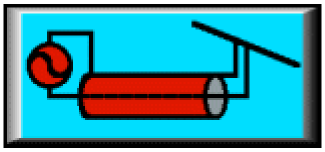

Some Aspects of Series and Parallel Coaxial Cable Assemblies

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In the course of developing this collection of notes, I have had occasion to use and to refer to both series and parallel coaxial cable assemblies. Perhaps a few notes specifically devoted to this subject might be useful to those who have never used coaxial cables in this way.

Basic Transmission Line Properties

Among these notes is a discussion of the basic properties of transmission lines: **12 Ways to See and Love Your Feeders**. That discussion is the background for these notes. However, let's review the salient properties of transmission lines as they are important to us in this context.

First, all transmission lines consist of two or more conductors so arranged that they do not radiate RF energy. Whatever the exact arrangement of conductors, 2-wire lines have equal current magnitude and opposite current phase at every point along the line, thus resulting in the confinement of RF fields to the region of the line. Since the lines do not radiate (when installed correctly), the energy applied at one end of the line is available for controlled use at the other end of the line.

All transmission lines exhibit a characteristic impedance that is a function of the capacitance between the wires and the inductance along the wires for any unit of length. Since this ratio is the same, no matter how many units of length we put together, the impedance is the same for any line length. Since the impedance is a function of reactance rather than resistance, the characteristic impedance does not represent a loss or a using-up of the energy. There are small elements of resistance and conductance that also play a role in forming the characteristic impedance of transmission lines, but line makers strive to keep these as low as feasible. These latter factors determine the basic loss per unit measure of a transmission line.

Second, we have two generally used types of transmission lines. (There are far more than two types, but most common applications in amateur radio and related areas of antenna work use only these two types.)

a. The parallel transmission line: the parallel line consists of two wires of constant and equal diameter with a constant spacing. To maintain constant spacing, line makers use various techniques, ranging from periodic non-conductive cross bars (ladder line) to molded coatings of special RF-rated vinyl (TV ribbon cable or "windowed" parallel line).

The insulating material between the wires, where the RF fields are most intense, creates a velocity factor (VF) for the line, so that the physical length of a wavelength of line is shorter than the electrical length of that line. Ladder line--using mostly air as the medium between wires--has a VF close to 1.0. Windowed lined, with a mixture of air and vinyl between the wires, may have a VF of 0.9 to 0.95. Ribbon cable, once widely used for TV antenna lead-in, has a VF of about 0.8.

Parallel line has the lowest inherent loss of the common transmission lines. Ladder line has the lowest loss of all. Therefore, as we use these lines in highly mismatched situations--with high SWR values on the line--the loss multiplier created by the SWR does not create significant total energy losses in the HF region.

However, we must install parallel transmission line free and clear of anything that might disturb the balance between the lines or penetrate the fields around the wires to couple energy to unwanted objects. This requirement is often the limiting factor in the use of parallel transmission line.

b. Coaxial cables: a coaxial cable consists of a center conductor and a surrounding conductive cylinder. Since the fields are wholly confined to the space between the inner wall of the cylinder and the outer surface of the center wire, the line is more immune to what occurs beyond the outer wall of the cylinder.

We often use braided wire for the outer cylinder of coaxial cables to obtain a flexible cable. However, the use of solid outer cylinder material has become common in VHF and UHF applications, with some HF uses.

Like any transmission line, we must maintain a constant spacing between the center conductor and the outer cylinder. The most common RF-rated plastics resulted in cables with a VF of about 0.66. Later foam insulating spacers raised the VF to about 0.8. The lowest-loss UHF solid-shell lines use spacers and an inert gas as the dielectric, with a VF between 0.8 and 0.9.

The losses of the best hard-shell coax lines rival those of ladder line. However, common coax lines have an inherent loss level much higher than that of parallel lines. In the HF region, the losses are largely a function of the limited current-carrying ability of the center conductor. As a result, the loss multiplier created by operating the lines at high values of SWR can result in significant loss of energy along the coaxial cable. The losses vary with frequency, increasing as we raise the frequency. And, of course, they increase with the length of the line.

