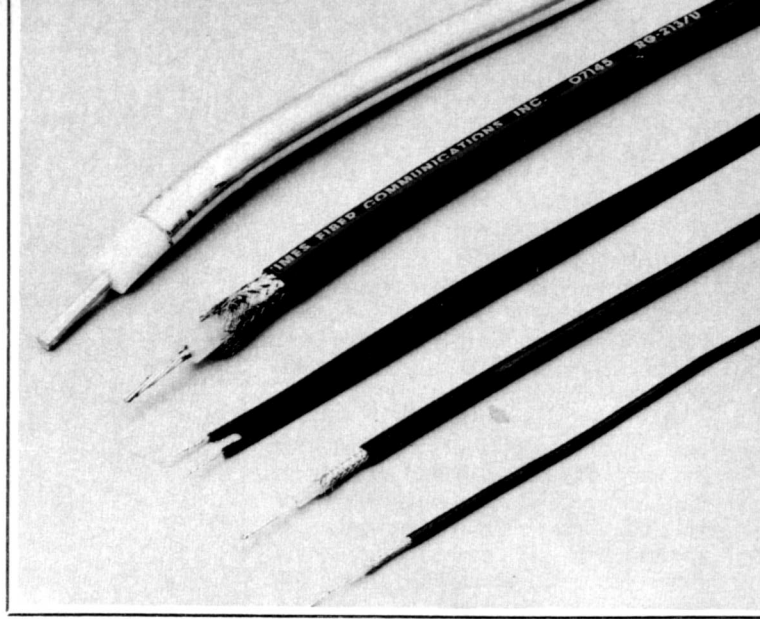# Feeding Your Station

Fat coaxial line, skinny cable, open-wire feeders or 300-ohm ribbon line — the correct choice can save the beginner a few dollars while helping to ensure maximum performance.

By Doug DeMaw,* W1FB

There are a host of important factors to consider when planning the feed system for any antenna. The cost of the line should *not* be the first item to ponder. Rather, we need to be aware of the *loss* (measured in decibels per foot) at our chosen operating frequency and the quality of the cable — insulating material, extent of shield-braid covering and inner conductor size. Not all similar feed lines provide the same quality and performance. The choice between coaxial lines and balanced open-wire or ribbon lines is still another matter to contemplate. Finally, we should determine the longevity of the line. Pollutants in the soil and air, plus the effects of sun and temperature, have a significant deteriorating effect on feed lines; certainly, we don't want to replace the transmission line more often than necessary. After all, these are tough economic times, and nothing we buy seems to be priced as we feel it should be! Let's examine the high points of selecting the best feeder cable for several types of applications.

The Matter of Losses

How much loss can we tolerate in a transmission line? Our objective should be to reduce the losses as much as possible, but there must always be some loss in the system, however slight it may be. Most manufacturers of transmission line rate the product in decibels of loss per 100 feet for a specified range of operating frequencies.[1] As the frequency is raised, the losses increase. For a given length of coaxial cable

the losses at 1.8 MHz may be so minor that we don't pay much heed to them. But at, say, 28 MHz and higher, they may be so great that half or more of our available transmitter power is lost en route to the antenna! This can happen even when the feeder is matched properly to the antenna at one end, and to the transmitter at the other end.

Fig. 1 contains a chart that will aid us in learning the various characteristics of feed lines, including the losses per 100 feet

[1]Notes appear on page 23.

at frequencies from 1 to 1000 MHz. We can observe from Fig. 1 that the least effective line we can select is miniature RG-174/U. The loss per 100 feet exceeds 5 dB at 29 MHz. Thus, if our transmitter puts out 100 W of rf power, only 31 W will reach the antenna, assuming we are operating at 29 MHz with 100 feet of RG-174/U cable! Imagine what this could mean if we were using a QRP (low power) station with only 1 or 2 W of transmitter output power. Ouch!

