Documentation for TLA.EXE Program
Version 2.02, August 16, 1998
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OVERVIEW

For those of you who may be familiar with the older TL program, TLA, Version 2.02 incorporates eight new functions:

(1) You may reverse the sense of load/input of the known impedance -- that is, the impedance can be specified at either the load or input end of the line.

(2) The Z and SWR may be entered from an Autek RF-1 RF Analyst or a Noise Bridge may be used.

(3) You may now change the unloaded Qs for both the inductor and capacitor(s) in an antenna tuner, and the transmitter power level as well -- up to 5 megawatts!

(4) You may change the resistance seen at the input of an antenna tuner to other than 50 ohms. This allows you analyze, for example, the currents, voltages and losses both for a tube-type amplifier pi-network or a solid-state pi or tee-network.

(5) You may now specify transmission-line length in meters or feet -- or in wavelengths, which is then converted to feet or meters. The unit of feet or meters is stored to a file called TL.DEF so that you needn't keep entering it for subsequent operations.

(6) TLA also stores in TL.DEF the values you enter using the #16 choice ("other" cable) from the main menu. The reactive part of the cable's characteristic impedance is automatically computed, although you may override the value manually.

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(7) The 1.5:1 and 2:1 SWR bandwidths for a tuner configuration are shown, along with the Effective Q of the tuner. This gives you an indication of how narrow a bandwidth the tuner design itself implies.

(8) The stray output capacitance for a tuner network with a series output reactance is taken into effect. The amount of stray can be changed by the operator.

Version 2.02 fixes a bug when using units of meters in Menu #16, "Other Transmission Lines." The program either refused to let the operator enter a value for matched-line attenuation or else computed the X0 component of the characteristic impedance wrong. This version also fixes an error in the matched-line attenuation for 450-ohm "windowed" ladder line that gave overly pessimistic values.

THE TLA PROGRAM

"TLA" is short for "Transmission Line, Advanced." The TLA program started out as "TL," short for just "Transmission Line." TLA has been under development, intermittently, for about 7 years and has developed into a sort of "Swiss Army Knife" for transmission lines and antenna tuners.

TLA will complete a computation in a fraction of a second on a powerful modern microcomputer, like the 100-MHz Pentium machine I am using now to write this documentation file. It takes about five seconds to work on an ancient 8088-based 4.77 MHz PC, with an 8087 numeric coprocessor installed. Roughly the same amount of time is needed for a 33 MHz 80486SX computer (with no numeric coprocessor.) TLA employs a lot of heavy-duty math, so a numeric coprocessor is extremely desirable.

The program is entirely character-based for output display. Hence any IBM-PC compatible computer will work with TLA. Hitting [Shift] [Print Screen] will print out a TLA screen on any printer that recognizes the 8-bit IBM character set. (You may have to set your printer for this manually.) TLA is a DOS program, although it works properly under all versions of Windows.

TLA displays everything in color. If for some reason you use <Ctrl>C or <Ctrl>Break to exit the program, you will be left in DOS, with a messy blue background. Either type CLS [Enter] or MODE=CO80 [Enter] to restore the screen to normal.

USING TLA

TLA is menu-driven and is reasonably "friendly." However, I must assume that the user has some technical knowledge about transmission lines and antenna tuners. The user must be familiar with the so-called "rectangular representation" of complex impedance, in the form Z = R +/- j X. Later in this file there are two tables of typical impedance data for several types of antennas. You can use this data with TLA to experiment with realistic situations and to gain familiarity with the program.

You boot up TLA once you have entered the subdirectory containing TLA.EXE, the executable file. You do this using the CD [change directory] command in DOS. Once there, Type:

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TLA [Enter]
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THE OPENING SCREEN

The opening screen shows a menu of the various types of transmission lines TLA models. The first eight choices are flexible coaxial cables, with "RG" designations and where available Belden part numbers. Choices 9 through 12 are Hardline coaxial cables. Choices 13 and 15 are for two-wire balanced transmission lines, such as 300-ohm transmitting line, 450-ohm "window ladder line" or 600-ohm wire line.

