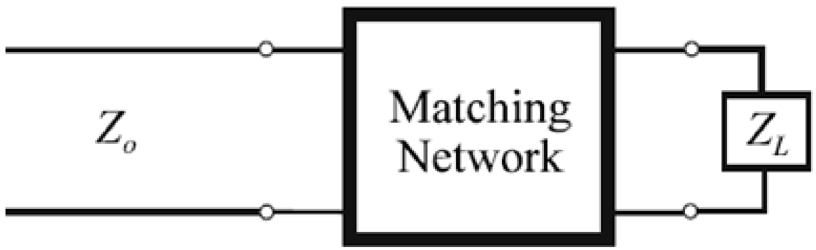
CHAPTER 11

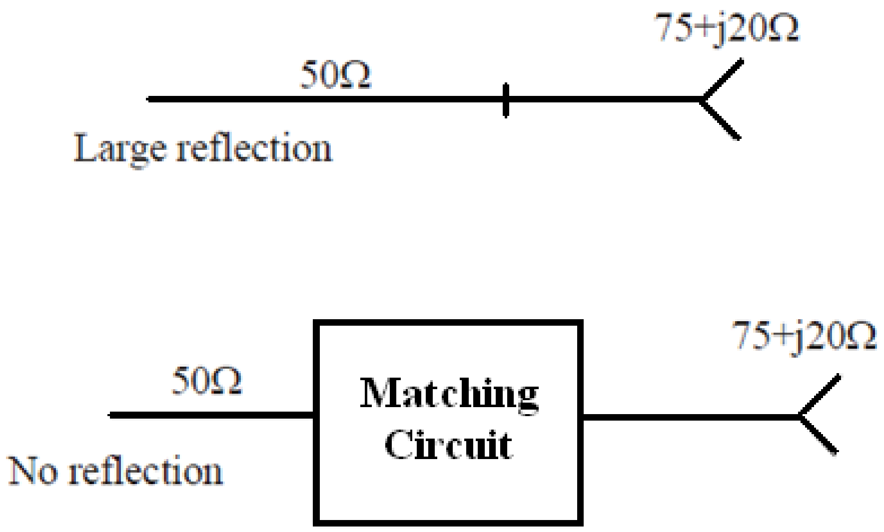
Transmission Lines

11.6 Some Applications of Transmission Lines

Transmission lines are used for ***Load Matching***.

- If a transmission line is connected to a load of different impedance to the T.L., ***reflection*** occurs.
- For maximum power transfer from source to load, a matching network is used.