Now, let's envision the same general situation while using the least lossy line — open-wire feeders. The loss per 100 feet at
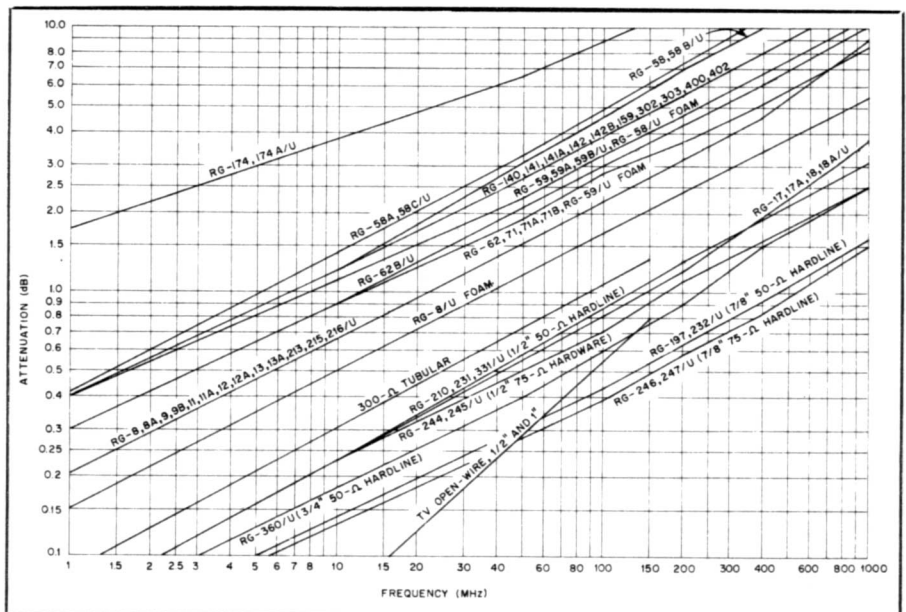

Fig. 1 — Method for determining transmission-line loss.

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29 MHz will be roughly 0.175 dB. Hence, for 100 W of output power we will be able to deliver 96 W to the antenna feed point, assuming the impedances are matched correctly at both ends of the line. So, we can see that even with the least lossy of feed line we will still be forced to sacrifice some of our power in the system. Additional losses will occur, however minor they may be, if we include Transmatches (antenna tuners) and baluns (balanced-to-unbalanced transformers).

There is no such thing in this business as 100% efficiency. So, somewhere along the course of our planning we must strike an acceptable compromise between losses and the cost of our feed line. RG-8/U coaxial line that contains foam dielectric is the frequent choice of amateurs for use from 1.8 to 30 MHz. The loss is 0.9 dB at 29 MHz and only 0.2 dB at 1.8 MHz. So, at 29 MHz our 100-W transmitter will deliver approximately 81 W of rf energy to the antenna feed point per 100 feet of foam RG-8/U line.

Semiflexible, aluminum-jacketed, foam-dielectric cable (Hardline) is the style of transmission line preferred by those amateurs who are willing to spend extra money for a low-loss feed system that should last for many years. This type of coaxial cable is well-suited to vhf and uhf work because of reduced losses and relative immunity to damage from the environment. Although the 0.5-inch-diameter Hardline (RG-210/U, etc.) is quite good in this respect, the 0.75-inch-diameter type (RG-360/U) is better with respect to losses. But, it costs substantially more than the smaller Hardline. The "flea on the dog's back" in either situation is obtaining the connectors for Hardline. Not only are these special fittings hard to locate — they cost a bundle! A method for adapting standard coaxial connectors to Hardline was treated in *QST* a few years ago.[2]

Using Open-Wire Feeders

You may hear old-timers extolling the virtues of open-wire feeders or "ladder line." In bygone days, the standard ham antenna was the end-fed or center-fed Zepp. It got its name from a style of antenna that was used on Zeppelin airships. Open-wire feed line was used with a tuner to permit operation over a wide range of frequencies. The tuner was used to provide an impedance match between the feed line and the station transmitter and receiver. The arrangement did not ensure a match at the antenna feed point; because the feeder losses were so low, however, the mismatch was inconsequential.

