4.0\,\%$$

If, however, you plan to use a feed line whose characteristic impedance is much greater than 50 ohms, such as twin-lead (300 ohms), window line (300 to 450 ohms), or ladder line (600 ohms), you'll need to use an RF transformer to help match your feed line with your transceiver.

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This next table (taken from my New Ham Page) is a mere set of suggestions that serves as a quick guide, to those who are looking for a general chart of the types of coaxial cable they should purchase, depending on their needs:

| Band(s) | Location | Movement | Duration | Length | Model |
|---|---|---|---|---|---|
| VHF or UHF | outside | little | temporary | over 50 feet | LMR-240 |
| VHF | inside | little | temporary | under 50 feet | RG-8X |
| VHF or UHF | outside | little | permanent | over 50 feet | RG-213 or LMR-400 |
| VHF or UHF | outside | little | permanent | under 50 feet | LMR-240 |
| HF | outside | little | permanent | over 50 feet | LMR-240 or LMR-400 |
| HF | outside | lots | permanent | under 50 feet | RG-8X |
| HF | inside | lots | temporary | under 50 feet | RG-8X or RG-58 |

Here are some column explanations:

**Location**: simply put, whether the cable will be exposed to the weather

**Movement**: "lots" of motion indicate the cable is likely move with the wind or get moved around periodically due to experimentation or changes in transceiver or antenna placement

**Duration**: "temporary" indicates your intention to experiment or eventually relocate your transceiver or antenna

**Model**: where the chart lists "RG-8X" it's assumed that a more expensive / higher-grade coax will also work, such as LMR-240, RG-213, or LMR-400 (I tend not to recommend RG-8 or Belden 9913 because they tend to be more expensive, for the same characteristics)

Final note on the above chart: other types of feed lines will work for you as well or better, but these are my personal recommendations, based on characteristics, reliability, price, availability, and convenience (ease-of-use.)

## Materials matter

The materials that make up your feed line, including center conductor type, dielectric substance, and jacket composition, are important to understand, to help you make an educated purchase or installation.

Coax that has a solid center conductor will typically have a much larger *bend radius* than that of a stranded conductor, meaning the solid core cannot be bent around a tight corner without incurring some damage to the cable. If bent too tightly, any cable will over-compress the dielectric, resulting in an impedance "bump" at that location. On the other hand, stranded-center

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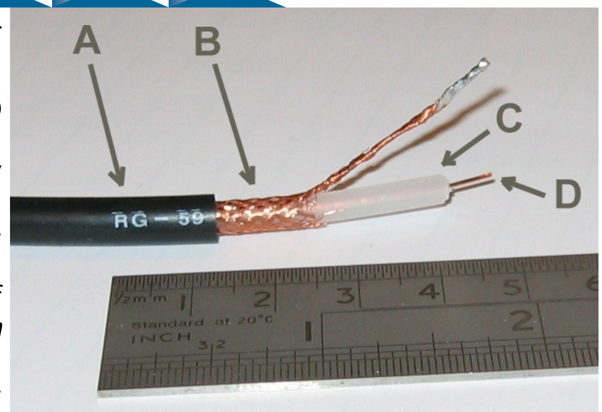
coaxial cables tend to exhibit a slightly higher loss than that of a solid core, thus a trade-off.




*RG-59 coaxial cable, showing*

*A. Outer jacket*

*B. Braided shield*

*C. Polyethylene dielectric*

*D. Center (solid core) conductor*

The *dielectric* is the (typically non-conductive) material between the two conductors that form the plates of a capacitor. Feed lines work by means of the capacitance between their paired conductors, and so the dielectric material becomes an important factor in their construction. Dielectric types include air, foam, solid plastic of some sort, and many other substances, but *in general*, the less dense the dielectric (the more air it contains), the lower loss the feed line exhibits. This is why hams who have really tall antennas often rely on ladder line, which uses air as its dielectric, and exhibits the lowest loss of all feed lines.

The jacket of coaxial cable is the outer sheath that covers and protects the braided shield, the dielectric, and center core from weather, particularly water ingress. A break or split in the jacket could potentially destroy the integrity of the cable, or at least produce an impedance abnormality in that area. If the jacket is exposed to sunlight, it must be constructed of a substance that's resistant to UV (ultraviolet) radiation, which can break down jacket materials over time, and allow water to enter the jacket and destroy the feed line. Intrusion from water, including precipitation, humidity, and vapor causes problems due to braided shield oxidation, dielectric breakdown, and material expansion.

## Other considerations

One characteristic that we haven't addressed much is *power-handling*, and we can ignore that to a point. That's because most modern feed line types can handle the power requirements for much of what our transceivers are capable of transmitting. For example, I recommend RG-8X for 70 cm, but that model can only handle 80 watts maximum. Since most base and mobile rigs transmit on less than 80 watts on UHF, we're *fairly* safe using RG-8X.

Another characteristic is *velocity factor*, which is the ratio of the electrical energy speed in a conductor, to that of the speed of light in a vacuum. The only situation in which you really need to take account of a conductor's velocity factor is in the construction of an antenna element or matching stub from that conductor. If you're using it for a feed line, you typically do not need to take velocity factor into account.

People also ask about manufacturers of feed lines, but the answer is often more subjective than technical. I often tell people that my favorite manufacturer of most coaxial cable is Times

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Microwave™. No, I don't get a kick-back from them, but I'm continually impressed by their quality. I also get asked about knock-off brands, such as those by ABR Industries, Altelix, Shireen, Workman, Tramflex, plus a couple of others, and I've used all of them, with fair to good results, the biggest differences typically being the quality of the jacket.

## What I use

And since we're addressing manufacturers and their varieties of feed lines, let's also mention the second-most important purchase consideration: price. Yes, I love Times Microwave, but they're far from the cheapest, and I'm the first to admit that you don't always get what you pay for. That's why I've spent the money and time to experiment with less-expensive brands, to find the best bang for my buck. In the end, it's still Times if I'm going to run a 60-foot length of coax. But admittedly, for shorter lengths, I've been quite pleased with ABR Industries and Altelix.

And where do I go to make these purchases? eBay. Even with Prime, Amazon is just a bit expensive for me. And I can purchase just about all the high-quality coax I need from here in the US. Pretty or not all of my outdoor coax have black jackets, primarily for UV protection. I suppose one day when they devise a reliable UV jacket in another color, I might be tempted to try it.

***LMR-400 coax ground connections***


***My humble bundle: LMR-400 for VHF, LMR-400 for HF, MC4 for solar, all spread out for a photo op, plus a 4 AWG ground wire in back***

You can see now why I've installed LMR-400 by Times Microwave™ for almost all my coax needs: it's relatively inexpensive, 50 ohms, easily obtainable, exhibits the least loss, and can handle all the power I can possibly throw at it. My feed line lengths are 65 feet (VHF/UHF), 75 feet (HF), and 90 feet (6 meters). I do have a 33-foot length of LMR-240 I use for experimental purposes. My wife Lisa KR5LYS uses 41 feet of LMR-400 for her VHF / UHF station.

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