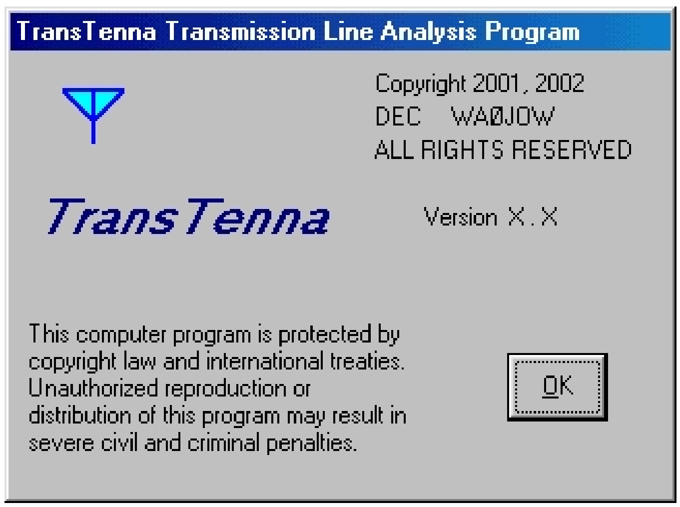
Transmission Line Analysis Software



Software Installation and Operation Manual

Don Cochran WAØJOW
21826 Gardner Rd.
Spring Hill, KS 66083
(913) 856-4075

Manual Revision 0

Table of Contents

1. Introduction

This manual provides instructions for the installation of the program, a description of the operation of the program and an explanation of the tools and other features provided.

TransTenna is transmission line analysis software specially designed for amateur radio applications using the popular SWR analyzers available from several manufacturers. It performs impedance transformation on a transmission line. It allows antenna/load measurements of series resistance and reactance (R and X) to be made at the receiver/transmitter end of the transmission line rather than directly at the antenna/load end of the transmission line.

This is achieved by making the measurements at the receiver/transmitter end of the transmission line using the SWR analyzer and then entering the measured values into the TransTenna program. TransTenna will perform the calculations to determine the series resistance and reactance (R and X) at the antenna/load end of the transmission line. The calculations made by the program take into account the transmission line characteristics including length, velocity factor, characteristic impedance and cable loss. The resulting calculations are presented as series resistance and reactance (R and X) and include the SWR at the antenna/load end of the transmission line.

This technique of making the measurements at the equipment end of the transmission line allows antenna analysis to be made with the antenna in its operating location and not affected by the operators presence in close proximity to the antenna or by surrounding structures which may be required in order to allow the operator direct access to the antenna feed point for a measurement. Even lowering the antenna to a height where the feed point can be reached from the ground will yield different results once the antenna is raised to its final height due to the effects of the proximity of the ground and other objects.

Measurements can be made at any time there is a need to analyze the antenna without regard for weather or time of day.

TransTenna is not limited in use with any specific instruments and may be used with any type of equipment capable of providing the series equivalent resistance and reactance (R and X) at the receiver/transmitter end of a transmission line. A calculator is also provided for use with instruments which give only Impedance and SWR measurement data. This calculator will determine the equivalent series resistance and reactance (R and X) for use by the TransTenna program.

TransTenna uses the general transmission line equations and its accuracy is limited only by the accuracy of the data entered by the operator. In effect, TransTenna provides an easy to use alternative to the Smith Chart for transmission line analysis.

2. System Requirements

PC with a 486 processor or better.

Microsoft Windows 95 or latter operating system or
Microsoft Windows NT version 4.0 or latter operating system.

8 MB of RAM.

Hard disk space required: 3 MB.

CD ROM or 3.5 inch floppy disk, determined by supplied TransTenna media.

VGA or higher resolution monitor.
640 by 480 pixels minimum resolution.

Mouse or compatible pointing device.

3. Program Installation

Installation of TransTenna is performed using a setup wizard very similar to other Windows based programs. As newer operating systems are released, the exact installation details and terminology can vary slightly. The following details apply to Windows 95/98. Other operating systems are similar.

TransTenna can be supplied on 3.5 inch floppy disks or a single CD ROM.

For 3.5 inch floppy disks:

Insert Disk 1 in the floppy disk drive.
Click on Start in the lower left of the screen.
Click on Run.
Type in A:\Setup.exe. (Where A is the floppy disk drive letter.)
Click OK
Follow the instructions in the setup wizard.

For CD ROM:

Insert the CD in the CD ROM drive.

If autorun is enabled, the setup wizard will start automatically.
Follow the instructions in the setup wizard.

If autorun is not enabled:
Click on Start in the lower left of the screen.
Click on Run.
Type in D:\Setup.exe. (Where D is the CD ROM drive letter.)
Click OK
Follow the instructions in the setup wizard.

The setup wizard will guide you through the installation. You may choose the directory where TransTenna will be installed or let the setup wizard install it in the default directory.

4. Program Removal

Removal of TransTenna is performed in a similar way to any Windows program. For Windows 95/98, click on Start in the lower left of the screen, click on Settings and then click on Control Panel. Select Add/Remove Programs by double clicking on the icon. This will display a panel listing the software installed on the computer. Scroll down if necessary and click on TransTenna. Next click on Add/Remove button and follow the instructions.

Other operating systems will be similar.

5. Program Operation

Launch the TransTenna program as you would any other Windows program on your computer. An opening panel, Figure 1, will appear.

This panel acts as a work sheet and allows the operator to enter data for the transmission line being used (Cable Data Entry) and for the measured series resistance and reactance at the "source" end of the transmission line (Measurement Data Entry). The "source" end of the transmission line is usually connected to the receiver/transmitter equipment.