Many amateurs still use Zepp-style antennas because they are convenient for multiband operation when there is room for only one antenna. Such a system is shown in Fig. 2. The purpose of the Transmatch (transmitter to transmission-line matcher) is to convert the balanced
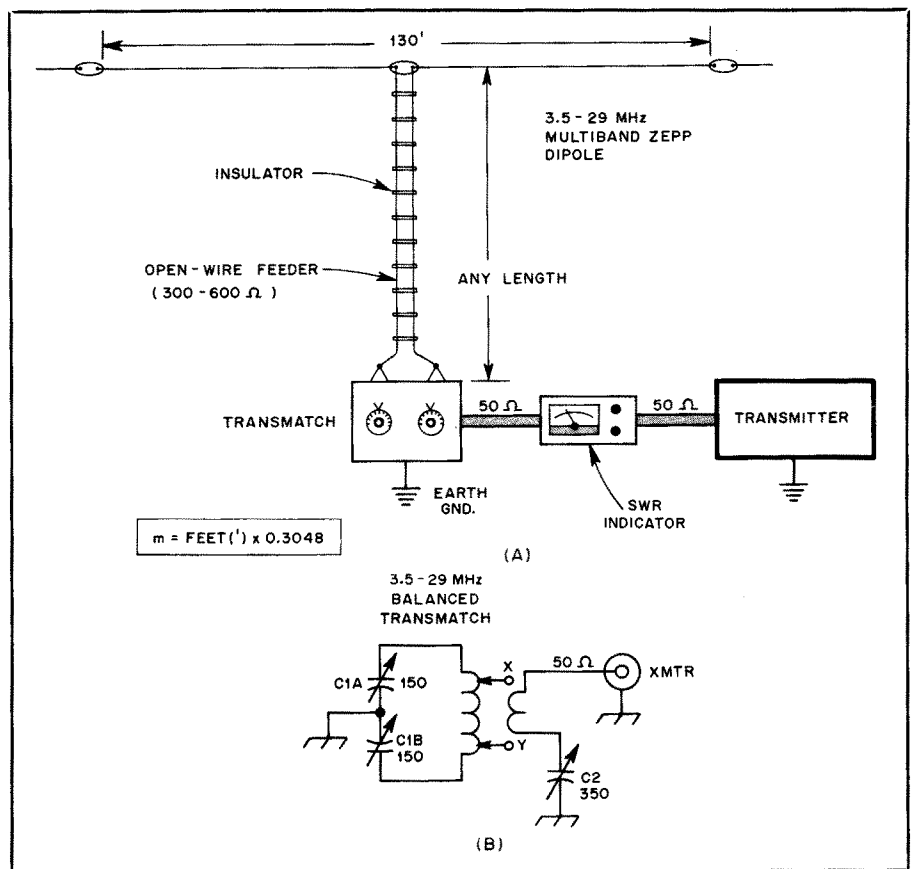

Fig. 2 — Example of a center-fed Zepp antenna for multiband use with open-wire feeders. A Transmatch is used to convert the system from a balanced to unbalanced condition while matching the line impedance to that of the transmitter (see text). Transmatch circuit is shown at B.

feed-line format to an unbalanced 50-ohm condition for interface to the transmitter and receiver. The Transmatch is adjusted to provide an SWR (standing-wave ratio) of 1:1, thereby assuring maximum power transfer from the transmitter to the antenna system.