Choice number 16 is for "other" transmission lines not found on the main menu. For this choice, the user manually enters the resistive part of the characteristic impedance, the matched-line loss (in dB/100 feet), the velocity factor and the maximum rms voltage for which the line is rated by its manufacturer. The program automatically computes the value of the reactive part of the characteristic impedance, which you can override if you like, although it doesn't make a lot of sense to do so, since the first characteristics determine the reactive portion.

The values for choice number 16 are stored in the TL.DEF file, so that once you enter your own values for a particular type of transmission line, you needn't manually enter them the next time you choose number 16.

Choices 1 through 15 use the parameters listed in Chapter 24 of the 18th edition of The ARRL Antenna Book, including the values for matched-line attenuation versus frequency, found in Fig 22, on page 24-16. (Note that the matched-line loss for 450-ohm "window" ladder line has been revised to have the same slope as #12 open-wire line, from the second printing of the 17th Edition onward.)

If you merely hit the [Enter] key, TLA will select the default value of "4," meaning RG-8A/RG-213, 50-ohm cable solid-dielectric cable. In most data entry points in TLA, there is a default value, indicated by square brackets and highlighted in red; e.g., [4] in the main menu. Merely hitting [Enter] will select the default value automatically.

TLA will then prompt you for the length of the transmission line, in feet. The default value is zero feet -- this is useful when evaluating antenna tuners by themselves, without an intervening transmission line between the tuner and the load.

Note: From the main menu you may select "S" for Special to change the default from feet to meters. TLA writes this information to disk in the TL.DEF file so that it boots up with your desired unit of measurement.

Note also that you may now enter the transmission-line length in wavelengths. The program automatically converts the value to either feet or meters, taking into account the velocity factor of the chosen line. To enter a length in wavelengths, append a "w" immediately after the length. For example, to specify a quarter wavelength, type:

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.25w
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followed by [Enter]. The length of an electrical quarter-wave of line (in feet or meters) will be used by the program for all subsequent computations. The physical length will remain constant even if you change frequency. This makes it easy to evaluate the effects of shorted quarter-wave stubs, for example.

Next, you will be prompted for the operating frequency, in MHz. The default is 3.5 MHz, selected as usual by hitting the [Enter] key without entering anything else. You can enter any frequency as high as 5000 MHz (5 GHz), or as low as 0.02 MHz (20 kHz). After you hit [Enter], TLA will compute and display the matched-line loss for the chosen line. The matched-line loss is for a load equal to the resistive part of the characteristic impedance for the particular transmission line chosen and for the length of line and the frequency chosen.

ENTERING THE IMPEDANCE

Next, TLA will prompt you to enter the resistive part of the load impedance, in ohms. If you don't enter a number, but simply hit the [Enter] key, TLA will automatically enter a resistive value of 0.00001 ohms. (It doesn't enter zero ohms, because that would result in embarrassing "divide by zero" problems later on.)

You may specify "R" to reverse the sense of input/load impedance entry, or you may specify "A" for computation of the complex impedance from data provided by an Autek RF-1 RF Analyst or "N" from a Noise Bridge. Note that the on-screen prompt will change when you key in "R", changing from:

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Resistive part of impedance at load:
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to

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Resistive part of impedance at line input:
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You may either enter the value of resistance and reactance measured at the shack-end of a transmission line and compute the impedance at the load, or vice versa, toggled by "R".

After you hit [Enter] for the resistive part of the load impedance, you will then be prompted to enter the reactive part of the load (or input), again in ohms. Note that an capacitive reactance must be preceded with a "-" (minus) sign. Merely hitting [Enter] will enter a reactance of zero ohms, the default value.

USING THE AUTEK RF-1 TO DETERMINE THE IMPEDANCE

At the prompt to enter the resistive part of the impedance, you may choose "A" to enter Autek RF-1 data. TLA will ask you first for the magnitude of the impedance Z, and then the SWR measured by the Autek RF-1. Since the magnitude of Z and SWR are both scalar quantities, TLA cannot determine the sign of the reactance, only its magnitude. TLA will prompt you to choose either plus (the default) or minus.