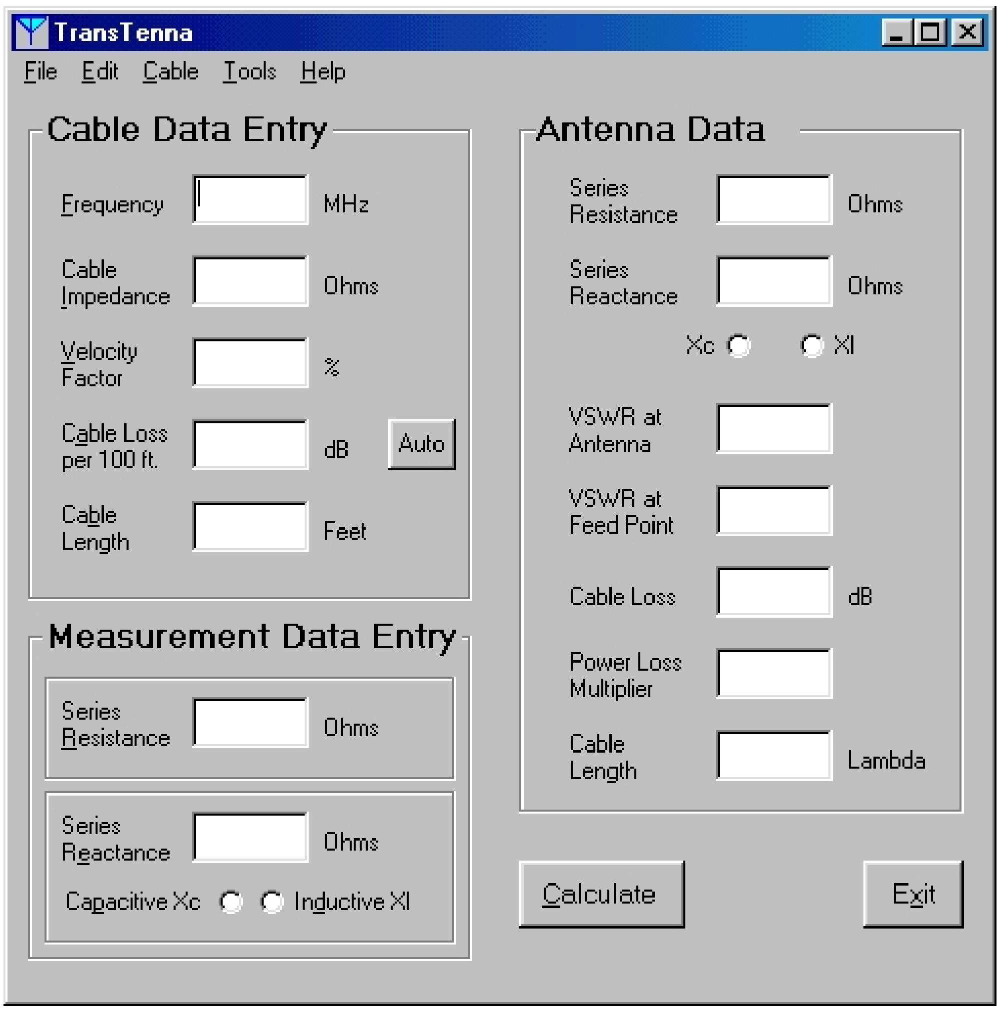


Figure 1
The Work Sheet

This worksheet is divided into three areas:

1. Cable Data Entry
2. Measurement Data Entry
3. Antenna Data

The Cable Data Entry fields provide entry of the measured and known transmission line parameters and data. This includes Cable Impedance, Velocity Factor, Cable Length, Cable Loss and Frequency.

The Measurement Data Entry fields allows the operator to enter the measured Resistance and Reactance data at the receiver/transmitter end of the transmission line.

When the Calculate button is selected, the program calculates and fills in the Antenna Data fields. This displays the calculated Antenna Series Resistance (R), Series Reactance (X), and VSWR. Additional calculations include VSWR at the Feed Point (receiver/transmitter end), Cable Loss in dB, Power Loss Multiplier and Cable Length in Lambda.

Use the TAB key, the Return key or the Mouse left button to move between data entry fields. You may also use the ALT key with the underscored letter key to move directly to a selected field.

Data entered into each field is error checked for a valid range of numbers for that specific field. This check is performed when the field is exited, that is when you move to the next field. If you exit a field without entering data, a default value will be entered automatically. The valid entry ranges for each field may be viewed by placing the mouse pointer over that entry field and waiting for a moment. The valid entry ranges for that field will then be displayed as a small pop up panel until you move the mouse pointer off the field.

When all entry fields have been completed, select the Calculate button. The program will then perform the mathematical calculations required to transform the entered data for the receiver/transmitter end of the transmission line to the opposite end, the antenna/load end of the transmission line. It will display the results of the calculations in the Antenna Data section of the work sheet.

If a required data entry field was left blank when you selected the Calculate button, an error message will pop up in a small panel to alert you, see Figure 2. When you close that error message panel, the cursor will automatically be placed in the field that is missing an entry.

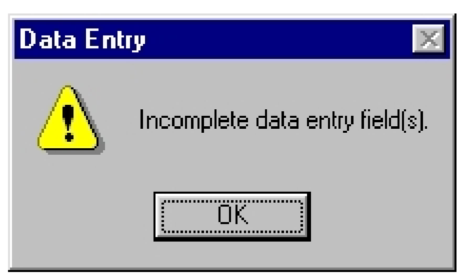


Figure 2
Data Entry error

6. Cable Data Entry

Frequency. --- Enter the operating frequency in MHz. The range of accepted values is from 0.1 to 999.999 MHz. If no entry is made, a default value of 10 MHz is entered automatically when the cursor is moved to the next data entry field.

Cable Impedance. --- Enter the transmission line characteristic impedance. The range of accepted values is from 1 to 999.99 Ohms. If no entry is made, a default value of 50 ohms is entered automatically when the cursor is moved to the next data entry field.

Example: RG-8/U has a nominal characteristic impedance of 52 ohms.

