Inexpensive Hardline

Easy conversion of 75Ω CATV hardline for 50Ω systems.

by Edward Krome KA9LNV

Like many hams, I always look for new facets of the amateur radio hobby to explore. This exploration tends towards the higher and higher bands, especially the microwave bands, where wide ham allocations allow for experimentation with a variety of modes. This article describes an easy way to overcome one of the hardware hurdles in UHF and above operation—the expense of low-loss cable.

The Problem

My latest project has been Mode L operation on AMSAT-OSCAR-13. Mode L uses a 23 cm uplink and a 70 cm downlink. I recently built up equipment for the 1269 MHz uplink, but found the strength of my signal less than what I would like. I only have about 13 Watts of power and a single 45-element loop yagi on that band. This should be adequate, but that 13 Watts must actually be at the antenna feedpoint rather than in the shack looking at a lot of cable. At 23 cm, even the best "standard" coaxial cable is not very good. Good quality RG-8 has 10 dB attenuation per 100 feet and is almost unusable. Even Belden 9913, considered about the best available, gives almost 6 dB loss per 100 feet. Losing 6 dB means that only one quarter of what you put into the cable actually comes out 100 feet later. As anyone who has ever acquired 23 cm equipment will tell you, those are pretty expensive Watts to heat cable with!

Finding an Answer

Increasing signal strength boils down to either increasing the power out or decreasing antenna system loss. I decided to concentrate on line loss. My investigation of really good cable (such as ⅞-inch 50Ω Heliax, at almost $5 per foot with $55 connectors) left me cold. After all, my children do have to eat.

Soon, however, a readily available cable caught my eye—the ¾-inch diameter aluminum-jacketed hardline used for CATV. This cable has some great properties—it loses less than 3 dB per 100 feet at 1.2 GHz, and it's inexpensive (usually free or nominal). It has, however, two main drawbacks: it's a 75Ω line (which matches nothing commonly used in ham applications), and poses mechanical problems with its aluminum jacket and copper-coated aluminum center conductor that tax the ingenuity of the home-brewer. This article shows you how to overcome these two problems.

Where To Get CATV Cable

CATV companies buy this cable in huge rolls. Time economies and signal considerations mean that they will frequently either sell or give away roll ends too short for their use. These roll ends can be quite long by amateur standards—one I was given contained almost 500 feet of brand new cable! Polite inquiries with the local CATV companies are a good place to start.

Electrical Requirements

According to the *ARRL Handbook* and *Antenna Book* (Transmission Line section, any recent year), all you have to do to use cable of one impedance in a system of differing impedance is to match the two impedances with a quarter-wave impedance transformer. This is just a section of transmission line whose impedance is equal to the square root of the product of the two impedances you are trying to match, and cut to one quarter of the free space wavelength at the frequency of interest. That's all! In equation form, the required matching impedance Z_{im} is:

$$Z_{im} = \sqrt{50\Omega \times 75\Omega} = 61.2\Omega$$

So, in order to use 75Ω line in a 50Ω system, you must add a 61.2Ω impedance matching section to each end of the 75Ω line.

The *Handbook* also tells you how to construct a coaxial line. The impedance of an air-insulated coaxial line is determined by:

$$Z = 138 \log (ID/OD)$$

ID is inner diameter of the outer conductor, and OD is outer diameter of the inner conductor. Rearranging, for Z = 61.2Ω, any combination of tubing with an ID/OD ratio of 2.776 will provide the required impedance.

There's been a number of impedance converters published in amateur literature, but most use "non-standard" materials. "Standard" is what you can buy in a hardware store or plumbing shop. I devised a Z-matching device using a readily-available material—¾-inch copper pipe.

This copper pipe, in its most common form, is actually 0.875 inch in outside diameter and has a 0.032-inch wall. This yields a 0.810-inch inside diameter. Looking at the ID/OD requirements, the closest available standard hobby brass tube for an inner conductor is 9/32 (0.281)-inch diameter. Plugging these dimensions into the above formula gives an impedance of 63.4Ω. It's unlikely this variance from the actual requirements for a perfect impedance match would seriously degrade the performance. A purist could silver-plate the brass up to 0.292-inch OD and be exact.