You will choose the sign of the reactance based on your knowledge of what the load actually is. Note that certain lengths of line will reverse the sign -- this includes any odd multiple of a quarter wavelength of line. For example, assume you are using 128 feet of RG-213 to feed your 80-meter dipole, which is resonant at 3.800 MHz. (The electrical length of the line is 3/4 wavelengths = .75 x 984 / 3.8 MHz x 0.66, where the 0.66 is the velocity factor.) The feedpoint impedance of a typical 80-meter dipole is somewhere about 50 ohms, with no reactance at resonance. Assume that you want to determine the feedpoint impedance at 3.750 MHz.

Since this frequency is lower than resonance, there will be some capacitive reactance at the feedpoint. Assume for now that the feedpoint impedance at 3.750 MHz is 48 - j 20. If you enter these values directly, TLA computes the impedance at the input of the line (that is, down in the shack) as 43.73 + j 14.78. Note that the sign of the reactance has been reversed by the fact that the electrical length of the line is close to 3/4 wavelengths. You will have to use your own judgement to choose the correct sign of the reactance when using an instrument such as the Autek RF-1 at the input side of the line.

Continuing with this example, assume that your Autek RF-1 shows Z = 46 and SWR = 1.4 at the shack end of the line. When you enter these values into TLA at 3.75 MHz using the "A" Autek entry mode, TLA computes the impedance as 43.7 +/- j 14.5. In this case, you would choose "+", since you must reverse the sign of the reactance due to the impedance inversion of that length of line. Now, TLA computes 48.34 - j 19.80 up at the antenna, very close to the value of 48 - j 20 we chose in this example.

You should see that the number of decimal points that TLA computes (two) are not justified by the amount of decimal points (one) that the Autek RF-1 computes SWR or Z. Computers programs are wonderful, but they are only as good as the data fed to them!

USING A NOISE BRIDGE TO DETERMINE THE IMPEDANCE

If you have chosen "N" to use Noise Bridge data, TLA will prompt you for the shunt resistance and then the shunt capacity (in pF) that you read from the Noise Bridge. If the shunt capacity is negative (meaning that the unknown impedance is inductive), enter the capacity value preceded with a minus sign, since "negative picoFarads" indicates inductance on these types of bridges. A capacitive reactance need not be preceded with a "+" (plus) sign, although you may enter one if you wish.

Not all Noise Bridges are calibrated in shunt values. For example, the units in late issues of the ARRL Handbook are calibrated in series impedance at 10 MHz. However, I built the Noise-Bridge function into TLA because my own unit uses shunt values.

The Noise Bridge routine in TLA also can compensate for the series resistor I sometimes must use to bring the unknown impedance into the range of my noise bridge's shunt capacitor, particularly on the lower frequencies. I often must use a series 100-ohm adapter on 80 or 40 meters, where the range of capacitive reactance of the variable capacitor is small.

TLA DOES ITS THING

After you finish specifying the impedance, TLA will go through its computations. It will present you with a screen showing the information you entered, plus the SWR at the load, followed by the SWR at the input of the transmission line. In general, the two SWRs will be different. If the line is very lossy or the SWR at the load is very high, the difference between the two SWR values may be significant, with the lower value at the input of the line. Measuring the SWR at the input of a lossy line with a high SWR at the load will mask the magnitude of the SWR at the end of that line, and may possibly lull you into complacency as you measure the SWR in the shack.

The next line on-screen shows the additional loss in the line due to the SWR at the load, followed by a line showing the sum of the matched-line loss and the additional loss due to SWR. This is the total loss in the transmission line.

On the next line down, TLA displays the transformed impedance at the input of the transmission line, both in rectangular (R +/- jX ohms) and polar coordinates (magnitude in ohms, phase angle in degrees). The resistance and reactance are shown to two decimal places, as noted above in the Autek discussion.