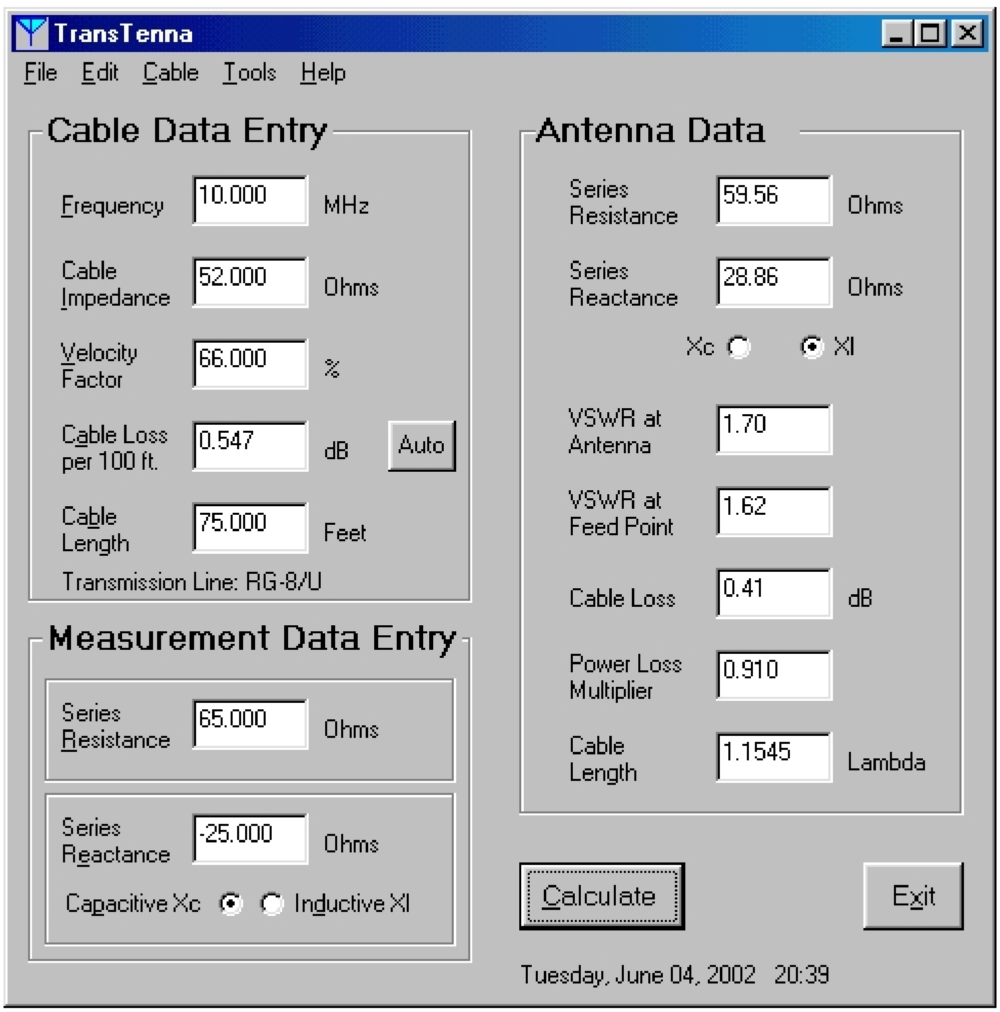


Figure 3
Completed Work Sheet Example

Velocity Factor. --- Enter the transmission line velocity factor. The range of accepted values is from 1 to 100 %. If no entry is made, a default value of 66 % is entered automatically when the cursor is moved to the next data entry field.

Example: RG-8/U has a nominal velocity factor of 66%.

Cable Loss per 100 Feet. --- Enter the cable loss in decibels. The range of accepted values is from 0 to 99.999 dB. If no entry is made, a default value of 0 dB is entered automatically when the cursor is moved to the next data entry field. This value can be estimated with some reduction in accuracy of the antenna data calculations. If you are completely unsure of the cable loss, leave the field at the default value of 0.

Auto Button. --- This button will calculate the approximate cable attenuation per 100 feet if you have selected a coax cable from the Cable menu selection as discussed in Chapter 11. It uses the Resistive Loss Constant, k1, and the Dielectric Loss Constant, k2, for the coax cable you have selected from the cable data file, CoaxList.txt, installed as part of the TransTenna program. It makes the calculation using the frequency entered in the work sheet. The calculation provides an approximate value which is automatically entered into the Cable Loss per 100 feet entry of the work sheet.

This automatic attenuation calculation provides improved accuracy for the calculated Antenna Data over leaving the entry at 0 dB. However, better accuracy may be achieved by using loss data supplied by the coax manufacturer. For the best accuracy, an actual measurement of cable loss per 100 feet at the operating frequency should be made.

Cable Length. --- Enter the length of the transmission line. The range of accepted values is from 0 to 9999.999. If no entry is made, a default value of 0 is entered automatically. This entry is critical to getting accurate data calculated at the antenna. When ever possible make as accurate measurement as practical. The higher the operating frequency, the more critical this factor becomes due to the shorter wavelengths. You can experiment with this entry by changing the cable length entry field and observing the effects on the antenna resistance and reactance data.

7. Measurement Data Entry

Series Resistance. --- Enter the measured series resistance at the source (receiver/transmitter) end of the transmission line. For this measurement the antenna or load should be connected to the opposite end of the transmission line. If an antenna is being evaluated, it should be at its final location for the most accurate readings. Antenna height, proximity to other objects and other factors will affect the antenna feed point impedance. This technique will provide more accurate measurement and analysis data for the transmission line and load/antenna.

Series Reactance. --- Enter the measured series reactance at the source (receiver/transmitter) end of the transmission line. Either capacitive or inductive reactance values can be entered. If the entry is capacitive reactance use a minus sign preceding the number entered or simply click on the Capacitive Xc button and the minus sign will be entered automatically. If the value is inductive reactance do not include a plus sign as it is implied to be a positive value. See the comments above under Series Resistance regarding accuracy of measurements.

If you are unsure of the sign of the x value, i.e. capacitive or inductive, refer to section 15 of this manual for additional information.

8. Antenna Data

Series Resistance. --- Displays the calculated series resistance at the antenna/load end of the transmission line. Ideally this value should be equal to the impedance of the transmission line for best power transfer from the transmission line to the antenna. Any other value will cause some power to be reflected back towards the transmitter end of the transmission line.

Series Reactance. --- Displays the calculated series reactance at the antenna/load end of the transmission line. Ideally (in a perfect world!) this value should be 0 ohms. Any other value indicates an antenna/load that may not resonate at the operating frequency and some power will be reflected back down the transmission line. In simple antenna systems such as a dipole, try making measurements at frequencies slightly higher or lower until this value is as close to zero as you can get. This will be the resonate frequency of the antenna.

Xc and Xl Indicators. --- The appropriate one will indicate type of series reactance, capacitive reactance (Xc) or inductive reactance (Xl).

VSWR at Antenna. --- Displays the calculated VSWR at the antenna/load end of the transmission line. Note that this value will only be equal to the VSWR at the Feed Point if the cable loss is 0 dB. If the cable loss is not 0 dB then the VSWR at the Antenna will be higher then at the Feed Point.

VSWR at Feed Point. --- Displays the calculated VSWR at the transmitter/receiver end of the transmission line. This calculated value is based on the measurement data you have entered on the work sheet.