You determine the length of the quarter wave section by the frequency desired. Since these devices are quite broadband, one length covers a given band. The 1296 MHz version, for example, works well on 1269 MHz. From the formula for free space wavelength, which also applies to air-insulated transmission lines:

¼ wavelength (feet) = 246 / F (MHz)

or

¼ wavelength (inches) = 2952 / F (MHz)

Interestingly, since 2 meters, 70 cm, and 23 cm are all harmonically related, and one quarter wave on 2 meters equals three quar-

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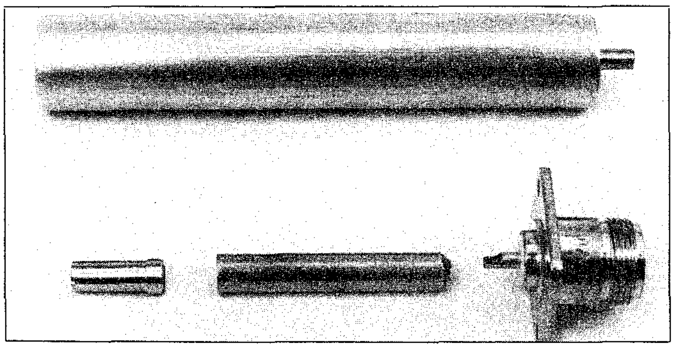

Photo A. Parts required for a single impedance converter. Note the spacer sleeve and outer shell (top row), and the center contact, center conductor with necked-down end, and the UG-58 (type "N") coaxial connector. The screw clamp is not shown.

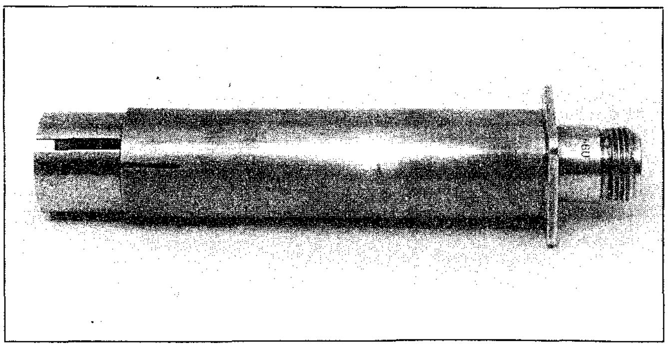

Photo B. Complete 23 cm impedance converter in process of being assembled to ¾-inch CATV hardline. Assembly will be complete when spacer sleeve is pressed in place between the outer shell and the hardline itself, and the screw clamp is installed.

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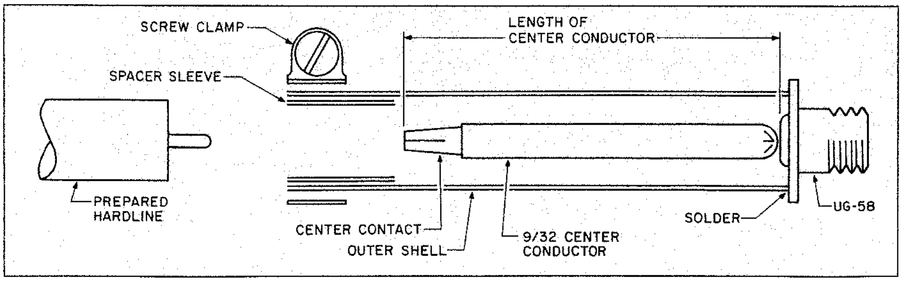

Figure 1. Cutaway of ¼ wave impedance converter, showing all parts of the completed unit.

ters on 432 MHz and nine quarters on 1296 MHz, you could theoretically use a single line and set of 2-meter impedance converters for all three bands. There are a few problems, however, with this "one line and matcher fits all." First, the more quarter wavelengths you use, the narrower the frequency response becomes, and the more likely that your impedance matching sections will become attenuators if they are not right on the money. Second, a single feedline precludes full-duplex crossband operation required for satellite work. Finally, at those frequencies, the cost of remote mounted antenna switching relays would far exceed the cost of separate feedlines!

Construction

The following construction plans appear to be the easiest 50Ω to 75Ω impedance matching arrangement to duplicate, using the most common materials I've run across. Although this project was originally intended for Mode L uplink use only, Table 1 includes dimensions for all popular VHF/UHF bands.

Parts

Build two identical units for each cable.

•Outer Conductor: Standard ¾-inch copper pipe, available at any plumbing supply house or hardware store. Insure that it actually measures ⅞″ (0.875″) outside diameter and has a 0.032″ wall thickness.