Continuing on down the screen, for 1,500 W of rf into the input of the line, the maximum RMS voltage along the line is displayed, along with the distance from the load where the peak voltage occurs. Note that transmission lines are rated by their manufacturers in terms of RMS voltage. TLA displays the rms voltage rating for the particular transmission line chosen, for comparison. At the bottom of the screen is a prompt to choose the next action -- the default is [T], for antenna Tuner.

CAVEATS

I must again caution you at this point. TLA displays results out to two, or even three, decimal places. Internally, computations are carried out to even more decimal places. In the real world, the one factor that varies the most in actual transmission lines is the Velocity Factor. This may easily vary plus or minus 10% for typical lines -- in fact, the velocity factor may even vary slightly for two pieces of cable cut from the same bulk roll! Along with the Velocity Factor, the exact value for the characteristic impedance Z0 also varies.

TLA will give you a good indication of what you can expect in the real world, but only plus or minus the velocity factor and the actual impedance at the antenna feed point! Please remember: TLA is fundamentally an educational tool. It can also be used very effectively as a design tool, provided that you know the exact parameters of your transmission lines and your antennas. If TLA helps open your eyes about transmission lines and antenna tuners, particularly the losses associated with each, then I will have achieved my goal in writing it.

OTHER INTERESTING THINGS

TLA can show a negative value for SWR when the load impedance is very highly reactive and inductive: for example, a 1.5 + j 1800 ohm load on a 95-foot long, 450-ohm line at 1.9 MHz yields a computed SWR of -670.03. This is certainly nonintuitive, but it is correct and it has no physical significance. What is happening is that TLA computes that the reflection coefficient is larger than 1.0, yielding the negative value for SWR.

EVALUATING ANTENNA TUNER CONFIGURATIONS

If you now select either "T" or [Enter], TLA will erase the screen and then display the Antenna Tuners menu. It is very important to realize that TLA's antenna tuner is assumed to be located in the shack, at the input end of the transmission line feeding the load. Presumably, the load is an antenna. (After all, putting the antenna tuner out at the antenna would result in a trivial computation for TLA, since the tuner would match the Z0 of the transmission line going to the shack, yielding a 1:1 SWR!)

You select one of four different configurations:

1 = Low-Pass L-Network
2 = High-Pass L-Network
3 = Pi-Network
4 = Tee-Network

A shortcut: from the screen following the main menu (showing the SWRs and losses in the transmission line) and from each antenna tuner screen, you may bypass the Antenna Tuners configuration menu by choosing directly "1", "2", "3" or "4", corresponding to the number of the desired antenna tuner network, followed by [Enter]. This is particularly useful when you want to quickly compare the efficiency of different tuning network configurations, one after another.

Choose one of the antenna-tuner configurations. For either high-pass or low-pass L-networks, TLA will immediately compute all values, using default unloaded Qs of 200 for any inductor and 1000 for any capacitor. (You may alter these values if you like from the Default (D) selection in the Antenna Tuners menu. See below.) The inductor is usually, but not always, the most lossy component in an antenna tuner. The default value of Q = 200 is pretty typical for a practical inductor mounted in a metal case.

The model for a lossy inductor is an inductive reactance in series with a loss resistance. For example, if the unloaded Q is 200 and the inductive reactance at the chosen frequency is +400 ohms, then the loss resistance is 2 ohms in series with the +400 ohms reactance (Q unloaded = 200 = 400/2).

TLA assumes a default value of 1000 for the unloaded Q of any capacitor, although the operator can change this too. Again, the model for a lossy capacitor is the capacitive reactance in series with a small loss resistance. The default value of unloaded Q = 1000 is typical of transmitting air-variable capacitors with wiping contacts.

If you choose either the Pi-network or Tee-network, you will be prompted to enter the value (in pF) of the output capacitor in the network. For the pi-network the default value is 500 pF, and for the Tee-network configuration the default value is 100 pF.

Once you have entered the necessary information, TLA will compute all component values needed to transform the impedance at the antenna tuner output to 50 ohms (or to a value of resistance you choose). If the chosen network configuration cannot perform the desired transformation, an audible alarm will sound, and TLA will either recommend another network or another output capacitor value to try. If TLA cannot match a particular load with any value you enter for the output capacitor, you can still escape back to the Network menu by hitting "N."