Cable Loss. --- Displays the total cable loss in dB. This calculation is based on the length of the transmission line in feet and the cable loss in dB per 100 feet.

Power Loss Multiplier. --- This value can be multiplied times the power applied to the source end of the transmission line to get the power presented to the antenna. For example, if the transmitter output power is 100 watts and the Power Loss Multiplier is 0.772 then the power reaching the antenna will be 77.2 watts (100 watts * 0.772 = 77.2 watts). The lost 22.8 watts is dissipated as heat in the transmission line due to the cable losses.

Cable Length --- This is the length of the transmission line in lambda. Lambda is the length of one wavelength in the transmission line. It takes into account the velocity factor of the transmission line and the frequency.

A time and date stamp is displayed at the lower right of the panel. This is useful when a screen has been printed to provide a permanent record for future reference.

9. File Menu Selections

Load. --- Loads a set of data entry values from a file on the computers hard disk drive. The file name is Default.txt and is located in the directory where TransTenna was installed. This is a text file and can be edited by using Notepad or any similar text editor that does not embed formatting data in the file. This file is overwritten each time the Save selection is made. See discussion in the next paragraph.

Save. --- Saves the current set of data entry values to a file on the computers hard disk drive. The file name is Default.txt and is located in the directory where TransTenna was installed. The file Default.txt is overwritten each time this selection is made. This file is a text file and can be edited by using Notepad or any similar text editor that does not embed formatting data in the file.

Print Graphic. --- Uses the current system printer to print a graphical copy of the screen. No provision is provided to select a printer. If a printer other than the current system printer is required, it must be selected prior to making this selection. This is typically done by selecting Printers from the Control Panel.

Print Text. --- Uses the current system printer to print the screen data in a text format. Use with dot matrix printers or with any printer when you want to conserve or toner compared to the Print Graphic selection.

Exit. --- Close the program and end this session of TransTenna. The program can also be closed by clicking on or selecting the Exit button at the lower right of the opening panel used as the work sheet.

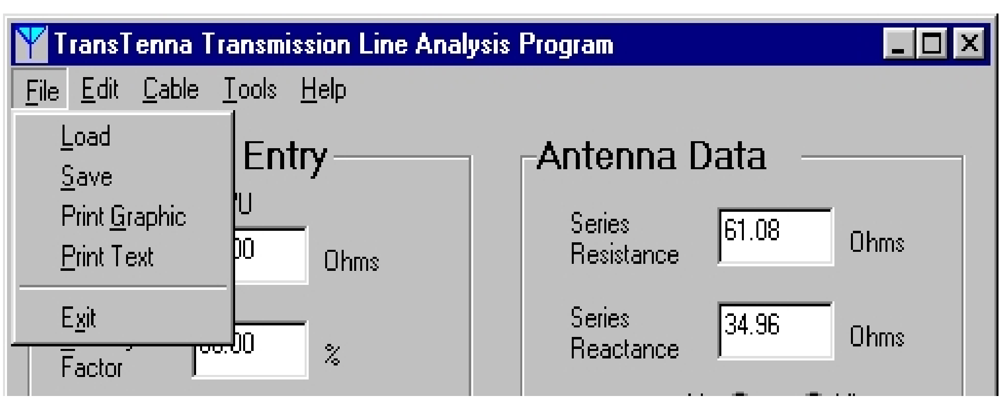


Figure 4
File Menu Selections

10. Edit Menu Selections

Clear Antenna Data. --- Clear all of the Antenna Data result fields.

Clear All. --- Clear all fields; Cable Data Entry, Measurement Data Entry and Antenna Data.

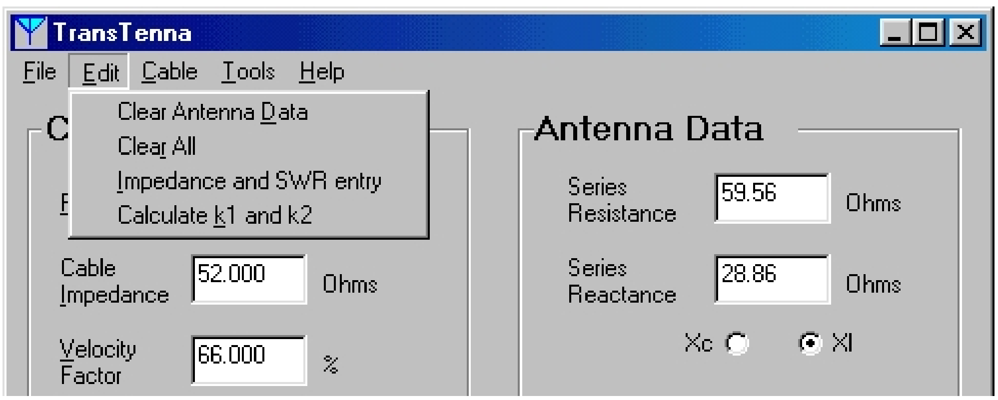


Figure 5
Edit Menu Selections

Impedance and SWR Entry --- This work sheet provides a special calculator to determine series R and X values when the impedance and SWR are known. Enter the Measured Impedance value and the SWR value into their respective data fields. Then click on the Calculate button to calculate the Series Resistance and Series Reactance which equates to the data entry values. By clicking on the Use button, the calculated Series Resistance and Series Reactance values will automatically be entered into the main work sheet.

Note that the sign of the Series Reactance, i.e. capacitive or inductive, cannot be determined when only the impedance and SWR are known. Please refer to section 15 for additional information on determining the sign of x.

The Cable Impedance must be entered before using this calculator.