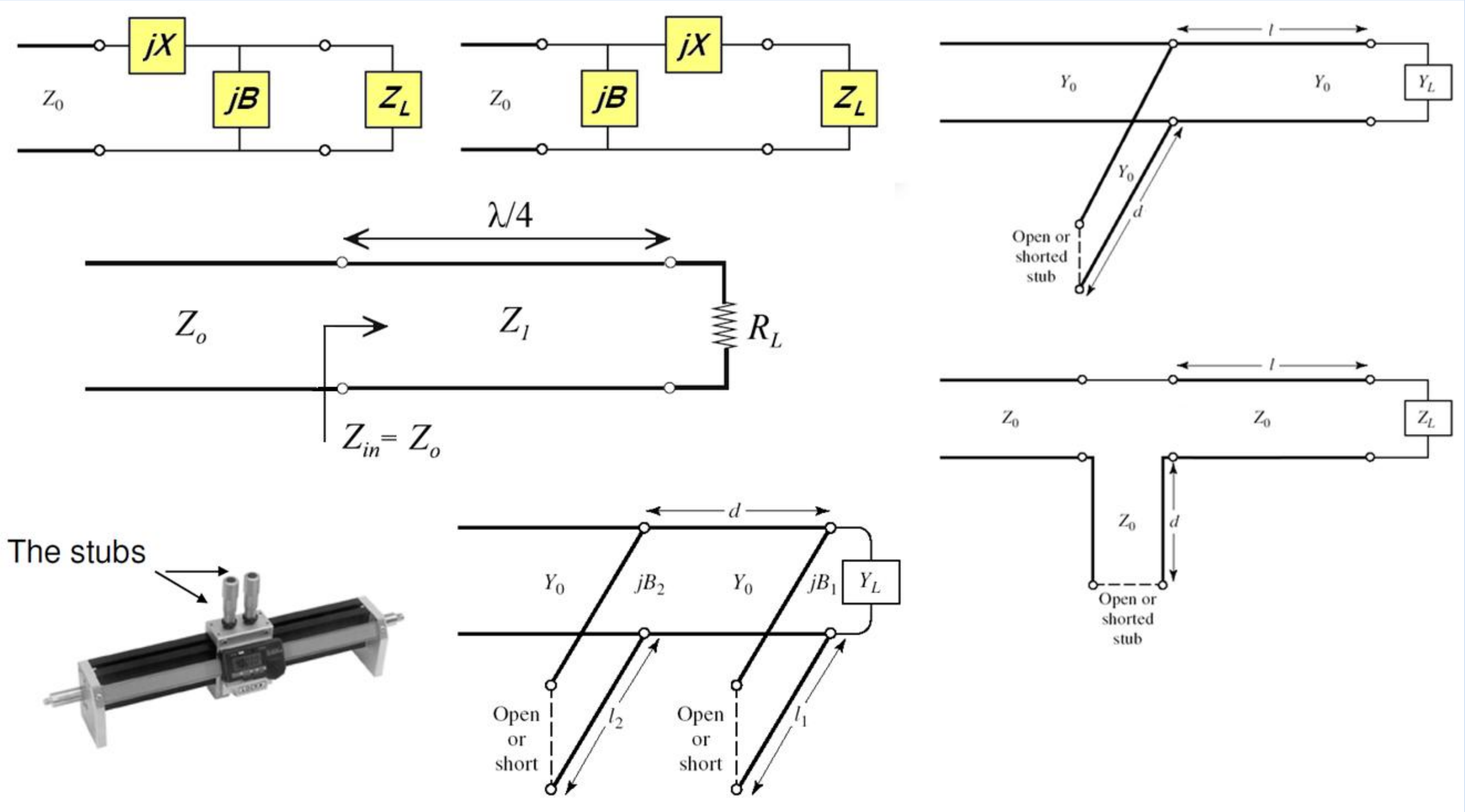




Matching Networks

- Lumped element networks.
- Lumped T and PI networks.
- Distributed networks
  - ($\lambda/4$) transformer.
  - Single Stub Tuner.
  - Double Stub Tuner.