THE ANTENNA TUNER SCHEMATIC SCREEN

Examine the antenna tuner schematic screen carefully -- a LOT of information is displayed there. At the top of the display, there is a summary of the transmission line parameters chosen: the frequency, the type of line, and the length of the line. On the next line the impedance at the load end of the line is displayed, in both rectangular and polar forms, as well as the SWR at the load end of the line. This SWR is usually computed for 50 ohms, although if you change the input impedance at the tuner's input, let's say to 200 ohms, the SWR shown on this line will change appropriately.

Look carefully at the on-screen schematic of the network you chose. The impedance at the output terminals of the tuner (i.e., at the input end of the transmission line) is shown at the right side of the schematic drawing. (This is a departure from earlier versions of TLA or TL and was changed because I sometimes became confused in the old method!)

TLA shows something called the "Effective Q," also known commonly as the "loaded Q" of a network. This is the loaded Q in the network at the specified load impedance, and is an indication of how "touchy" the tuning will be. The higher the effective network Q, the more carefully you must tune the variable capacitor(s) and/or variable inductor in the tuner in order to achieve the desired transformation.

Thanks to Frank Witt, AI1H, this line shows the computed 1.5:1 and 2:1 SWR bandwidths for the tuning network itself, calibrated in kHz and in percentage of the tuned frequency. Here, the load is assumed to be constant and the frequency is shifted internally to compute the bandwidth numbers. If the computed bandwidth is greater than 30% of the center frequency, TLA will display "Large" rather than a value in kHz. Note that real-world antennas are very often narrowband devices, and the antenna -- not the tuner -- sets the limits for how far you can change your frequency without retuning the antenna tuner.

The loss in an antenna tuner is also closely related to the effective network Q -- the higher the effective network Q, the higher will be the loss. Efficiency in an L-C network is defined as:

Efficiency (%) = 100 x (1 - (QL/QU))

where QL is the loaded Q, and QU is the unloaded Q of the network components. See page 13.7 of the 1995 ARRL Handbook for more details on this subject.

For a given network loaded Q ("effective network Q" in TLA), components with higher unloaded Qs will result in lower tuner losses. This makes intuitive sense, especially if you recall that "Q" stands for "Quality Factor," and higher unloaded Qs mean higher quality, less lossy components.

CHANGING DEFAULT VALUES

In TLA you may change the antenna-tuner default values for five parameters:

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(1) the unloaded Q of the inductor(s)         [default = 200]
(2) the unloaded Q of the capacitor(s)        [default = 1000]
(3) the transmitter power                     [default = 1500 W]
(4) the resistance seen at the tuner's input  [default = 50 ohms]
(5) the stray shunt capacitance at the output [default = 10 pF]
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Note that the stray shunt capacitance in item (5) is only used when the tuner configuration has a series element (either inductor or capacitor) at the output terminals.

You may change the defaults after TLA has finished its first tuner computation or directly from the Antenna Tuners menu screen. You enter "D" from one of the tuner screens to change the Default values to what you like.

Follow the on-screen prompts. As usual, hit [Enter] to use the default value shown on-screen. Once you have changed any default values, they will remain in effect until you either reboot TLA or respecify the values from within TLA, using "D" as above. Just for your information, I've limited the maximum amount of power from the transmitter to 5 MegaWatts. I suspect that limit won't affect too many of you.

Note that default item number 4) above allows you to experiment with tuner configurations. You might, for example, use a wideband impedance transformer, such as a 50:200 ohm balun at the input of a tuner. This way to may see if the physical component values for various loads are more practical than for a 50-ohm input, the default value. Another use is given in detail below -- evaluating a pi-network tank circuit in a transmitter.

Note that a change to these tuner defaults is not saved to disk. However, the change remains in effect until you exit from TLA.