Coaxial cables find their best uses in situations where the antenna feedpoint impedance--either naturally or as adjusted by a network at the antenna terminals--is a close match for the characteristic impedance of the transmission line. Where the impedance is highly variable, such as with a multi-band doublet or loop antenna, parallel transmission line is the generally recommended method of transferring power from the transmitter to the antenna. Parallel line, of course, usually requires an impedance transformation system, such as an ATU, at the transmitter end of the line, since transmitters tend to have output impedances that allow for only limited variation.

Varieties of Coaxial Cable

Most of us are familiar with only two varieties of coaxial cable: 50-Ohm cable and 70-Ohm Cable. However, coaxial cable comes in a variety of characteristic impedances (Zo). The following incomplete list samples the available possibilities.

Zo (Ohms)   **Cable Types (in ascending order of power capacity)**

35	**RG-83**
50	**RG-174, RG-58, RG-213 (RG-8)**
70-75	**RG-59, RG-11**
93	**RG-62**
125	**RG-63**

Many of these cable types are available in different versions, using solid or foam insulation and having different velocity factors. There are also additional cables, especially in the 70-75-Ohm region, that have only manufacturer numbers. The list shows no 70-Ohm cable as thin as RG- 174, but there are video cables in the 0.15" total diameter region that we can easily use for low power amateur applications in the VHF and UHF region.

There are also special versions of the common 50-Ohm and 70-Ohm cables with certain characteristics of interest to users. Maritime-rated outer jackets are available on some cables. As well, we can find outer jackets designed especially for burial. A number of new low-loss flexible cables have appeared on the market.

Some of the cables with special construction features require that we turn to a dealer who specializes in cables. As well, 35-Ohm, 93-Ohm, and 125-Ohm cables are sufficiently uncommon to require us to inquire with a dealer. The WireMan, Inc (of South Carolina) has proven highly reliable in my experience and carries in stock many of the uncommon cable that I have noted.

Series-Connected Coaxial Cables

There are applications in which we need a parallel transmission line that is shielded, that is, that is relatively immune to the unbalancing influences of very nearby conductive materials. For such applications, we can create a series-connected coaxial cable.

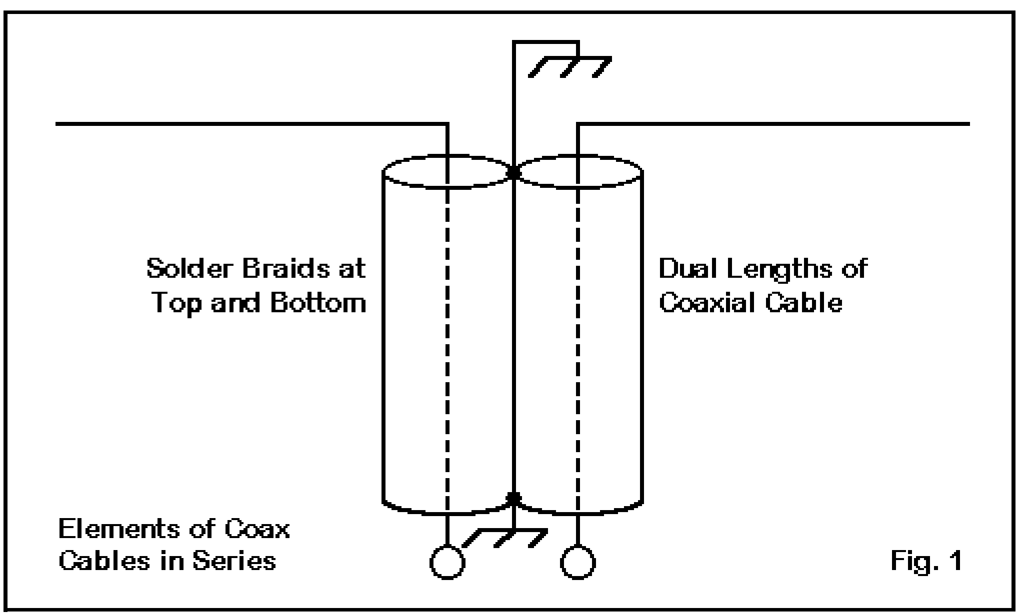
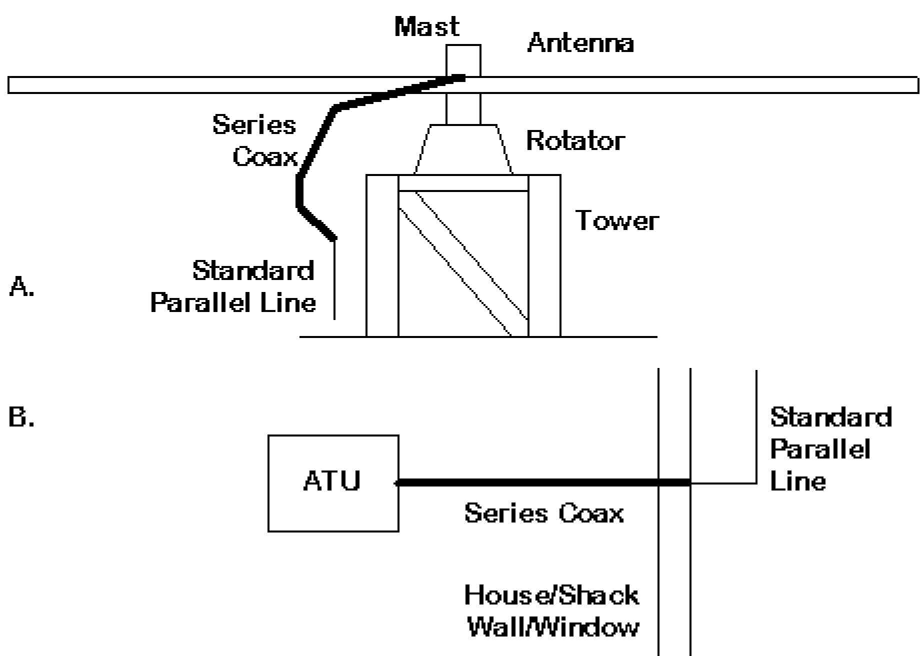