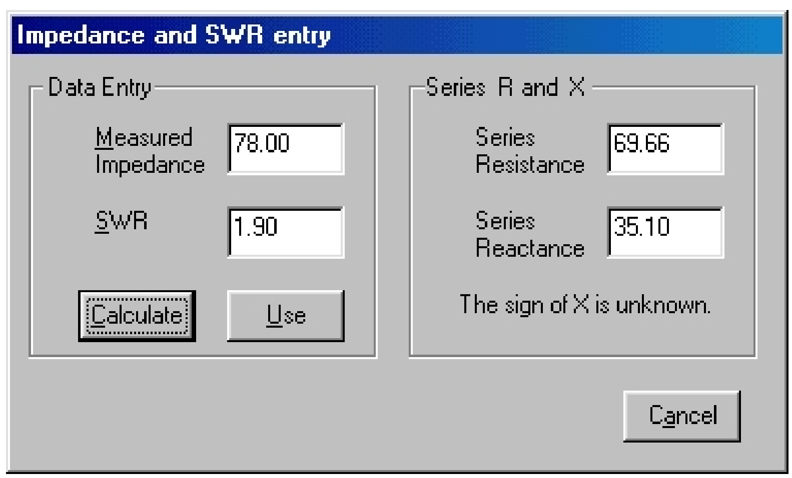


Figure 6
Impedance and SWR Conversion
to R + j X

Calculate k1 and k2 --- This work sheet can be used to calculate the approximate values for Resistive Loss Constant k1 and Dielectric Loss Constant k2. These constants are used by the Auto calculation feature found on the main work sheet to calculate the approximate cable loss per 100 feet. The constants k1 and k2 are read from the cable data file, CoaxList.txt, installed as part of the TransTenna program. This file is read when a cable is selected by using the Cable menu feature of the program as discussed in section 11, Cable Menu Selection, of this manual.

If you add a cable to the CoaxList.txt file, use this calculator to determine values for k1 and k2. Two sets of data must be entered. These are the loss in dB per 100 feet (meters) at two frequencies. The lower of two frequencies will be Frequency 1 and the higher of the two frequencies will be Frequency 2. Obtain this data from the cable manufacturers data for the cable you are adding or make actual cable loss measurements on the cable.

Note that using k1 and k2 to calculate the loss per 100 feet is subject to some accuracy limitations. These include accuracy of the manufactures data, age of the cable, deterioration of the cable, effects of connectors, accuracy of measurements, etc. Best accuracy for determining the cable loss is from actual measurements on the cable at the operating frequency.

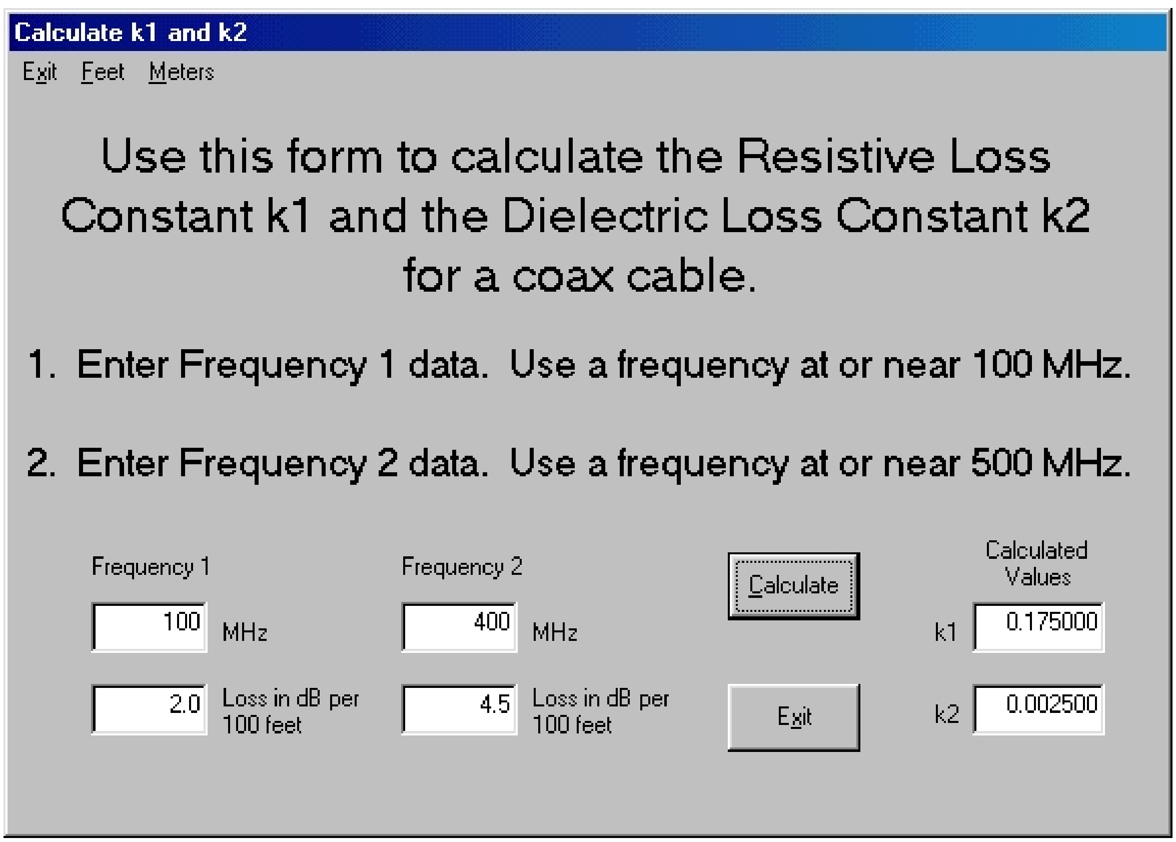
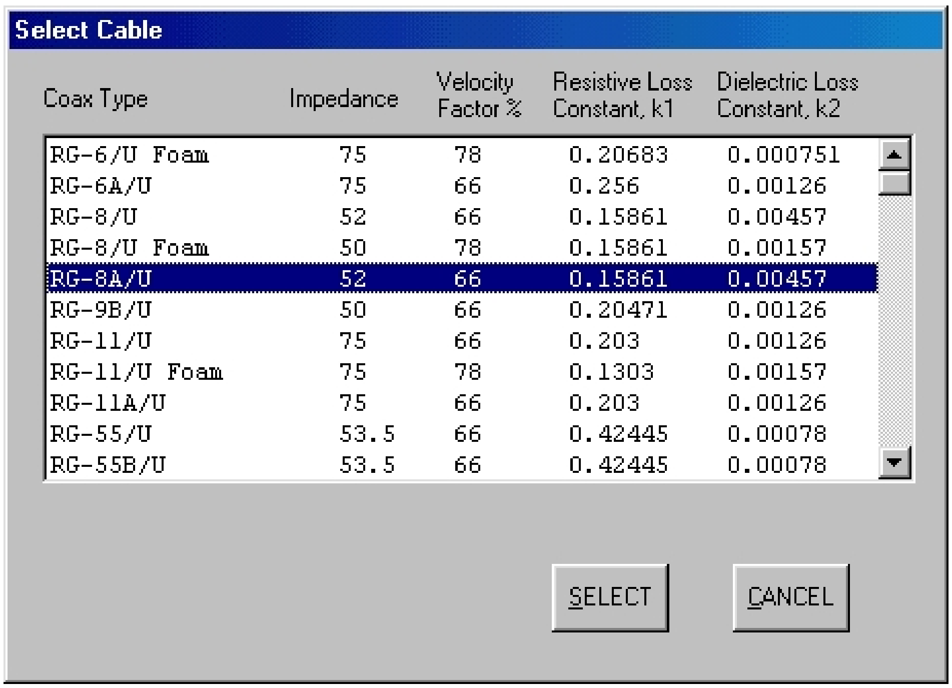