TUNER LOSSES, DETAILS

Examine the line showing the estimated power loss in the tuner. The loss shown is computed for the level of transmitter power you specify from the "D" prompt, as explained above. The loss is expressed in watts, in dB, and also as a percentage of the power at the input. For example, a particular tuner configuration might lose 114 W out of 1,500 W put into it, yielding a loss of 0.34 dB, or 7.44% of the input power. If the input to the tuner is 100 W, rather than 1,500 W, the loss would still be 0.34 dB, or 7.44% of 100 W = 7.44 W.

The next line on-screen summarizes the amount of loss in the transmission line itself, plus the total loss in the line and the antenna tuner, both expressed in dB.

STRESSING THE TUNER

Now examine carefully the table for the individual components in the antenna tuner. The reactances for each element are shown first, followed by the peak voltage, the RMS current, and the power lost. Each is computed for the value of transmitter power you specify. (Note that the reactances are displayed to three decimal points, so that the purists among you may take these numbers and manually verify that the program is working the way it should. I too used this data to verify the program myself during development.)

Note that the voltage shown by TLA is the peak voltage across each component. Pardon the pun, but this is potentially a little confusing, especially where a series element is concerned. What is shown is not the voltage from the element to "ground" (the common terminal); it is the voltage across the component itself. In addition, the current shown is that flowing through each component, but here the current is the rms value, because this is what heats up a component.

Exceeding the peak voltage rating across any component in a tuner will probably cause an arc. This may or may not be disastrous, depending on whether the arcing component develops a permanent "carbon track" or not. Exceeding the rms current-carrying ability for a component will often result in smoke, due to the excessive amount of power dissipated in that element. The inductor in a tuner will sometimes melt because of excess power dissipation.

This occurs most frequently with low-resistive loads, with or without a high reactive component. For example, you can simulate a stressful situation by specifying a load impedance of 3 + j0 at 3.5 MHz, for a Tee-network configuration having a 100 pF output capacitor. For the full amateur legal power level of 1,500 W, the insulation of the shunt inductor will not only have to withstand almost 10,000 V peak, but worse yet, it will have to dissipate almost 650 W of power at more than 18 A of circulating current. Toasted coil, if it doesn't arc first, which deserves the term "zapped," I suppose.

TLA allows you to play around with various impedances, unloaded Qs and different network configurations, without having to endure the smoke and arcing that occurs in many tuners, even ones supposedly rated to handle a "full gallon" of rf. Now, for fun, increase the size of the output capacitor in the Tee-network and/or increase the unloaded Q of the inductor to help unstress the beleaguered antenna tuner in the example above -- or change to a lower-loss configuration than the Tee-network.

Now, let's try something really dramatic. At a frequency of 3.5 MHZ, enter a value of 0.00001 ohms for the resistive part of the load (this is the default value when [Enter] is hit by itself), with a reactance of zero ohms. Then select the Tee-network, with an output capacitor of 100 pF. The tuner will absorb all 1500 W of input power -- in other words it tunes up wholly into itself, given a short at the output!

In general, L-networks will exhibit the least loss among the various network configurations, but they often require awkward values for inductance and capacitance. The Tee-network configuration is often used because it can accommodate a wider range of impedances with practical values of variable capacitors and inductors, albeit with sometimes disastrous internal losses. The pi-network configuration is flexible, but it too will often require very large values for capacitors.

TLA AND TRANSMITTER OUTPUT PI-NETWORKS

TLA has another useful feature built into it that allows you to evaluate the capabilities and losses in a pi-network used at the output of a vacuum-tube power amplifier. You can change the default input resistance seen at the input of the network from the 50 ohms most commonly used for an antenna tuner to the desired loadline resistance needed for a tube or transistor. For example, an 8877 power tube wants to see a load of about 2200 ohms for a plate voltage of 3100 V. You would change the default from 50 to 2200 ohms in TLA, as explained above.