Fig. 1 shows the basic elements of a series-connected coaxial cable. In this application, we use the center conductors of two coaxial cables that run side-by side--to ensure that they are of the same length. We can separate the lines, since the currents and voltages on each leg of the line are functions of the center conductor and the outer cylinder. By connecting the outer cylinders (or braids) together at the top and bottom, each line will have comparable current magnitudes in opposite phases at each measurement point along the cable length. Many applications permit only

a ground connection for the braid at the lower end of the cable. However, if a grounding point is available at the upper end of the line, it is useful for sustaining the balance between the currents on the two center conductors.

The characteristic impedance of a series connected coaxial cable is twice the impedance of a single cable of the same type. However, the power rating will be about the same as for a single cable, since the current- carrying ability of the center conductors has not changed. However, in higher impedance situations--for which series cables are often used--the current level may be naturally lower than when the same cable is used in a well matched situation. On the other hand, the series cable may be used in highly mismatched situations, resulting in high peak currents resulting from the high SWR level.



Two Simple Applications
for Series Coaxial Cables

Fig. 2

Fig. 2 illustrates two common applications for series-connected coaxial cables. The top portion of the sketch shows a multi-band antenna calling for parallel transmission line. However, the metallic structure and the variable spacing created by the rotator require some insurance that the line's balance will not be disturbed. The sketch shows the use of series- connected coax used for the critical region, with standard parallel line used thereafter.

Since the series-connected coax section has a much high loss level than standard parallel line, we wish to use it only where necessary, with standard parallel line used wherever we can maintain it in a fixed and proper position relative to the tower or other objects. One European maker of a 2-element quad using a single driver for all bands uses the series-connected cable for the rotating driven element.

Perhaps the best cable for such applications is series-connected RG-63. The single-line Zo of 125 Ohms results in a 250-Ohm series-connected cable. The relatively high impedance makes the transition to and from 450-Ohm windowed or ladder line a small matter. Indeed, new users of transmission lines should be aware that there are no special losses created by linking two transmission lines of different Zo values. The new line simply encounters an impedance value at its terminals and proceeds in perfectly normal fashion to transform that impedance according to its own characteristic impedance.

The Wireman at last report had stocks of RG-63 that we can use for series-connected applications--and he was contemplating carrying a dual version with the outer jackets molded together for use as a shielded parallel line.