Figure 7
Constants k1 and k2
Calculation

11. Cable Menu Selection

This selection opens a window and allows the operator to select a cable type from the list. By highlighting a cable from the list and clicking on the Select button, the Cable Impedance and Velocity Factor for the selected cable will be automatically entered into their respective fields of the work sheet. The selection may also be made by double clicking on the desired selection of cable. The cable type selected will appear at the bottom of the Cable Data Entry fields on the worksheet.



Coax Type	Impedance	Velocity Factor %	Resistive Loss Constant, k1	Dielectric Loss Constant, k2
RG-6/U Foam	75	78	0.20683	0.000751
RG-6A/U	75	66	0.256	0.00126
RG-8/U	52	66	0.15861	0.00457
RG-8/U Foam	50	78	0.15861	0.00157
RG-8A/U	52	66	0.15861	0.00457
RG-9B/U	50	66	0.20471	0.00126
RG-11/U	75	66	0.203	0.00126
RG-11/U Foam	75	78	0.1303	0.00157
RG-11A/U	75	66	0.203	0.00126
RG-55/U	53.5	66	0.42445	0.00078
RG-55B/U	53.5	66	0.42445	0.00078

Figure 8
Cable Menu Selection

As shown in Figure 8, the Cable Menu Selection lists numerous popular coax types. For each Coax Type, the nominal Impedance, Velocity Factor %, Resistive Loss Constant, k1 and the Dielectric Loss Constant, k2 are listed. As discussed in the previous paragraph, Impedance and Velocity Factor are used in the main worksheet. Resistive Loss Constant, k1 and the Dielectric Loss Constant, k2 are used to calculate the approximate coax cable loss per 100 feet for entry into the worksheet.

For further discussion of the Attenuation per 100 feet entry on the worksheet, refer to the Auto button discussion in section 6 of this manual.

The cable data is contained in a file called CoaxList.txt located in the directory where TransTenna was installed. This file is a text file and can be edited to change, add or remove cable types by opening it with a text editor. A preferred editor is Notepad or Wordpad or any similar text editor that does not save embedded format information in the file. If you use a word processor, be sure to save the file as an ASCII DOS TEXT file. Do not save any format characters in the file.

It is recommended that you make a backup copy of the file before opening it.

The following instructions for editing this file also appear in the file itself.

```
; This file is the list of coax types to be displayed in the
; program when the "Cable" menu is selected on the main
; window of the program.
;
; This file can be edited using WordPad or a similar text
; editor. If you use a word processor, you must save the
; file as an ASCII text file (no embedded formatting
; characters).
;
; Each comment line must begin with a ";" (semicolon)
; character in the first character position on the line. The
; program will ignore lines beginning with a semicolon.
;
; You may add additional coax data to this file. The maximum
; number of entries is 300.
;
; Use a semicolon to separate each field. Each line
; must contain five fields.
;
; Field 1 is the coax type and is 19 characters max.
; Field 2 is the cable impedance and is 7 characters max.
; Field 3 is the velocity factor and is 7 characters max.
; Field 4 is the resistive loss constant, k1, and is 9 characters max.
;       Enter 0 if the resistive loss constant is unknown.
; Field 5 is the dielectric loss constant, k2, and is 8 characters max.
;       Enter 0 if the dielectric loss constant is unknown.
;
;
; Each entry must have 5 fields or the line will
;    not be displayed in the list.
;
RG-6/U Foam;75;78;0.20683;0.000751
RG-6A/U;75;66;0.256;0.00126
RG-8/U;52;66;0.15861;0.00457
```

RG-8/U Foam;50;78;0.15861;0.00157
RG-8A/U;52;66;0.15861;0.00457
RG-9B/U;50;66;0.20471;0.00126
RG-11/U;75;66;0.203;0.00126
RG-11/U Foam;75;78;0.1303;0.00157
RG-11A/U;75;66;0.203;0.00126
RG-55/U;53.5;66;0.42445;0.00078
RG-55B/U;53.5;66;0.42445;0.00078
RG-58/U;53.5;66;0.444;0.00126
Etc.

Note that each field on a line is separated with a semicolon.

12. Tools Menu Selection

Metric Conversion. --- This tool will allow you to easily convert measurements between meters and feet. Conversions can be made from feet to meters or from meters to feet by clicking on the appropriate button, Feet or Meters.

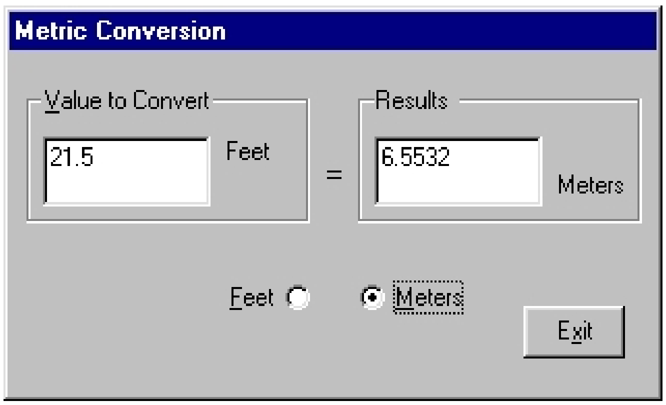


Figure 9
Metric Conversion

SWR to Return Loss. --- This tool will allow you to convert a SWR value into return loss in dB. Return loss is equal to the difference in dB between the forward power and the reflected power.

The percent of reflected power is also given.