•Inner Conductor: Hobby brass tubing measuring 9/32″ (0.281″) outside diameter. Miscellaneous sizes of brass tubing and assorted shapes are available in many hardware stores and model shops. These are typically stocked in 12-inch lengths. Where longer pieces are required, buy two 12-inch lengths for each converter and slip a 4-inch length of the next smaller size inside, then solder them together. Be sure the assembly is straight.

•Coaxial Connector: You can get away with using the UHF type (SO-239) connector at 2 meters, although it is not ideal. At any higher frequency, always use high quality Teflon™ and silver N connectors, normally designated UG-58/U. These connectors cost $3–5 each new, but if you are going to go to the trouble of building equipment for these bands, it is false economy to use cheap connectors. Also, stay away from the inexpensive bright nickel plated ones, as they will corrode, and usually do not have insulators capable of tolerating the soldering heat required for assembling these impedance converters. It's depressing to watch the center melt and drop out of a connector as you attempt to solder the flange.

Good used UG-58s are widely available at hamfests and surplus outlets. A good cleaning in the dishwasher and the use of a used (soft) Scotch-Brite™ cleaning pad does wonders. Stay away from cleaning with steel wool, as you'll leave brass where silver used to be! Also, steel wool has the bad habit of leaving little electrically-conductive strands in the least noticeable places.

•Center Contact: Since the center conductor of the CATV hardline is copper-coated aluminum, you will need some form of finger connector for positive contact. The most elegant solution I have seen was published by Bill Olson W3HQT in his ">50" column for *QEX* magazine in March, 1988. Bill used the double female center pin removed from a UHF "T" connector, cut in half to provide two sets of fingers for two impedance converters that just fit the hardline center conductor.

•Miscellaneous:

Silver hobby solder. This is a high-strength, low-temperature solder available at most hardware and hobby stores. Silver solder resists corrosion in outdoor service, and is reputed to provide better conductivity to RF than its ordinary lead-tin relative. It has separate solder and flux.

Hose clamps. Use stainless steel, screw types. One for each impedance converter.

Hand tools. Include a tubing cutter, hacksaw, small triangular file, and small steel square for alignment. Also, a small pencil torch is much easier to use than a regular propane torch.

No Al Ox™, or similar compound for preventing corrosion between the aluminum outer jacket of the hardline and the copper impedance converter. Available at electrical supply houses.

A **soldering and assembly fixture**, made by drilling an 11/16-inch hole, ¾ inch deep in a wood board. Not absolutely necessary, but sure beats trying to hold a hot connector in your fingers.

Parts Preparation

•Center Contacts:

Disassemble the UHF T connector by grasping the male connector center pin with vise grips and unscrewing it counterclockwise. Drive the double female center conductor out of the end of the connector. Note that some T connectors have a slight crimp on one end, so gently drive the pin out the opposite end. Discard all pieces except the double female pin. Saw the double female in half to make two center contacts, one for each end of your hardline system.

Fit the end of the contact opposite the fingers to the 9/32 center conductor tube. It may well be a perfect, tight fit. If not, turn the outside diameter of the solid end to fit the 9/32 tube tightly. It is best to use a lathe, but you can do a satisfactory job by chucking the pin in the chuck of a drill clamped in a vise and "turning" it with a file. When clamping the contact in the drill chuck, slide it in far enough for the jaws to contact the solid part, not the fingers. Be careful. Turning down a 1/16 to ⅛-inch length is adequate since the contact and the center tube conductor will be soldered together. Set the prepared pins aside for later assembly.

•Center Conductor:

One end of the 9/32-inch tube center conductor must be necked down to the ⅛ inch diameter of the solder pin on the UG-58. Do this before you cut the tube to length, so that if you goof, you can cut the end off and try again.

First, clean the tube and insure that one end is square. Scribe a mark around the tube 3/32 inch from the end. Then, cut eight equally spaced slots in the end of the tube to the 3/32 line. With the small triangular file, file each slot slightly to create eight equal fingers that each taper to about 1/16 inch at the outer ends. Remove all burrs. Gently bend each finger inward a little at a time until you have a ⅛-inch hole in the center. Be patient. Check the fit on the center pin of the UG-58. When you are satisfied, clean and tin the end lightly with the silver solder and flux.

Now assemble the UG-58 and the center conductor. Place the connector, threaded end down, into the hole in the "assembly fixture." Tin the connector pin. Heat the necked-down end of the center conductor and slip it over the connector pin, then solder the two together. While the joint is still hot, use the steel square to insure that the center conductor is perpendicular to the flange of the connector in all planes. Hold the piece until it cools.

