<u>Determination of the characteristic impedance Z_0 of a transmission line, using a Vector Network Analyzer (VNA).</u>

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Calibrate the network analyzer for 1 port reflection measurement [S_{11}], at the reference point for connection of transmission line under test. The display format should be set for Smith Chart, and the system characteristic impedance calculation value set for 50 Ohms. The sweep stop frequency for Method 1, needs to be set at a value which corresponds to a transmission line electrical length of at least ¼-wavelength. Error may be introduced, from a non-ideal s/c or o/c set at the end of the transmission line under test. To minimize this error a s/c, which is a more acceptable reference, is therefore normally utilized with Method 1 but an o/c may be used.

<u>Method 1.</u>

<u>By measurement of the imaginary part of impedance at an electrical transmission line length of $^1/_8$-wavelength.</u>

A lossless shorted stub looks like a reactance whose value and sign depend on its length.

From the equations 1.8-20 [1] and 92-3-14 [2] below, that relate to transmission line stub transformation at $^1/_8$-wavelength, it follows that the (imaginary) input impedance (Z_{in}) is equal to the characteristic impedance (Z_o).

using $\bar{z}_{in}(\text{shorted stub}) = j\tan\beta l$ (1.8-20) [1]

where

$\bar{z}_{in}$ = normalized input impedance

β = phase constant

l = physical length

so for $\lambda/8$ $\beta l = \pi/4$ radians or 45°

giving $\bar{z}_{in} = j1.0$

and using $Z_{in} = +jZ_o\tan(\beta l)$ (2-3-14) [2]

or $Z_{in} = Z_o(j\tan(\beta l))$

so for $\lambda/8$ $Z_{in} = +jZ_o$

The VNA Smith Chart display should be calibrated and coordinates normalized for a 50 Ohm system. To use this to determine the imaginary part of an unknown input impedance at $^1/_8$ -wavelength, it is first necessary to determine the frequency at $^1/_4$-wavelength and then make an impedance measurement at half this frequency.

i) Connect transmission line under test to VNA measurement reference point.

ii) With the receiving end of the transmission line s/c, record the frequency for $^1/_4$-wavelength transform i.e. at o/c position.

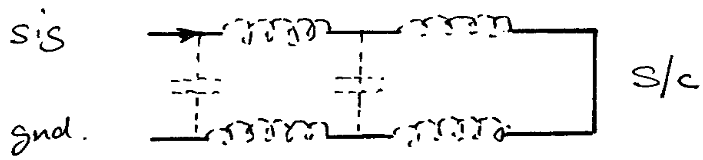
iii) Measure value of imaginary part of input impedance (and hence transmission line characteristic impedance) at half this frequency i.e. $^1/_8$-wavelength.

Method 2.

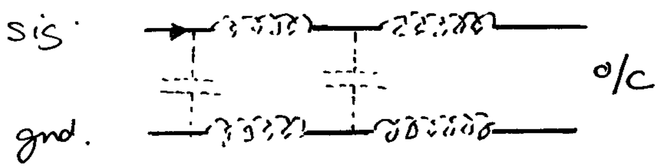
By measurement of inductance and capacitance or measurement of impedance.

i) Connect transmission line under test to VNA measurement reference point.

ii) With the receiving end of the transmission line s/c, at a fixed frequency, measure the input impedance or value of inductance (off marker).



iii) With the receiving end of the transmission line o/c, at the same fixed frequency, measure the input impedance or value of capacitance (off marker).



iv) Calculate Z_o as examples show with either equation below:

Example calculation using first equation:

using $Z_o = \sqrt{\frac{L}{C}}$

example: measured values for 1m, UR70 cable (75Ω) @10 MHz.
s/c 370nH.
o/c 79pf.

then $Z_o = \sqrt{\frac{L}{C}} = \sqrt{\frac{370\times10^{-9}}{79\times10^{-12}}} = \boxed{68\Omega}$

Example calculation using second equation:

using $Z_0 = \sqrt{Z_{sc} Z_{oc}}$ (2-1-95)[2]

example: measured values for 1m. UR70 cable (75Ω) @10MHz.

s/c $Z = 0.9\Omega\ j23.3\Omega$

o/c $Z = 0.9\Omega - j201\Omega$

then $Z_0 = \sqrt{\left(\sqrt{0.9^2+23.3^2}\right) \times \left(\sqrt{0.9^2+(-201)^2}\right)}$

giving $Z_0 = \sqrt{23.3 \times 201}$

$= \sqrt{4683.3}$

$= \boxed{68\Omega}$

References.
[1]. Handbook of Coaxial Microwave Measurements. David A. Gray. General Radio.1968.

[2]. Microwave Circuit Analysis and Amplifier Design. Samuel Y. Llao. ISBN- 0-13-581786-2