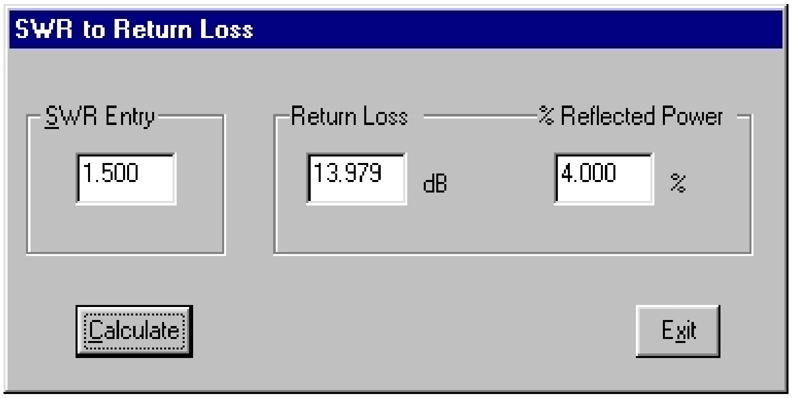


Figure 10
SWR to Return Loss

Return Loss to SWR. --- This tool will allow you to convert a return loss in dB to SWR. Return loss is equal to the difference in dB between the forward power and the reflected power.

The percent of reflected power is also given.

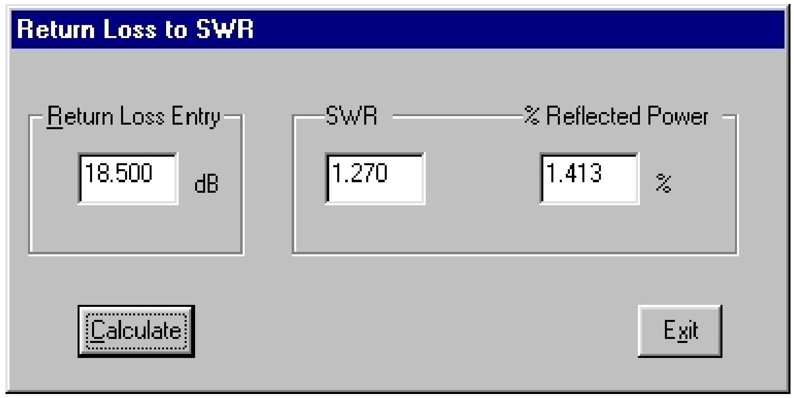


Figure 11
Return Loss to SWR

Power to SWR. --- This tool will allow you to convert measured forward and reflected power readings to SWR.

This tool is especially useful if you use a power meter which reads both forward and reflected power.

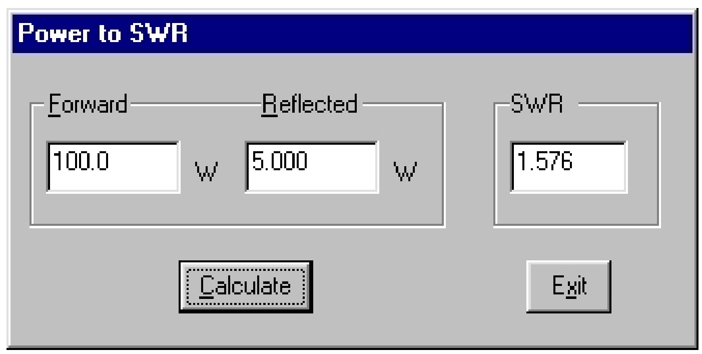


Figure 12
Power to SWR

Wavelength Calculator. --- This tool will allow you to calculate the wavelength in both feet and meters for a frequency. It takes into account velocity factor and calculates 1, ½ and ¼ wavelengths.

For wavelength in a transmission line, use the velocity factor for that line. This tool makes

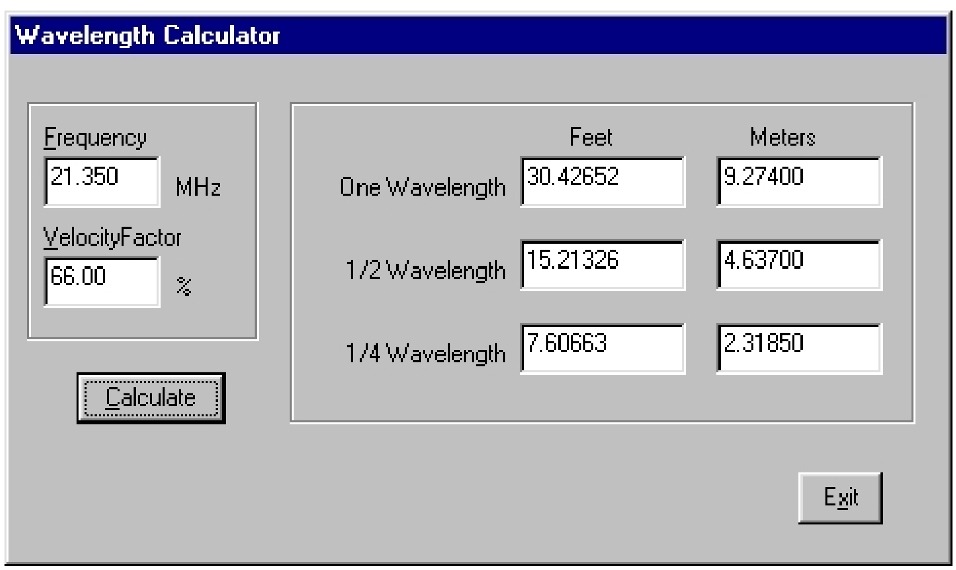


Figure 13
Wavelength Calculator

determining the length of baluns and stubs much easier by doing the math for you and also allowing you to quickly analyze changes in length.

If calculating an antenna length, use a velocity factor of 100 %. This may result in an antenna that is slightly long (it is easier to shorten an antenna than it is to lengthen it). For better accuracy you may consult one of the many antenna books to get the value to use. One popular publication uses a value of 0.95 (95 %) for making a HF dipole antenna with wire. In this case the velocity factor would be 95 %.

Attenuation. --- This tool will allow you to calculate cable attenuation in dB when the power at the source and load ends of the transmission line is known.

Use this tool with a transmitter, wattmeter and dummy load to get accurate cable loss data at the precise frequency you need. It is also useful to evaluate a length of coax, if its history may be questionable, before you commit to using it.