Some of you are no doubt wondering, "What should the open-wire line impedance be?" Actually, its value is not critical. A multiband antenna of the type seen in Fig. 2 may not be matched to the antenna feed point on any band, irrespective of the typical balanced feeder impedance. Generally, we will use open-wire line that ranges in impedance from 300 to 600 ohms. This depends on the wire diameter and center-to-center spacing between the two wires. Most commercially made open-wire feed line is 300 or 450 ohms with respect to the characteristic impedance. Homemade ladder line may be as great as 600 ohms in value. We can easily calculate the line impedance by applying Eq. 1.

$$Z_o = 276 \log \frac{2S}{d} \text{ ohms} \qquad \text{(Eq. 1)}$$

where Z_o is the feeder impedance, S is the distance (center to center) between the two wires and d is the diameter of the conductors. The dimensions are in inches. Hence, if we made an open-wire line from two

lengths of wire that had an outer diameter of 0.125 inch, and the center-to-center spacing of the wires was 4 inches, the impedance would be

$$Z_o = 276 \log \frac{8}{0.125} = 498.5 \text{ ohms} \qquad \text{(Eq. 2)}$$

Spacers of good insulating quality should be used at 12-inch intervals, approximately, to maintain the desired spacing between the wires. Steatite, ceramic, Plexiglas,® fiberglass or phenolic is suitable. Some amateurs, in an effort to keep the cost low, have used pieces of wooden dowel rod after boiling the pieces in paraffin (canning wax).

What About TV Ribbon Line?

Can we use 300-ohm TV ribbon as balanced feeders? Sure! It suffers from a significant limitation, however: The insulating material — usually polyethylene — increases the line loss, as is the case with coaxial cable. Therefore, we will not enjoy the benefits of the almost air-dielectric open-wire line. But, we will have a balanced system.

An annoying problem with the use of TV ribbon is a change in the SWR when it rains, when the line becomes dirty, or when ice and snow are present. This can happen to a lesser extent when using open-wire line, but it seldom presents the annoyance that

we will experience with ribbon types of 300-ohm line.

If TV line must be used, try to obtain the uhf style of feeder. It will be foam filled, or may have sections of the insulating material cut out at short intervals along the inner portion of the line. Also, try to select 300-ohm line with large conductors. Some of the "cheap" ribbon line has inferior insulation and very tiny conductors. Avoid this variety! It will be very lossy.

Back to Coaxial Cables

Commercial antenna designers need to consider a number of factors when choosing a proper feed line: power rating, operating voltage (rms or peak), shielding integrity, velocity factor (V_f) and environmental damage, for example. Not all of these points will be of concern to us amateurs, since we are dealing with low levels of rf power, comparatively speaking, and will not be operating our stations at altitudes greater than 10,000 feet or in ambient temperatures exceeding 100° F. Those two conditions must be taken into account by many commercial operators, however, since the greater the heat and altitude the lower the power capability of the transmission line. An article on this subject, along with derating charts and other feed-line matters not discussed here, was published in *RF Design*.[3] We will focus instead on the velocity factor and potential environmental damage. The operating voltage will also be treated.

Velocity Factor

Each type of coaxial or balanced feed line has a specific velocity factor. The V_f is dictated by the dielectric material used as insulation between the conductors. We can learn the V_f from

$$V_f = \frac{100}{\sqrt{\epsilon}} \% \qquad \text{(Eq. 3)}$$

were V_f is the velocity factor as a percentage of the speed of light and ϵ is the dielectric constant of the insulation. Solid polyethylene (for feed lines) has a dielectric constant of 2.31, and Teflon is rated at 2.07. Air is specified as 1.0, which indicates no need for concern about the V_f of air-insulated lines. Foam polyethylene has an ϵ constant of 1.56, so we must be mindful of whether our coaxial line contains solid or foam insulation. In accordance with these constants, we may apply the V_f of 66% for solid polyethylene cables and 80% for foam types of feed lines. If we should be fortunate (or wealthy) enough to obtain Teflon-insulated feeder cable, we can use 69% for the V_f.

