Measuring Electrical Length

The electrical length of a transmission line determines many aspects of its electrical behaviour. Parallel feed lines, tuned stubs, and quarter wave resonators are all made possible by the ability to measure exact electrical length. This article is guide to using the new series of TE3000 analysers and software utilities to the measure electrical length of a coaxial cable.

Article Contents:

1. Electrical length basics
2. The automated ‘Electrical Length’ software utility
3. The on board ‘Cable Length’ display format
4. Hints for proper operation

Equipment Used:

- 1.2m RG58 cable with N type male connections
- TrewMac TE3001 Network Analyser

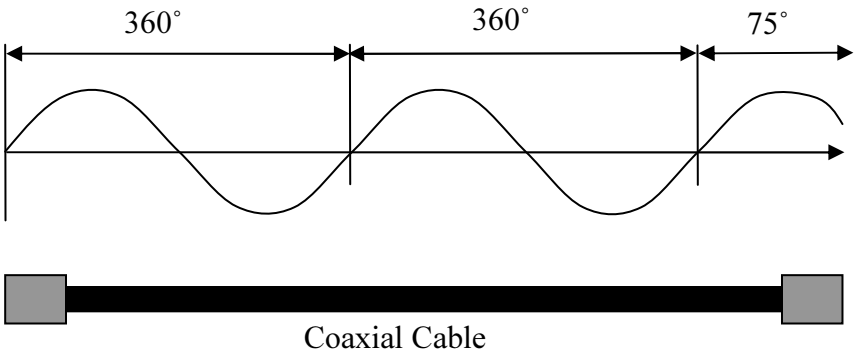
1. Electrical Length Basics

The electrical length of a transmission line is dependant upon the frequency at which it is measured. It can be expressed in wavelengths or degrees.

One wavelength $\lambda = 360°$

Essentially, electrical length tells us how many sine wave cycles will 'fit' into the length of a particular cable.

For example, if a cable has an electrical length of 795˚ this means it is 360˚+360˚+75˚=2.2λ or 2.2 wavelengths long:



Coaxial Cable

The easiest way to measure electrical length with an impedance analyser is to terminate the cable with an OPEN and look at the reflection coefficient angle ϕ.

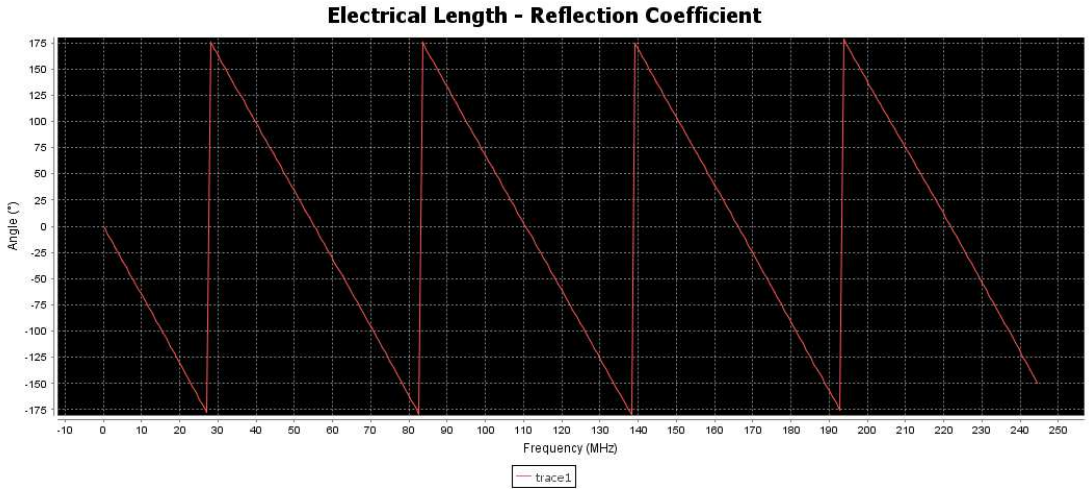
(An OPEN is used because it reflects the entire signal back to the analyser for measurement.)

However, there are a few complications…..

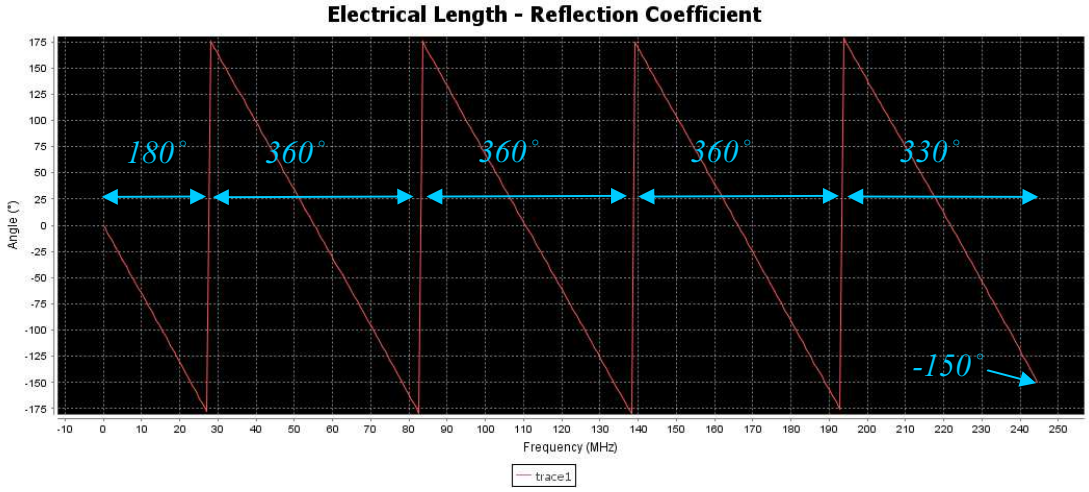
ϕ represents the electrical delay of a <u>two way</u> traverse of the cable.