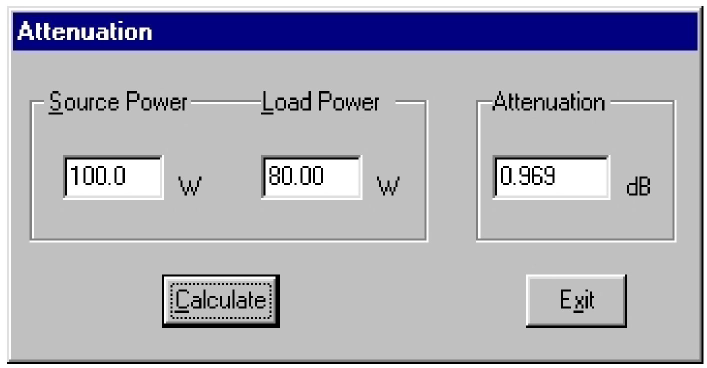


Figure 14
Attenuation

13. Help Menu Selection

About Program. --- This selection will display a screen showing program version and copyright notice.

Operation, .txt file. --- This selection will load and display a text file for operator assistance. This file is named HelpText.txt and is located in the same directory where TransTenna is installed. It is an abbreviated version of the operator manual and is intended to provide the operator with quick access to program operation assistance. This file will be opened by the program associated with txt files.

Operation, .pdf file. --- This selection will load and display the instruction manual for the TransTenna program. This file is named Operators Manual.pdf and is located in the same directory where TransTenna is installed. It is the full version of the operator manual and is intended to provide the operator with complete access to program operation and assistance. This file is in pdf format and will be opened by the program associated with pdf files.

14. Invalid Data Entered

TransTenna calculates values at the load/antenna end of the transmission line using the general transmission line equations. Since the entered data is used to calculate the antenna/load parameters, it is possible under some circumstances to enter data which cannot be realistically achieved in a conventional transmission line and antenna/load scenario.

For example, if you have a 50 ohm transmission line of infinite length connected to a transmitter with a 50 ohm output, there can be no reflected power coming back to the transmitter since the power never reaches the load to be reflected. In this case a perfect match exists between the transmitter and the transmission line. The resistance and reactance measured at the transmitter end of the transmission line will be 50 + j0 (series resistance and reactance).

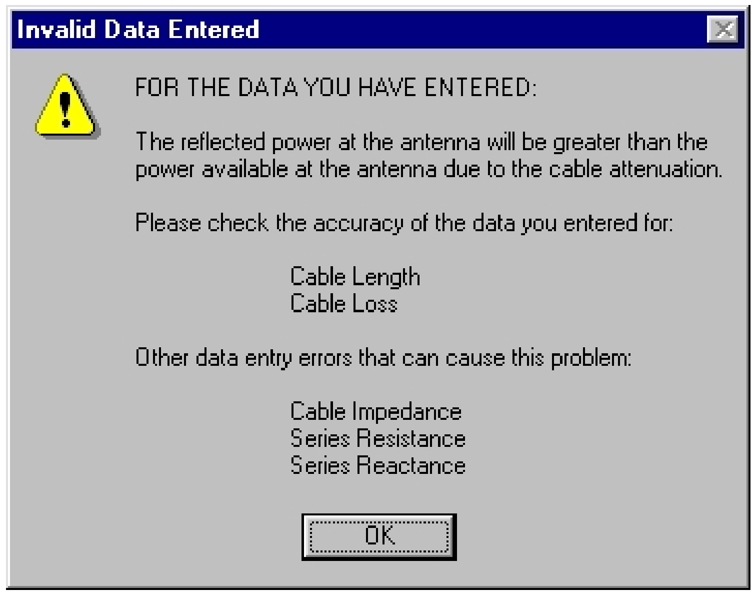


Figure 15
Invalid Scenario Message

Just because you can enter a different value such as 25 + j30, does not mean that this is a <u>valid</u> measured value. Error checking is used to avoid most problems of this nature. If an invalid scenario is entered, the program will prompt you to check your data entry, see Figure 15. As with any calculation, the accuracy of the data you enter affects the accuracy of the results. Have you heard the phrase "Garbage in, garbage out"? Well, it applies to impedance transformation along a transmission line also.

15. Determining the Sign of X

When we use the term X or jX, we are referring to the reactive part of the complex impedance. This reactive part can be either a negative value (-jX) which indicates capacitive reactance or a positive value (jX or +jX) which indicates an inductive reactance. If you do not know the sign of jX or can not read it from the test instrument you are using, getting accurate results will require a little extra work. Lets look at some examples.

1. We may not care about the sign of jX if the value of jX is small compared to the resistance

desired. For example lets assume the calculated antenna impedance is 46 + j3 ohms and the SWR is 1.12:1. In this case we may be quite satisfied with the 1.12:1 SWR and no further analysis is required. Does it matter whether it was a + j3 ohms or a - j3 ohms if we are not going to do anything about it?

2. We can solve for two results at the antenna end of the transmission line by using a positive value entry for Series Reactance in the Data Entry field and then calculate again using a negative value for the entry. This gives two solutions and the ambiguity must be resolved by some other method such as trial and error in making an antenna adjustment.

3. In some antenna systems such as simple dipoles and verticals that are intended to be resonant at the operating frequency, the sign of jX can be determined by changing the test frequency. Find the resonant frequency where the reactance (jX) is smallest. As you move slightly below the resonant frequency of the antenna, it becomes capacitive and the X term is - j ohms. As you move slightly above the resonant frequency of the antenna, it becomes inductive and the X term is + j ohms. Remember that we are talking about the calculated antenna resistance and reactance not the values measured on the test instrument.

4. Another method involves adding a small length of transmission line to the antenna feed line and observing the change in the measured resistance reading on the test instrument. Adding transmission line will rotate the impedance point plotted on a Smith Chart clockwise, in the direction of the Generator. By adding a small length such as 0.01 wavelength, the resistance will change and the direction of change will tell you if the reactance is inductive or capacitive i.e. in which half of the Smith Chart the impedance is located.

If the resistance goes down, the impedance is in the lower half of the Smith Chart and therefore the reactance is capacitive and the X term is - j ohms.

If the resistance goes up, the impedance is in the upper half of the Smith Chart and therefore the reactance is inductive and the X term is + j ohms.

This method does have an ambiguity when the X term is very low compared to the characteristic impedance of the transmission line. In this case it is possible to add a small length of transmission line and have the resistance value as read from the test instrument read the same value. This can occur when the impedance is nearly purely resistive and the added transmission line moves the impedance point on the Smith Chart from the lower half to the upper half, or vice versa, an equal distance relative to the horizontal axis of the chart. In this case the addition of a second short length of transmission line will provide the desired results and the resistance reading will change as discussed above.