Since each style of cable has a V_f, we can think of this as a time delay factor along the line. This time delay (T) can be obtained from
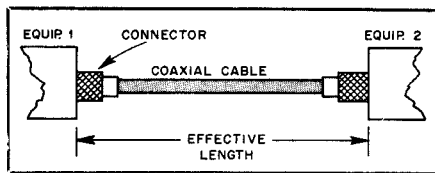
$$T = 1.016 \sqrt{\epsilon} \qquad \text{(Eq. 4)}$$

Fig. 3 — When you are cutting a length of coaxial cable to a specific part of a wavelength, it is essential to include the coaxial connectors in the measurement. The velocity factor of the cable is also included in the calculations (see text).

Table 1

Characteristics of Some Popular Coaxial Feed Lines

Cable Type	Nom. Impedance	pF/ft	Max. rms Voltage
RG-174/U	50 ohms	30.4	1500
RG-58A/U	50 ohms	28.5	1900
RG-59A/U	75 ohms	21.0	2300
RG-8A/U	50 ohms	29.0	5000
RG-11A/U	75 ohms	0.5	5000

Alum. jacketed Hardline (foam dielectric)

1/2 inch	50 ohms	25.0	2500
3/4 inch	50 ohms	25.0	4000
7/8 inch	50 ohms	25.0	4500
1/2 inch	75 ohms	16.7	2500
3/4 inch	75 ohms	16.7	3500
7/8 inch	75 ohms	16.7	4000

Additional types and characteristics can be found in Chapter 3 of the *ARRL Antenna Book*, Fourteenth Edition.

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where T is in nanoseconds/ft and ϵ is the dielectric constant of the cable insulation.

What does all this mean? Is it worth bothering with? By all means! Suppose you needed to cut a piece of RG-8/U coaxial line (solid polyethylene insulation) to one quarter wavelength at 3.9 MHz. Perhaps this line section is needed as a matching transformer. The free-space length of such a line would be found from L(ft) = 246/f(MHz). Therefore, the line for that condition would be 63 feet long. But, we must take into account the V_f of our feedline section. Hence, we will multiply 63 by 0.66 to secure the correction factor. The total length (including connectors) of the quarter-wave section then becomes 41 feet 7 inches.

Indeed, the coaxial connectors are a part of the electrical line length, as illustrated in Fig. 3. In an ordinary antenna system that is matched properly to the terminations at each end, we need not be concerned about the precise length of the feed line, except for the losses resulting from long runs of such cable.

Operating Voltage

Feed lines are rated for maximum safe rms (root mean square) operating voltages. The rf voltage from our transmitters is the rms type, assuming the wave form is pure. We can learn what the line input voltage is if we first measure the transmitter output power into a 50-ohm dummy load.

E(rms) is obtained from

$$E = \sqrt{PR} \text{ volts} \qquad \text{(Eq. 5)}$$

where P is in watts and R is in ohms. Therefore, if we delivered 100 W to a 50-ohm load, our rms voltage would be 70.7. This assumes an SWR of 1:1. If the line to the antenna exhibits an SWR other than this, however, we need to include this factor when determining the *effective* line-input voltage. This is accomplished by multiplying the actual input voltage by the square root of the SWR. So, if we had 100 W of power (70.7 volts rms) and an SWR of 1.7:1, the effective input voltage would be 92. We can learn from this that the higher the SWR the greater the possibility of damage to the feed line at the higher power levels. Table 1 lists the maximum safe rms voltage for a number of common feed lines.

Environmental Considerations

It's no secret that air contains all manner of man-caused pollution. These acid and alkali materials can, with time, contaminate the plastics used as coverings on coaxial cables. The poison migrates into the cable and causes it to be lossy. How bad the contamination, and the length of time required to spoil a feed line, depends on the level of contamination for a given region. Those living in large cities and industrial regions will fare the worst in this respect. The ultraviolet (UV) radiation from the sun will also affect the plastics in our antenna systems.