A second use for the same type of series connected cable occurs at the shack end of the line. Very often, there are innumerable metallic wires, conduits, and masses within our homes that make it nearly impossible for use to eliminate unwanted coupling from standard parallel transmission lines, even in the short distance between the wall and the ATU. We can turn to a section of series-connected RG-63 for the indoor run. Here, we should be sure to ground both ends of the shield to the master station ground system that goes to a deep ground rod in the shortest feasible distance.

Although "twin-RG-63" is perhaps the most versatile series-connected coax cable (or shielded parallel line, as it is sometimes called), some applications may call for a custom impedance value, such as 100 Ohms or 140 Ohms. **Fig. 3** illustrates one such application.

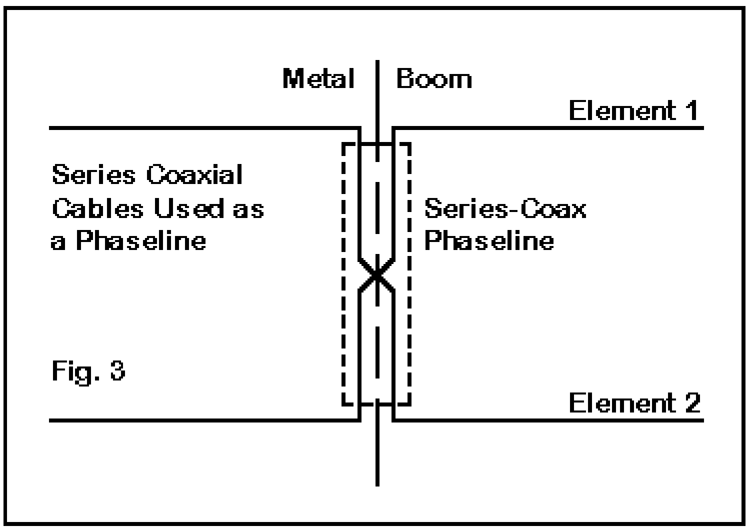


Fig. 3

The antenna represents a specifically designed 2-element horizontal phased array. The boom is metallic, so we might well encounter difficulties using an open-wire phasing line between the two elements. Since the array was designed to use a 100-Ohm phase line, series connected 50-Ohm coax cable neatly fulfills the requirement. In fact, the phaseline is run within the boom for weather protection, and the braids may be grounded to the boom at both ends. The system is currently being used on commercial phased arrays for 30 and 40 meters.

In all of these applications, designers are fully aware of two factors that may play a role in their use of series connected coaxial cables. First, is the velocity factor of the cable. It is not especially important in the applications in **Fig. 2**, but it is critical to the use of such lines in a phased array such as outlined in **Fig. 3**.

The second factor is the higher losses per unit of length of series- connected coaxial cable than of standard open-wire parallel transmission line. These losses are not significant in the short line length used in **Fig. 3**, but they do have a bearing on the applications shown in **Fig. 2**. In general, where series connected parallel line is used solely to avoid unwanted coupling to a parallel transmission line, we should use it only for those distances where the coupling may occur. Wherever we can control such coupling by proper installation of standard parallel transmission line, we should use that low-loss line.

Parallel-Connected Coaxial Cables

The use of parallel-connected coax cables of the same length normally involves cases where we need a cable of 1/2 the Zo of a single line of the same cable. Obviously, this opens up the door to having cables of some odd but useful characteristic impedances. Two 50s in parallel give us a 25-Ohm cable--a value not commercially available. Two 70s give us 35 Ohms, a value very useful in 1/4-wavelength matching sections. Two 93s give us 46.5 Ohms, again useful in matching sections. Two 125s give us 62.5 Ohms, once more useful in matching sections or as a main line.