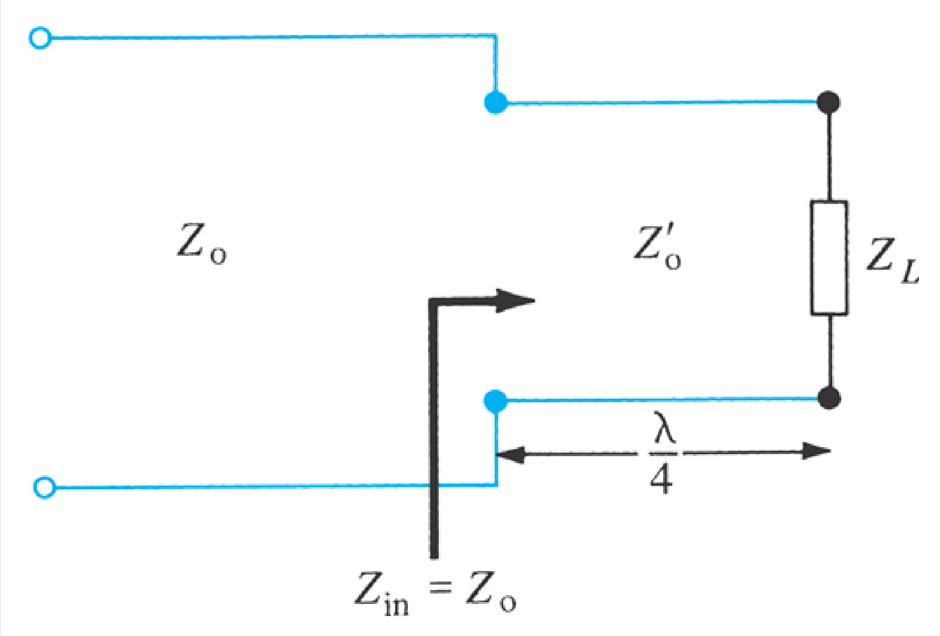
Matching Networks



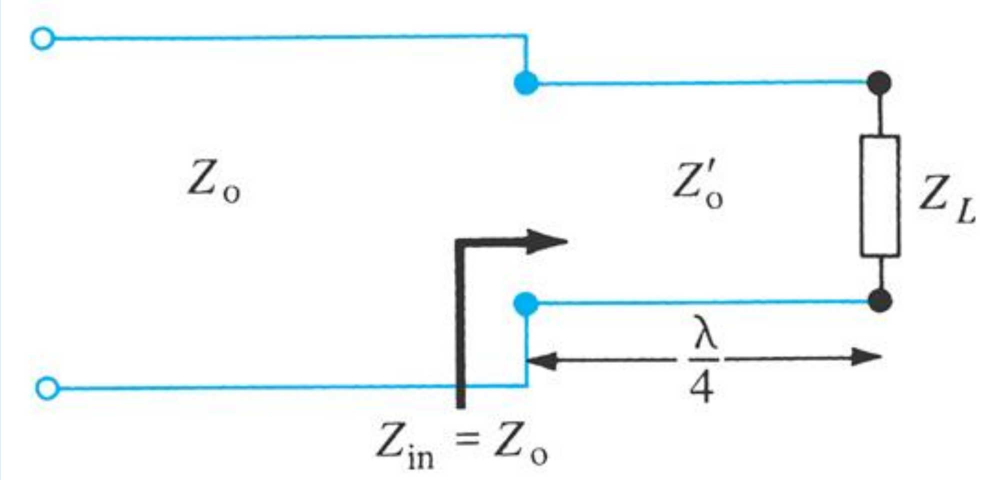
A. Quarter-Wave Transformer (Matching)

- When $Z_L \neq Z_0$, the load is ***mismatched*** and a reflected wave exists on the line.

- The mismatched load Z_L can be properly matched to a line (with characteristic impedance Z_0) by inserting prior to the load a **λ/4** transmission line (with characteristic impedance Z_0')



Quarter-Wave Transformer



To find the value of Z_0' required for matching:

$$Z_{in} = Z_0'\left[\frac{Z_L + jZ_0'\tan\beta l}{Z_0' + jZ_L\tan\beta l}\right]$$

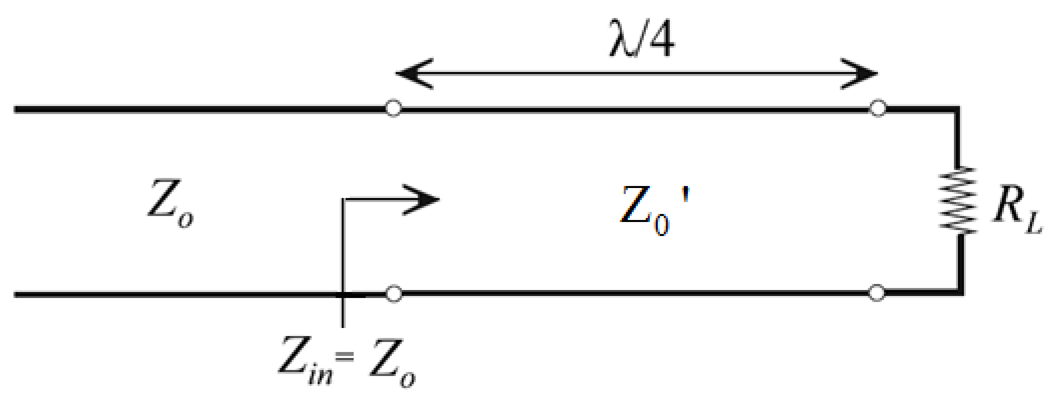
$$\text{But}\quad \beta l = \left(\frac{2\pi}{\lambda}\right)\left(\frac{\lambda}{4}\right) = \frac{\pi}{2},\quad \tan\beta l = \infty \quad \rightarrow Z_{in} = \frac{(Z_0')^2}{Z_L}$$