Cables that contain foam dielectric are generally more resistant to pollution damage than are the solid-dielectric types; the air bubbles in the insulation help to restrict the migration process. Aluminum-jacketed Hardline is more likely to resist the effects of pollution than is RG-style flexible line with its braided-copper outer conductor. Moisture is the first-order enemy of coaxial cables, especially when the moisture carries damaging chemicals into the feed line. Acid rain, a common threat in some areas nowadays, can cause oxidation of the feeder conductors. Because of UV radiation in areas of high sun activity, polyethylene jacketing is preferable to PVC outer-jacketed lines. In areas of high sun intensity, PVC lasts about half as long as polyethylene.

Special Impregnated Cables

If we chance to live where the salt content in the air is high, or if a substantial level of air pollution is prevalent, we may be wise to invest in one of the impregnated RG-8/U types of coaxial line. I use this style of line for all underground installations, and tend to prefer it for above-ground use as well. The center conductor is solid rather than stranded. Otherwise, the cable is very similar to RG-8/U. The transmission line is pressure-pumped
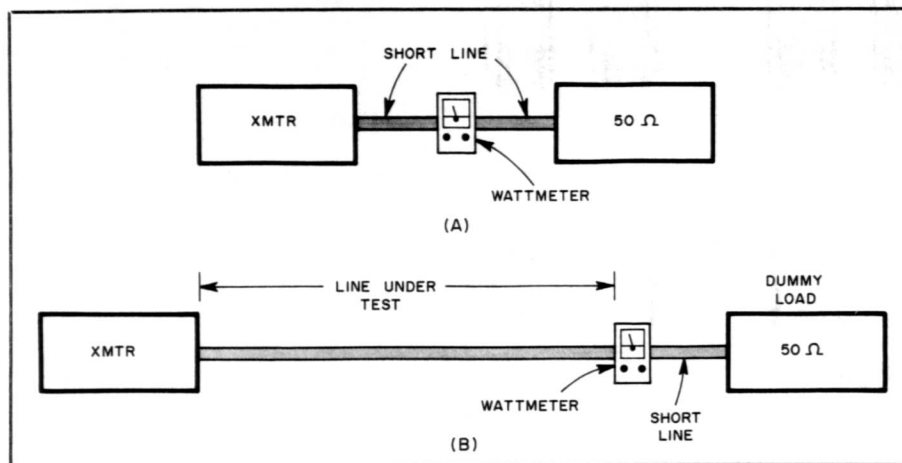
Fig. 4 — An old piece of coaxial feed line can be tested for losses by establishing a given transmitter output power (A) and maintaining it. Next, as shown at B, the wattmeter and dummy load are moved to the far end of the line to be tested and a second power reading is taken. The loss in decibels is then found from dB = 10 log P1/P2, where P1 is the highest power observed and P2 is the lowest reading.

with a sticky, low-loss compound to prevent dirt, air and moisture from penetrating it. It costs more than standard RG-8A/U, but it will last a lifetime under normal circumstances. It is available from at least two manufacturers.[4] It is also immune to damage from rodents, in that it is self-healing (some rodents delight in gnawing on exposed wires).

If you are suspicious of your feed line because it has been out of doors for a long time, or if it has been buried in the soil, it would be prudent for you to do a power-loss measurement of the line. This is a simple procedure. The essentials are shown in Fig. 4. The transmitter power is set to a specified amount after we connect a power meter and dummy load to the transmitter output. Next, the suspected coaxial line is attached to the transmitter, while the power meter and dummy load are moved to the far end of the feed line. A second power reading is taken. The loss in decibels is then compared to the loss of a new feed line, at the operating frequency. (See Fig. 1 and calculate the loss per foot.) If it is greater than 10% of the rated value, the feed line should be replaced.

