Introducing an Improved Version of *Transmission Line for Windows* Software

A popular piece of ARRL software gets a makeover.

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The ARRL Laboratory team conducted balanced line tests outdoors at ARRL Headquarters in Newington, Connecticut.

For many years, *Transmission Line for Windows* (*TLW*) has been one of the PC software programs provided on the CD-ROM that comes with *The ARRL Antenna Book*.[1] The CD includes many useful antenna-related programs, as well as the contents of the book and *EZNEC* models of many of the antennas described in the book. In addition, a special version of *EZNEC* can run all of those models.[2] The CD is such a valued resource that many argue that the price of the book is really for the CD, with the comprehensive book as a free bonus!

I can state that among all the programs and data on *The Antenna Book* CD, I find *Transmission Line for Windows* (*TLW*) to be the program that I use the most. *TLW* painlessly allows you to enter an impedance value that can be obtained from measurement, antenna modeling, or just inferred from an SWR or measurement or analysis of conditions at either end of a transmission line. The program then displays the complex impedance at the other end, along with and including the effects of line loss (see Figure 1) depending on your chosen feed line, length, and frequency. With the results *TLW* provides, you can design an antenna system or an antenna tuner. Not only that, *TLW* also painlessly designs an antenna tuner (your choice of topology) that will match the load to 50 Ω, calculates the tuner loss, and specifies the voltages and currents on all the components! (See Figure 2.)

The Need for an Update

The version of *TLW* that has been included in the recent edition of *The ARRL Antenna Book* was last updated in 2006 by the original programmer and (now retired) *Antenna Book* editor, R. Dean Straw, N6BV. The transmission lines it supported included 22 specific types of 50 Ω coaxial cable, five types of 75 Ω coaxial cable, one type of 93 Ω coaxial cable, and unspecified balanced transmission lines including 300 Ω twinlead, 450 Ω window line, and 600 Ω open-wire line. In addition to the built-in line models, there is a capability to specify a "user-defined transmission line," in terms of characteristic impedance, velocity factor and attenuation characteristics versus frequency. While this seems like a lot of choices, it came up a bit short on the increasingly popular balanced transmission lines, especially window line, which is available in multiple wire sizes and characteristics. The prior version only offered a generic "450 Ω window line" choice.

Of even more importance, ARRL International Member Steve Hunt, G3TXQ, performed an independent analysis that

[1]Notes appear on page 40.

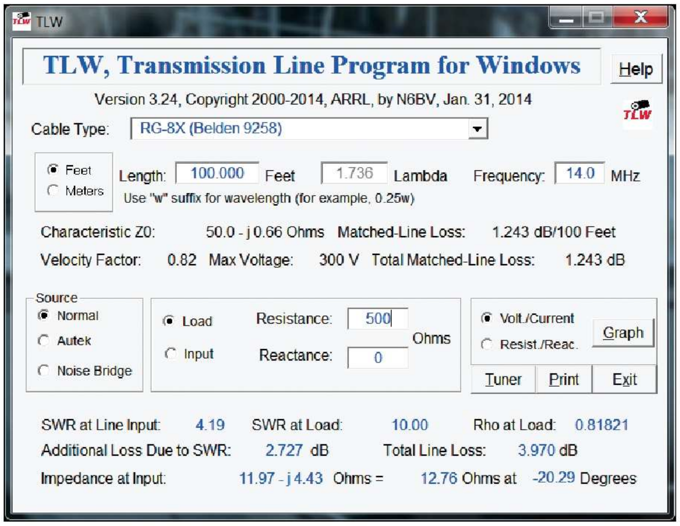

Figure 1 — An example of a *TLW* transmission line analysis. In this case, a 100-foot length of RG-8X is terminated with a resistive load of 500 Ω (10:1 SWR) on 14 MHz. Along the lower portion is displayed the impedance seen at the bottom — note the transformation of the impedance — as well as the loss of the mismatched line. If you have data taken at the bottom of the transmission line, just click the INPUT button rather than the LOAD button and enter the data. Clicking the TUNER button will allow the software to design an antenna tuner to match this load.