Next, lay the previously-prepared center contact pin next to the soldered center conductor and connector assembly. Measuring from the insulator on the UG-58 out to the end of the center contact pin fingers, set the overall length to that required by the frequency of interest. Mark the center conductor tube so that, when cut and pressed together with the center contact pin, it will be the right length. Cut the 9/32 tube. Clean and deburr the end. Put some flux on it and press the center pin into the end of the tube. Recheck the overall length, then solder. Remove all traces of flux with alcohol.

•Outer Conductor:

Standard ¾-inch copper pipe with its 0.032″ wall is almost exactly 0.065″ larger than the outside diameter of the jacket on the ¾-inch hardline. So, we need to prepare a spacer sleeve to match the two diameters. First, square one end of a piece of copper pipe, then clean and deburr it. Now, with a tubing cutter, cut off a 1-inch long section. This length will be the spacer sleeve. Now mark and saw a ¼-inch wide section lengthwise from the side of this sleeve. Deburr the cut, then compress the sleeve evenly until it will just start into the end of the uncut copper pipe.

Clean the uncut outer conductor and remove the ridge left by the tubing cutter from the inside end Slot the end of the pipe in 4 places, to ½ inch from the end of the tube. Deburr.

Cut the outer conductor to length with the tubing cutter as specified in Table 1 for the band desired.

•Final Assembly:

Stand the previously-prepared center section on end in the hole in the "assembly fixture." You will soon be glad that you made this fixture. Lightly flux the flange of the UG-58 and the unslotted end of the outer conductor. Stand the outer conductor on the flange and center it. Look in the opposite end of the assembly and insure that the center contact pin is well aligned in the center of the outer conductor. If not, this is your last chance to fix it. When alignment is correct, heat the outer conductor and flange until the flux bubbles, then touch the solder to the surfaces. When the heat is right, the solder will flow between the parts. Use enough solder to get a strong, complete bond between the parts. Do not disturb the assembly until it cools. Then, clean all flux away with alcohol. The converters are now complete and ready for assembly to the hardline.

Frequency (MHz)	Length of center conductor. (inches)	Length of outer shell (inches)
144	20.5	21⅝
432	6.83	8
902	3.27	4⅜
1296	2.27	3⅜

Table 1.

Hardline Preparation

Completely install the hardline without the impedance converters. Keep any bends as large as possible. To avoid kinking the line, I have found it helpful to cut radius forms from wood, and then bend the line over them. A 10-inch radius seems adequate.

Cut the hardline with a hacksaw. Then score the aluminum outside jacket with the tubing cutter back ½ inch from the end. Grasp the end of the hardline jacket with pliers and rock it gently to break the jacket at the score. Remove the end section of the jacket. Cut through the foam insulation to the center conductor with a sharp knife, flush with the end of the outer jacket. Do not nick the center conductor. Twist and pull off the section of insulation, then scrape the center conductor clean but do not damage the copper coating. Trim the end of the center conductor to protrude ⅜ inch beyond the foam insulation. Round the end with a file.

Clean the outside of the aluminum jacket with a Scotch Brite pad and alcohol. Since copper and aluminum clamped together are subject to galvanic corrosion (and aluminum oxide is a dandy insulator), lightly coat the newly cleaned aluminum surface with No Al Ox.

Assembly

Start the split copper spacer sleeve into the slotted end of the impedance converter outer conductor. Slide the impedance converter over the prepared hardline, insuring that the hardline center conductor enters the center contact pin. Slide them together as far as possible. The end of the contact pin should butt against the hardline dielectric. Then tap the spacer sleeve between the two surfaces until it is flush with the slotted end of the outer conductor. Secure with a hose clamp. That's all it takes! Be sure to waterproof the assembly for outdoor use.

Performance

While I lack access to the equipment required to accurately measure return loss, experiments with a directional coupler indicate no perceptible difference in SWR whether the measurement is taken at the input or output end of an assembly of two impedance converters and 50 feet of 75Ω CATV hardline. In practice, they work great. I use this arrangement on 144, 432 and 1296 MHz. On 23 cm, the bandwidth is broad enough to make no performance difference between use on 1296 terrestrial and 1269 satellite. And the reduction in line loss on Mode L satellite uplink is so dramatic that it has made a signal that was, with 13 Watts into 50 feet of Belden 9913, barely readable on SSB, to a quite satisfactory signal.

This simple project is bound to save you many dollars on low-loss transmission line cable. Good luck! 73