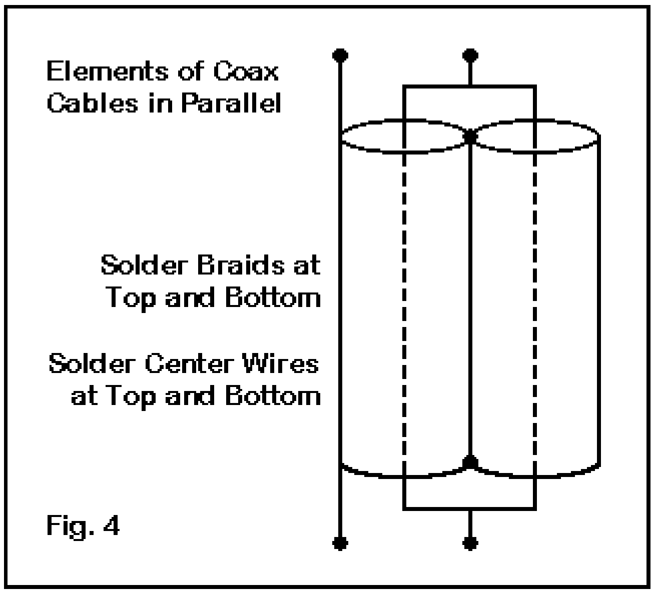


Fig. 4 provides data on how to hook up cables to achieve a parallel connection. The two center wires are soldered together at both ends. As well, the two braids are soldered together at both ends. If you are using RG-58 (50-Ohms) or RG-59 (70 Ohms), the two cables will--with proper preparation of the ends--fit inside the barrel of a standard coax male connector. You can seal the spaces with a non-reactive, non- conductive sealant--after everything is properly soldered.

However, consider using direct splices between the parallel coax section and any main cable to which you connect it. If you work in the VHF/UHF region, especially with small cables, you may be able to avoid the introduction of small reactances by using a carefully constructed direct cable splice. You can always strengthen the junction by adding some surface stiffening between the linked sections. Heat shrink tubing with a little epoxy inside (but not on the junctions of wires) can add strength to spliced thin lines.

Paralleled cables will provide roughly twice the power handling capacity of a single cable in the HF region. The surface area of the center wires is doubled. However, be sure to calculate your power limit for the new impedance and the current peaks that will be present at this impedance.

One of the main uses of parallel-connected coax cables is to form a 1/4- wavelength matching section with an impedance that is correct for the desired match. The ideal matching section impedance is the square root of the product of the input and output impedances. Here are a few examples of common matching section applications.

Antenna	Impedance	Line Zo	Match Section Zo
2-element Quad	**115**	**50**	**76 (use 70 Ohm cable)**
3-element Yagi	**25**	**50**	**35 (use RG-83 or paralleled 70-Ohm cables)**
2-element Yagi	**40**	**50**	**45 (use paralleled RG-62 sections)**
Dipole	**72**	**50**	**60 (use paralleled RG-63 sections)**

Fig. 5 illustrates the general matching section situation. The matching section--whether composed of 1 line or paralleled lines--is simply inserted between the odd antenna impedance and the main feedline, with center conductors connected and with braids or outer cylinders connected.