Because it's for a two way traverse, ϕ is twice as large as the electrical length.
Because it represents a delay, the change in ϕ with frequency is always negative.
Lastly, because it's limited between +/-180˚, it wraps around at 360˚ intervals and we distinguish for example between 10˚ and 10˚+360˚=370˚

This is shown on the sweep of the cable in the chart below.



What we can do is count the total degrees by adding the sections together:



$$180° + 360° + 360° + 360° + 330° = 1590°$$

Divide by 2 to get the electrical length:

$$\frac{1590°}{2} = 795°$$

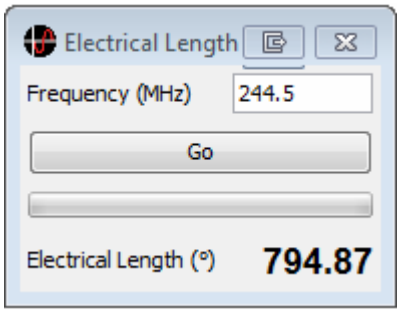
2. The automated Electrical Length utility

This how the automated software utility works; by sweeping the cable and totalling the reflection coefficient angle as it goes.

Be sure to use the correct calibration type according to the measurement setup. For example, if the transmission line to be measured is a coaxial cable connected to the N type connector on the fascia of the TE3001, use STD cal.

Procedure

- Select Electrical Length from the Utilities menu
- Enter the frequency of interest
- Press Go



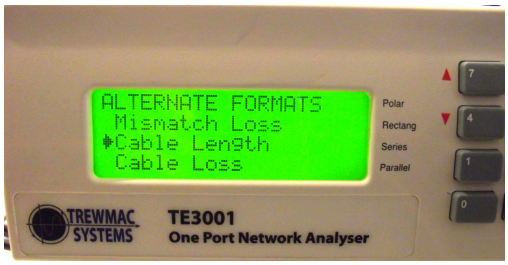
The utility will scan the transmission line and return the total electrical length.

Another advantage of this utility is that it will function for both OPEN and SHORT terminated cables.

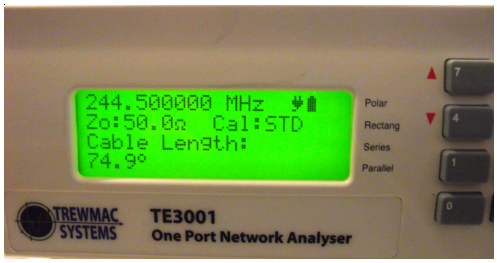
3. The on board Cable Length display format

The electrical length display format on board the TE3000 analysers use the value of reflection coefficient angle to calculate an equivalent electrical length.

Press and hold the Format key to access the list of alternate display formats. Scroll down and select Cable length.



Selecting Cable Length format



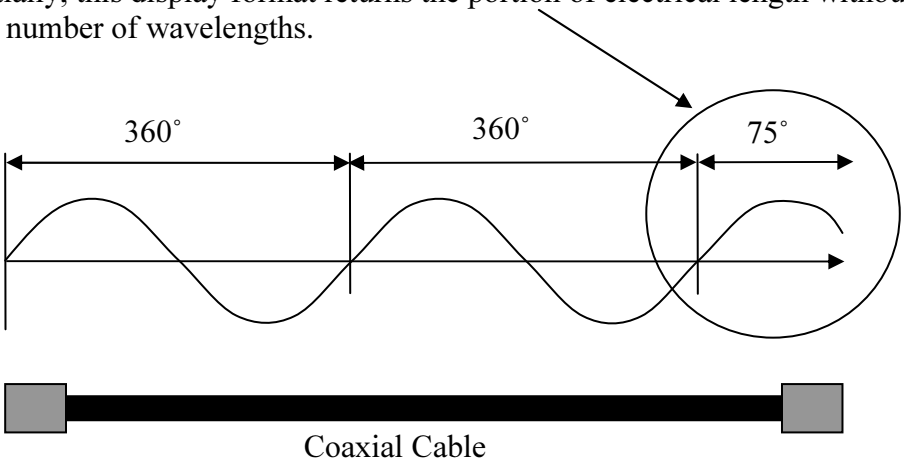
Measurement result at 244.5MHz

The reflection coefficient angle at the frequency of interest (244.5MHz) was -150˚

The analyser computes the electrical length as $-\frac{(-150°)}{2} = 75°$

This is not indicative of the total electrical length of the cable, but rather the 'apparent' electrical length seen by the analyser at the frequency of interest.

Essentially, this display format returns the portion of electrical length without the whole number of wavelengths.



For some applications, like phased array feed lines, this apparent electrical length is all that's required. In fact, some cables may purposely be 360˚ longer to reach to a farther location while having the signal remain in phase.

For other applications requiring the total electrical length, use the automated function.

4. Hints for proper operation

The on board Cable Length display format is only for use with OPEN terminated cables.

While the automated utility can measure both OPEN and SHORTED cables they will results in different electrical lengths. This is because the SHORT termination will effectively add some length to the cable being measured.