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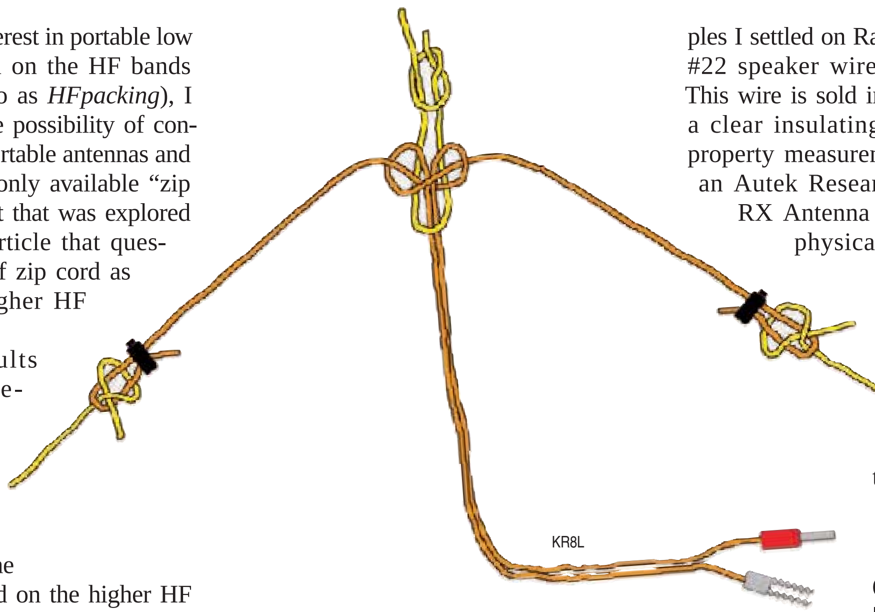
Zip Cord Antennas and Feed Lines For Portable Applications

Don't let lack of real transmission line keep you off the air!

William A. Parmley, KR8L



Because of my interest in portable low power operation on the HF bands (often referred to as *HFpacking*), I decided to look into the possibility of constructing lightweight, portable antennas and feed lines using commonly available "zip cord."[1] This is a subject that was explored previously in a *QST* article that questioned the usefulness of zip cord as a feed line for the higher HF bands.[2]

Although my results are in general agreement with the earlier tests, I believe I can show that with the proper selection of material and careful deployment, feed line losses can be minimized on the higher HF bands, making zip cord dipole and feed line combinations satisfactory performers. This is especially true for portable, low-power operations in which some compromise may be acceptable in the interest of saving weight and bulk. Other potential uses for this type of antenna and feed line combination might include ARRL Field Day or a "stealth" situation in which the operator needed an easily stowed antenna that could be erected quickly whenever she wanted to operate. Of course, this would also make an ideal addition to an emergency operations *Go Kit*.

My plan was to use zip cord as a half-wavelength feed line so that the dipole's impedance would be repeated at the transmitter end of the feed line. The impedance terminating a feed line is repeated every half wavelength. Please see any edition of *The ARRL Antenna Book* for more discussion.[3] Because of this, the characteristic impedance of the feed line would be of secondary importance. Also, because the resulting feed line would be relatively short, losses would be minimized. This meant that I would not be able to erect the dipole at "optimum" height, but since the goal of this project was to create light weight, compact, pocket sized antennas and feed lines that could be used in the field with temporary supports, antenna height was not a primary consideration.

After testing a couple of different samples I settled on RadioShack No. 278-1385, #22 speaker wire as a likely candidate. This wire is sold in 100 foot rolls and has a clear insulating jacket. All electrical property measurements were made using an Autek Research Model VA1 Vector RX Antenna Analyst. Formulas and physical property information were taken from *The ARRL Antenna Book*, *The ARRL Electronics Data Book*[4] and the *VA1 Instruction Manual*. I made an effort to characterize the wire as completely as possible, as discussed below.