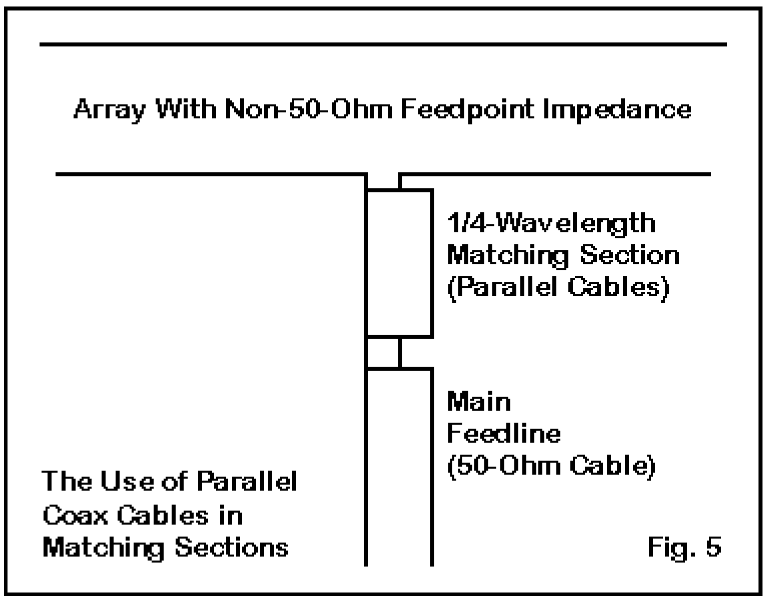
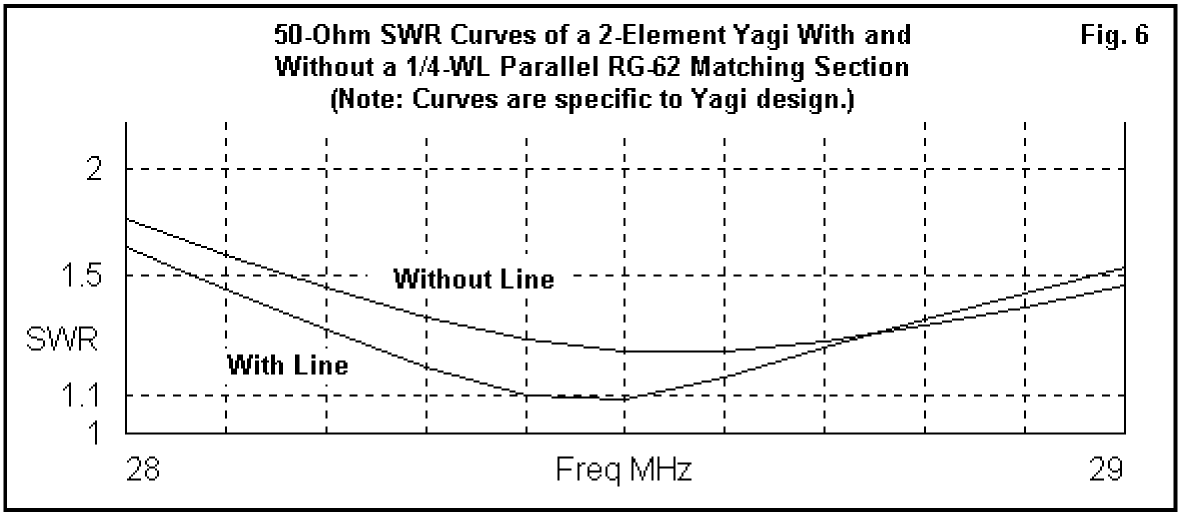


Fig. 5

Let's take an example that may be finicky. Suppose I had a 2-element Yagi with a feedpoint impedance of about 41 Ohms at mid-band. Such an array would give me under 2:1 SWR across the band. However, we can do a bit better. Let's make up a parallel section of RG-62 and make it 1/4 wavelength. The net impedance of the paralleled lines is 46.5 Ohms. At the design frequency, I obtain an impedance of about 52 Ohms. Moreover, the section helps my make the SWR curve more symmetrical across the operating passband. See **Fig. 6** for the relative SWR curves as they apply to a specific Yagi design.



Even though common practice tries to get away with minimal work, nothing in good engineering practice--except possibly excessive cost--says that I may not be as finicky as I desire. The symmetrical curve for the array with the section added will likely prevent an SWR sensitive rig or amplifier from reducing power at the low end of the band--if one needs a reason other than personal satisfaction for adding the section.

As noted in another item ("**When is a Quarter Wavelength Not a Quarter Wavelength?**), the sections that we add can be length-adjusted to provide the most desirable SWR curve for a given situation. Hence, we are not limited to using matching sections only when we have ideal input and output impedances to go with ideal paralleled coax matching sections. Antenna modeling software is perhaps the fastest way to adjust the length of "slightly off" sections so that we can effect the best possible match.

We can, of course, use paralleled coax as the main feedline for special situations. In some cases, we may wish to use the odd impedance values that happen to match an antenna to create feedlines that run all the way into the shack, where we might apply the final impedance transformation. The decision to use this option will depend on numerous factors, such as the losses in the lines that form our options, the weight of the paralleled lines relative to a single line, and the cost of the line.

In the End. . .

. . .both series-connected and parallel connected coaxial cables have a place in the array of transmission line techniques at our disposal. Careful measurement and fabrication go a long way toward making our use of them successful.

In the process of thinking about feedline needs, do not overlook some of the available lines other than the 50-Ohm and 70-Ohm lines we most often think about. The odd-values--either alone or in series or parallel combination--may provide just the characteristic impedance for a given job.