Now, following the recommendations in the ARRL Handbook, you want to achieve an effective network Q between 12 to 15 in order to ensure adequate suppression of harmonics. At a frequency of, let's say, 29.7 MHz, with a 50-ohm load at the output of the pi-network tank, TLA tells you that an output capacitor of 500 pF (the default value) yields an effective network Q of 33.1. This will result in good harmonic suppression, but it will also result in excessive losses, burning up 290 W in the tank circuit at 1500 W into the tank circuit. It's obvious that we need to lower the network Q.

An output capacity of 200 pF at 29.7 MHz will lower the network Q to 15.2, but now the required value of the capacity at the input of the pi-network is only 32.6 pF. The plate capacity of the 8877 is about 15 pF, and there will inevitably be stray capacity of at least 10 pF. This means that the minimum value of the tuning capacitor must be less than 7.6 pF in order to achieve the desired overall capacity of 32.6 pF. This is a tough requirement, especially for an air-variable capacitor that is used on 80 or even 160 meters too! Further trials with TLA will result in a compromise, although you may still find it necessary to use an expensive vacuum-variable capacitor to achieve a low minimum value.

FEEDBACK, PLEASE

This is where TLA stands. In a very complex program like this, I'm sure people will find bugs. I'd really appreciate detailed feedback concerning any problems found. My e-mail address at ARRL HQ is n6bv@arrl.org.

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APPENDIX A -- TRANSMISSION-LINE LOSSES

Several years ago I wrote sidebars to two QST "New Ham Companion" articles by Steve Ford, WB8IMY. These dealt with the stresses on transmission lines used with multiband center-fed dipoles. The computed losses, for both RG-213 coax and for open-wire transmission lines, raised some eyebrows -- and some hackles. Some people were astonished at how high the transmission-line losses could be when an extremely high SWR was involved -- such as when an 80-meter dipole was used on 160 meters, an octave lower than its resonant frequency.

After much debate and correspondence, I revised the loss algorithm in several versions of the older program TL. In October, 1995, Frank Witt, AI1H, and Scott Townley, NX7U, kindly provided me with more information on the true nature of the complex characteristic impedance. This was incorporated into TL and now TLA. After all the changes, the losses for severe SWR cases are close to what the original TL computed, but they are more exact nonetheless!

Now, the loss computations very closely match the calculated examples for truly severe mismatches in the book "Reference Data for Radio Engineers," published by Howard W. Sams and Co. The examples, on page 22-11 of the Fifth Edition, were for RG-218 (old type RG-17), terminated at 2.0 MHz with a 0.4 - j 2000 ohm load. This is about what an unloaded mobile whip would look like in the absence of ground-related losses. A 124-foot long RG-17 line would have more than 35 dB of loss with this load, and a 24-foot long piece would dissipate almost 20 dB.

APPENDIX B

Below are listed some sample impedance data you may use to play with using TLA.

SAMPLE TEST DATA

100-foot long, center-fed dipole, 50 feet over ground with dielectric constant (relative permittivity) of 13, conductivity of 5 mS/m. Computed by NEC2 for flat-top configuration.

Freq. MHz	Feedpoint Impedance
1.83 MHz	4.5 - j 1673 ohms
3.8 MHz	39 - j 362 ohms
7.1 MHz	481 + j 964 ohms
10.1 MHz	2584 - j 3292 ohms
14.1 MHz	85 - j 123 ohms
18.1 MHz	2097 + j 1552 ohms
21.1 MHz	345 - j 1073 ohms
24.9 MHz	202 + j 367 ohms
28.4 MHz	2493 - j 1375 ohms

66-foot long, center-fed inverted-V dipole, apex at 50 feet high over ground with dielectric constant of 13, conductivity of 5 mS/m.

Freq. MHz	Feedpoint Impedance
1.83 MHz	1.6 - j 2257 ohms
3.8 MHz	10.3 - j 879 ohms
7.1 MHz	64.8 - j 40.6 ohms
10.1 MHz	21.6 + j 648 ohms
14.1 MHz	5287 - j 1310 ohms
18.1 MHz	198 - j 820 ohms
21.1 MHz	103 - j 181 ohms
24.9 MHz	269 + j 570 ohms
28.4 MHz	3089 + j 774 ohms