Table 1

Measured Velocity Factor

Frequency (MHz)	*Velocity Factor (VF)*
3.31	0.68
6.75	0.69
13.67	0.70
27.77	0.71

Table 2

Calculated Attenuation of Zip Cord Compared to Small Coax, dB/100 feet

Frequency (MHz)	*RS 278-1385*	*RG-174*	*RG-58*
3.31	0.97	2.7	0.8
6.75	1.48	3.3	1.2
13.67	2.39	4.0	1.6
27.77	3.41	5.3	2.4

Characteristic Impedance

This is a property that I could not measure directly with the VA1, although I was able to make some calculations and educated guesses.

To begin I measured the center-to-center distance (S) between the conductors of RadioShack No. 278-1385 speaker wire as 0.082 inches, and found the conductor diameter (d) of #22 wire listed in *The ARRL Electronics Data Book* as 0.0253 inch. For parallel conductors with air dielectric the characteristic impedance is given by:

$$Z = 276 \times \log(2S/d)$$

or

$$Z = 276 \times \log(2 \times 0.082/0.0253) = 224\ \Omega$$

Again, this is for an air dielectric. The plastic insulation on the wire should reduce the characteristic impedance by some amount, and although I didn't have a way to measure this effect I did come up with a way to estimate it. Here's where the "educated guess" part comes in.

First I did a similar calculation for nominal 300 Ω twin lead, yielding a result of about 400 Ω, meaning that the polyethylene insulation must reduce the calculated

[1]Notes appear on page 36.

value by a factor of about 0.75. *The ARRL Antenna Book* says that for an insulated line, the characteristic impedance can be calculated by multiplying the "in air" value by the inverse square root of the dielectric constant for the particular insulation being used. For polyethylene the dielectric constant is 2.3, so the adjustment factor should be about 0.65. However, with typical 300 Ω line the insulator is very thin so that the field between the conductors is only partially in the insulation and partially in air. It seemed reasonable that the adjustment factor (0.75 in this case) would fall somewhere between pure insulation (0.65) and pure air (1.0).

The type of insulation used on the RadioShack speaker wire isn't specified, but I made the assumption that it is polyethylene or a similar material (this seemed safe since many plastics have a similar dielectric constant of about 2.3). In addition, since the insulation between the conductors of the speaker wire is thicker (perpendicular to the plane containing the two wires) than the insulation for 300 Ω twin lead, it seemed reasonable that it must have a greater influence on the characteristic impedance since more of the field between the conductors will pass through the insulation and less through the air. Based on all of this I assumed that the adjustment factor for the characteristic impedance would probably be closer to 0.65 than to 0.75, so the characteristic impedance for this line might be:

$Z = 224 \times 0.65 = 145.6$, or about 150 Ω.

Again, this value is not particularly important, but keep it in mind and we will use it later to estimate line loss.

Velocity Factor

The velocity factor (VF) of the line was measured using the VA1. The technique involves shorting the end of the line, then sweeping the instrument over a range of frequencies to find the lowest impedance at several points. The lowest frequency will be the frequency at which the line is a half wavelength, the next will be two half wavelengths, etc. The velocity factor can then be calculated by the ratio of the physical line length to the value of a half wavelength in vacuum at the particular frequency (given by the formula $L = 492/f$, where L is in feet and f is in MHz). The results for my roll of No. 278-1385 speaker wire near four amateur bands are shown in Table 1.