We can slow down the deterioration process measurably by applying a quality sealant to the open portions of the cable when the antenna system is first commissioned. This will prevent unwanted moisture from entering the line and flowing along the inner and outer conductors. I like to use noncorrosive Silastic® compound or five-minute epoxy cement. I also apply sealant around the back side of my coaxial connectors. The putty used for dry floral arrangements works nicely as sealant for coaxial fittings.

Shielding Integrity

Bargain-price coaxial cable often has very poor shield-braid construction. The manufacturers of this material skimp in an effort to speed production and increase their profits. Well designed single copper braid provides 85 to 90 percent shielding efficiency. Two layers of this braid are even better, and triple-layer braid is best.

But these are quite expensive, and are not necessary for most of us. The extra shielding is essential for duplexer harnessing in repeater stations, and where incidental radiation must be held to a minimum. By comparison, aluminum-jacketed Hardline has an isolation rating (per foot at 100 MHz) of 700 dB. Single-braid line, such as RG-8A/U, provides only 48 dB of isolation. These isolation amounts are referenced to the desired transmitter output power.

If you are tempted to buy low-cost feeder cable, sneak a peek at the shield braid before paying for it. If there are gaps between strips of stranded braid, don't buy

it. Some imported cables fit this description all too well!

What Have We Learned?

The object of this discussion has been to caution the newcomer about the matters of feed-line loss, potential deterioration of the cable and the velocity factor of a length of transmission line. A single lost decibel in a transmission or reception system may seem rather inconsequential. After all, few of us could discern an increase or loss of 1 dB while listening to a signal. But decibel losses are cumulative, so it is to our advantage to salvage every decibel possible. When we add up the potential losses in a complete amateur system — losses from feed-line attenuation, baluns, Transmatches and poor matching — it can become startling, especially at the higher frequencies! It isn't a casual matter to have even a 3-dB system loss, for that means we have cut our available rf power by 50%. We must accept some losses, but being miserly about the situation is wise. Three dB, for example, could mean the difference between being copied or lost in the QRN (noise) or QRM (interference).

We might summarize by saying that we should try to buy quality feed line, avoid the small-diameter coaxial cables for runs greater than 50 feet up to 30 MHz, and seal the points where moisture can enter the line. If we need to bury the feeder cable, we should consider using impregnated feed line. For vhf and uhf antenna systems, we should attempt justification of Hardline in preference to flexible feeders to minimize losses. RG-174/U line should be avoided at all costs, even for use in the lower part of the high-frequency spectrum.

Generally speaking, we will fare pretty well for all but the most demanding applications if we use foam-insulated RG-8A/U line in our 50-ohm systems. It represents a reasonable compromise between cost, longevity and minimum losses. Open-wire line will always be best for very long feed lines, however.

Notes

[1]mm = ft × 0.3048; mm = in. × 25.4.
[2]DeMaw, "Connectors for CATV 'Hardline' and Heliax," QST, Sept. 1980, p. 43.
[3]DeMaw, "RF Coaxial Cables — Choosing the Right One," RF Design, May 1980.
[4]VB-8 coaxial cable from Decibel Products Corp., 3184 Quebec St., Dallas, TX 75247 (W5KF, VP). Imperveon 50-ohm cable from Times Fiber Communications, 358 Hall Ave., Wallingford, CT 06492.

Strays

STRAY HINTS

☐ "Strays" are those interesting fillers used when space allows in QST. Think you have an item with Stray potential? Here are some hints to help your submission become one. (1) Be sure the information will be of interest to most readers of QST. (2) Submit your material before deadline — the 8th of the second month preceding desired publication (i.e., arrive at Hq. before December 8 for February QST). (3) Any photographs you send should be good-quality, black-and-white glossy prints. Color prints, slides and instant photos do not usually reproduce well.

Items submitted are normally acknowledged, but that doesn't necessarily mean that your Stray will be appearing in QST. We receive far more material than we can find room for. If you want your material returned, please include a statement to that effect and an s.a.s.e.

Follow the above hints and maybe your Stray will find a home in QST. — Andrew Tripp, KA1JGG