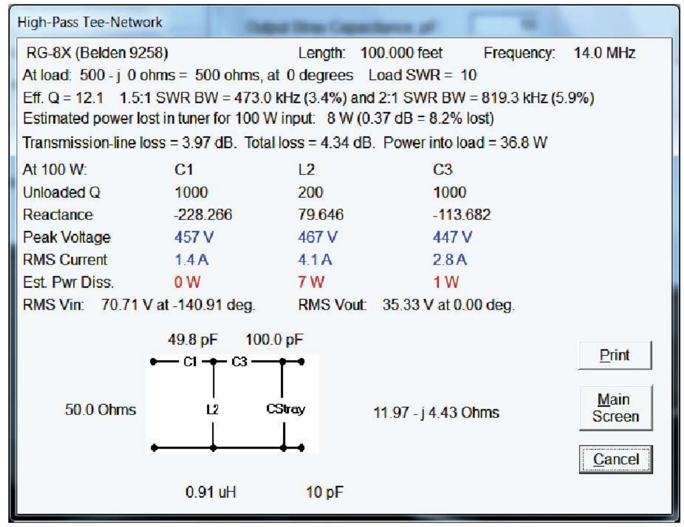

Figure 2 — Clicking the TUNER button (seen in Figure 1) results in a choice of tuner configurations (L-network, pi-network or T-network). Here we selected a high-pass T-network and a power of 100 W. *TLW* designs the tuner in this configuration to match the 11.97 –*j*4.43 Ω at the bottom of the transmission line to the 50 Ω needed by most transceivers. In addition to specifying the components needed, *TLW* shows the stress on each, and the loss through the tuner.

indicated that the loss predicted for the balanced lines by *TLW* was optimistic. *TLW* predicted a loss that was even less than the loss contributed by the ac resistance of the copper itself.

The loss calculations in *TLW* are based on curve fitting to published data, which is a very reasonable approach for coaxial cables that are associated with detailed data determined by the manufacturers and included in their specifications. Unfortunately, that kind of precise data for balanced transmission lines is generally not available. Instead, the balanced transmission line data used by *TLW* was extracted from measurements reported in early ARRL publications that turned out to be somewhat inaccurate.

Dean Straw, N6BV, graciously agreed to reexamine the balanced line calculations with new measurements performed by the ARRL Laboratory. The Lab obtained multiple specific transmission lines from manufacturers and conducted tests in a carefully controlled environment. The test team was led by ARRL Laboratory Test Engineer Bob Allison, WB1GCM, and supported by Senior ARRL Lab Engineer Zack Lau, W1VT, and ARRL EMC Engineer Mike Gruber, W1MG. The results they obtained were consistent with Steve Hunt's, G3TXQ, analysis, as well as some sample testing that he conducted independently.

With the new data in hand, Dean proceeded to update the software to our new version, which includes two specific 450 Ω types of window line — Wireman #551, composed of #18 AWG solid copper clad steel, and Wireman #554, composed of #14 AWG, 19 strand, copper clad steel conductors. In addition, the 300 Ω twinlead is now specified as a tubular type composed of #20 AWG wire and the 600 Ω open-wire line is specified as having #12 AWG conductors. In addition to providing more accurate results, this presentation will allow users to better relate the results to the lines they are actually using. For a line that is somewhat different, they have specific cases are included from which to extrapolate.

How Much of a Difference Are We Talking About?

The difference between the predicted window line attenuation from the earlier (2006) version of *TLW* and the newly released (2014) version of *TLW* obviously depends on which type of line you were actually using and the way you were using it. Tables 1 and 2 compare the earlier version's results to the revised version's results

Table 1
Comparison of Attenuation (dB) of 2006 *TLW* Results to 2014 *TLW* Results for 1:1 SWR, Coax and Window Line (WL — including two types, 554 and 551, in 2014) and Open-Wire Line (OWL)

Frequency (MHz)	RG-8X Coax 1:1	WL 1:1 2006	#551 WL 1:1 2014	#554 WL 1:1 2014	OWL 1:1 2006	OWL 1:1 2014
3.5	0.560	0.045	0.130	0.088	0.032	0.032
14	1.243	0.099	0.254	0.180	0.069	0.069
28	1.852	0.146	0.355	0.259	0.101	0.102
50	2.584	0.203	0.470	0.350	0.140	0.140