Since I planned to build my antennas mostly for the 20 meter band and above, I chose to use 0.70 as the velocity factor of this line. (I could just as well have said that I picked 0.70 because it is a round number or because it is approximately the average of the four readings. I think these results are

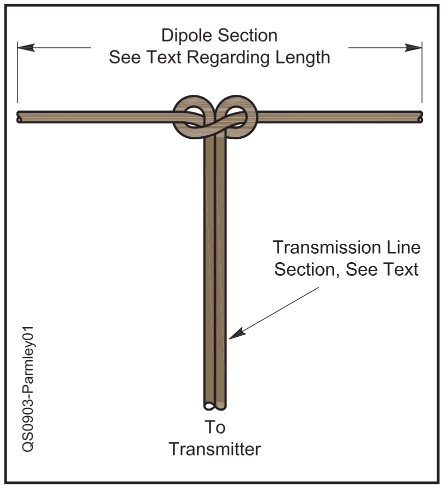


Figure 1 — The center of the antenna section can be secured with an electrician's (or underwriter's) knot as shown.

amazingly consistent considering the use of a consumer grade handheld instrument. There is only a 4% variation in measured velocity factor over a frequency range of about an order of magnitude.)

Attenuation

The attenuation or line loss was also measured using the VA1. For this calculation the series of minimum impedance measurements taken during the frequency sweep (see Velocity Factor, above) were applied to the following formula from the *VA1 Instruction Manual*:

Loss = $8.69 \times Z_{MIN}/Z_0$, where Z_0 is the characteristic impedance of the line.

The calculated loss is given in Table 2. Values for RG-174 and RG-58 (as read from the log-log graph in *The ARRL Antenna Book*) are listed for comparison.

Now, let's think again about how I planned to use this feed line (a single half wavelength between transceiver and antenna). As the frequency increases so does the loss, but the length of a half wavelength of feed line decreases. As a result, the feed line loss remains less than 1 dB as we go up in frequency. In fact, the loss of a half wavelength line decreases from about 1 dB at 80 meters to about 0.5 dB at 10 meters.

If the estimate of a 150 Ω characteristic impedance is correct, then the SWR on the line will be about 3:1, which introduces at most an additional 0.7 dB of loss (as read from the graph of mismatched line loss in *The ARRL Antenna Book*). Total feed line loss would then be about 1.5 dB, and certainly less than 2 dB. As you can see from the table, the line is slightly more lossy than RG-58. It is closer in size and flexibility to RG-174 and is much less susceptible to damage from bending and rough handling than is coaxial cable, an important consideration given the intended use. It might be reasonable to make the feed line a full wavelength long on the higher bands in order to increase the antenna height. Whether the increase in height would offset the increase in feed line loss probably depends on the individual installation.

Construction

Having characterized the wire as completely as possible I next wanted to check my calculations by building and testing some examples. First I calculated the antenna length using the formula $L_A = 234/f$ and then calculated the feed line length using the formula $L_F = (VF) \times 492/f$. I used the quarter wavelength formula for the dipole since the wire was going to be "unzipped" to form the two halves of the antenna and applied the standard 5% reduction in length for "end effects." I used the half wavelength formula for the feed line multiplied by the measured velocity factor. A single piece of speaker wire of length $L = L_F + L_A + X$ was then cut, where X had a couple of feet added to the length for margin of error. The feed line length (L_F) was measured and marked, and the remainder of the wire, including the extra length, was unzipped to make the dipole section. An electricians' knot (see Figure 1) was tied at the junction of the dipole and the feed line.

At the transmitter end of the feed line I unzipped the wire a couple of inches and attached a banana plug to one side and an alligator clip to the other. The banana plug fits perfectly in the center conductor of a transceiver's SO-239 coax connector, while the alligator clip makes a convenient way to attach to the transceiver's ground connection (as shown in Figure 2). I completely ignored the issue of feeding a balanced load with an unbalanced source here, but if you think about it, this is not an uncommon practice for simple wire antennas, and hams have been doing this kind of thing for ages. We're just more accustomed to seeing this where the feed line (coax) meets the antenna (dipole) than where the transceiver meets the feed line. For low power (QRP) applications I have not found this arrangement to be a problem. For those who are concerned about this, a few turns of the transceiver end of the feed line can be wound through an appropriate toroidal core to make a 1:1 transmission line transformer. I did test the transformer configuration briefly and found no difference in performance, feed point impedance or SWR.

For the initial setup of the dipole I measured and marked the calculated antenna length on each leg and folded the wire back on itself at this point and taped it in place. Later I found that a spring compression cord

Figure 2 — Rear of radio showing banana plug and clip lead connections.

Figure 3 — Self contained station using a zip cord antenna and feed line.

stop of the type found on drawstrings on jackets and other items of clothing worked much better than tape, especially when the length of the dipole legs needed to be adjusted. These should be available in most fabric stores. In addition to shortening the dipole while leaving the option of lengthening it without subsequent splicing and soldering, I found that this technique created a convenient attachment loop at the end of the wire. Finally, I tied a piece of light nylon line to the loop on each end of the dipole (no other insulator was used) and proceeded with deployment and testing.

Deployment and Testing

After building antennas and feed lines for 30, 20 and 17 meters, the initial testing was done by installing the antennas in an inverted V configuration with the apex at about 20 feet. This was done using either a telescoping fishing pole, or by tossing a line over a tree branch and pulling the dipole up with that. The ends of the dipole were brought down to 6 to 8 feet off the ground and tied off with nylon line that was then tied to tent stakes. The dipole was pruned to resonance using the VA1 by changing the fold point at the end. The extra wire was left in place and was not trimmed off. The 20 meter and 17 meter antennas were also tested as indoor dipoles by attaching the apex to a ceiling lamp and taping the ends to the walls with masking tape. In this configuration they were easily tuned to resonance.

In practice I found that once the antenna was tuned to resonance it was possible to adjust and optimize the feed point impedance by changing both the horizontal and vertical angles between the two legs. In my particular outdoor installation the best match was found with the dipole legs arranged at a horizontal (azimuthal) angle of between 90 and 120°. For indoor applications the feed point impedance was found to be adjustable by changing the amount of droop in the legs, proximity to walls or floors, and the angle between the legs. As should always be done with parallel wire feeders, I made an effort to keep the feed line clear of other objects and equidistant from both legs of the dipole to the maximum extent practicable.

Conclusion

I have used these antennas and feed lines for SSB, CW and PSK31 at QRP power levels in indoor, backyard and backpack portable situations. Figure 3 shows a self contained portable station. Portability is excellent, deployment is simple and on-air performance seems to be very good. As noted in the original article by K1TD, some zip cord may be significantly more lossy than the type that I used, so it is important to make measurements before committing to a particular type. (One sample I tested, an example of #24 speaker wire, was at least as lossy as the wire that Jerry used.) If you want to try building your own zip cord antennas and feed lines I suggest spending some time with *The ARRL Antenna Book*, particularly the chapters on transmission lines and Smith charts. This will enhance not only your understanding but also your enjoyment of this project.

Notes

[1]Information about HFpacking is available on the Internet at **hfpack.com**.

[2]J. Hall, K1TD, "Zip Cord Antennas — Do They Work?" *QST,* Mar 1979, pp 31-32. This was reprinted in C. Hutchinson, K8CH, Editor, *More Wire Antenna Classics Volume 2.* Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 7709. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[3]R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[4]*The ARRL Electronics Data Book* is out of print.

Photos by the author.

Bill Parmley, KR8L, was first licensed in high school, then dropped out of Amateur Radio while in college and the military. He was licensed again in 1979 and upgraded to Amateur Extra in 1981. He is an ARRL member. His interests range from QRP on 160 meters to meteor scatter on 222 MHz and from CW to digital voice. Bill has a Master's degree in physics from Michigan State University. He served as a nuclear submarine officer in the US Navy, and has worked as a nuclear engineer for several electric utilities, and as a safety engineer, project manager and program manager for the US Department of Energy. Bill and his wife Anne, KA8TER, are now retired and enjoy living on the small southern Illinois farm where he grew up. You can read more about his Amateur Radio interests and activities at **kr8l.us***, and you can contact him at 1123 Country Club Rd, Metropolis, IL 62960 or at* **kr8l@kr8l.us**.

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