Table 2
Comparison of Attenuation (dB) of 2006 *TLW* Results to 2014 *TLW* Results for 10:1 SWR, Coax and Window Line (WL — including two types, 551 and 554, in 2014) and Open-Wire Line (OWL)

Frequency (MHz)	RG-8X 10:1	WL 10:1 2006	#551 WL 10:1 2014	#554 WL 10:1 2014	OWL 10:1 2006	OWL 10:1 2014
3.5	1.972	0.179	0.498	0.344	0.128	0.128
14	3.952	0.490	1.161	0.852	0.345	0.345
28	5.243	0.699	1.543	1.174	0.494	0.499
50	6.368	0.935	1.926	1.505	0.660	0.660

for a number of representative cases. All data is for 100-foot lengths that can be scaled to different lengths if desired. Note that nominal "450 Ω" window line actually has characteristic impedance closer to 400 than 450 Ω. The "matched impedance" value of the model is about 405 Ω for the 2006 version and close to 403 Ω for the 2014 version. For the 10:1 SWR mismatched case, 1⁄10 of the model Z_0 was used as the terminating impedance. For comparison, the attenuation of traditional 600 Ω open wire line and popular RG-8X, 50 Ω coax is also shown. Note that the values for previously unspecified 600 Ω open wire line match those of the #12 AWG open wire line in the new version.

What This Means

First, we should reiterate that there has been no change to the way *TLW* handles coaxial cables. Because these have been based on solid data from manufacturers, they are as good as they have been in the past. With window line the story is a bit different, depending on your perspective. For a length of window line that is matched to its load, the difference comes down to tenths of a decibel in most cases. That may seem significant on a percentage basis, but not in terms of its effects on radio communications.

For mismatched window line, however, the difference is indeed significant. For many years ARRL publications have stated that mismatched window line exhibits *less loss* than matched coax. In light of this new information, it is now more accurate to say that mismatched window line has loss that is *comparable* to that of matched coax. This is probably not too dramatic a change, but those who use window line in the presence of SWR higher than 10:1 should probably reassess their options, including improved impedance matching and/or shifting to open-wire line.

Note that this change not only has impact on the results from *TLW* analysis, but also applies to the tabular and graphical data for balanced lines that has appeared in both *The ARRL Antenna Book* and *The Radio Amateur's Handbook* for many years. Needless to say, the next editions will include corrected data.

On a personal note, for some years I have been successfully using a 135-foot center-fed Zepp as my main antenna on most bands. With the exception of an excursion to a 12:1 SWR on 40 meters, it has a 400 Ω SWR of less than 10:1 on all bands from 80 through 6 meters, and is much easier to deal with than 10 separate matched dipoles. I'm still happy with my decision.

The ARRL Offers Special Thanks

We are particularly appreciative of the efforts of Steve Hunt, G3TXQ, for bringing the balanced line attenuation disparity to our attention and especially for his patience in working with us on demonstrating the nature and extent of the problem. Our thanks to R. Dean Straw, N6BV, for his willingness to depart from his well-earned retirement in order to tackle this problem and execute a very positive solution in short order. Also, special thanks to the ARRL Lab team, who despite being fully booked, made extra efforts to obtain the data needed to allow this version to come to fruition.

Update Your Version of *TLW*

The files needed to update your recent (*The ARRL Antenna Book*, 20th edition or newer) version of *TLW* to the latest version are available to anyone who owns a CD from *The ARRL Antenna Book*. The "TLW3V3.24.zip" file can be downloaded from the *ARRL Product Notes* web page, **www.arrl.org/product-notes**, and are also the *QST* in Depth section of the website at **www.arrl.org/qst-in-depth**. In order to provide all the features of the software, you will need to save the new version 3.24 "TLW3.exe" file to the same directory that held your earlier version in order that it has access to the various support files. Also included in the package is a revised set of documentation. If you haven't tried it before, I hope you will find *TLW* as useful as I have.

Notes

[1] *The ARRL Antenna Book,* 22nd Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 6948. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[2] Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

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