For a matched system, Z_{in} must equal Z_0, Hence

$$Z_{in} = \frac{(Z_0')^2}{Z_L} = Z_0 \quad \Rightarrow \quad \boxed{Z_0' = \sqrt{Z_0 Z_L}}$$

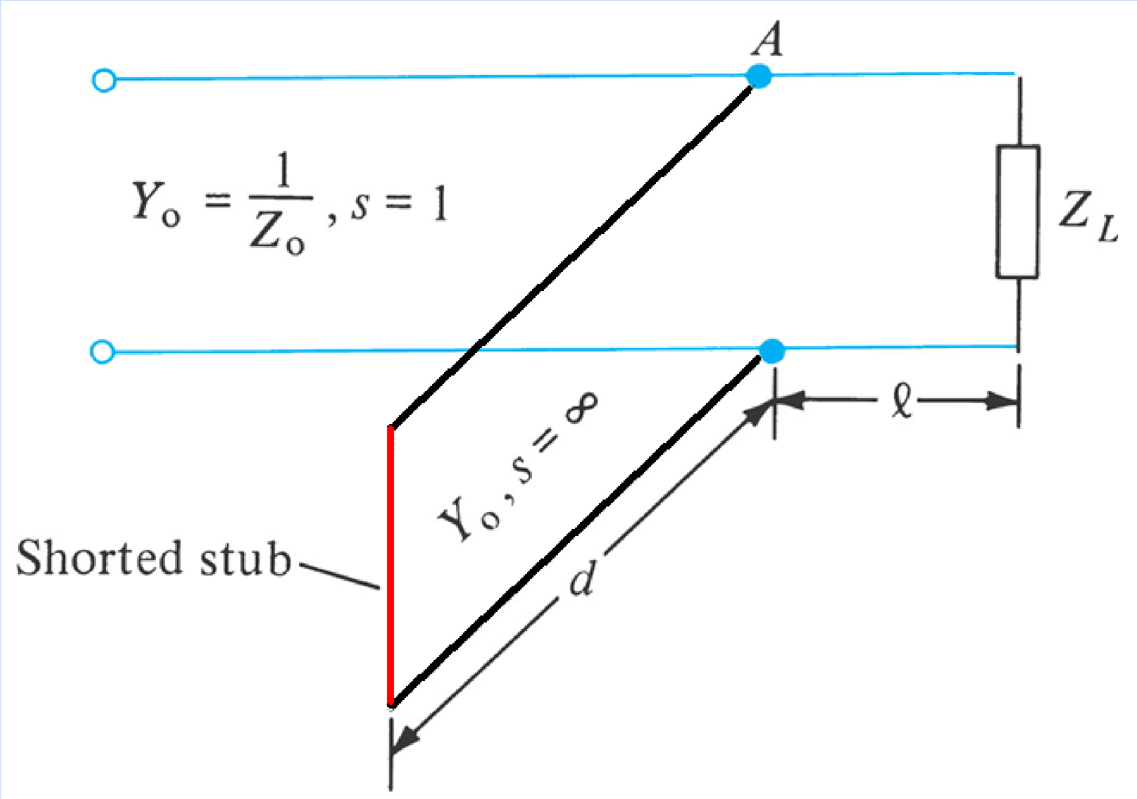
Quarter-Wave Transformer

$$Z_0' = \sqrt{Z_0 R_L}$$



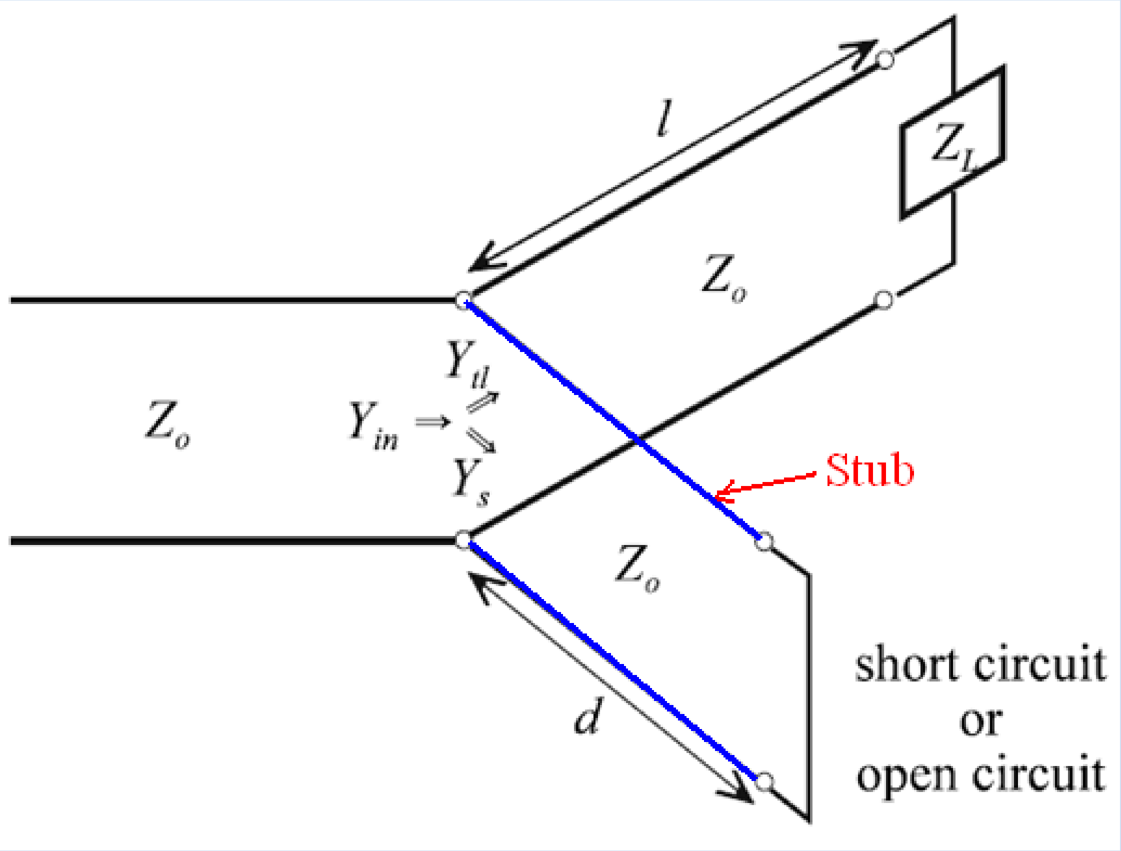
- This is not at every frequency, as the transmission line is only λ/4 at one frequency. (disadvantage: **narrow band**)
- Although the impedances can be complex in general, transmission lines have a real characteristic impedance. Hence this matching only applies to **real** load impedances.
- **Example:** To match a 120 Ω load to a 75 Ω line, the quarter-wave transformer must have a characteristic impedance of $\sqrt{(75)(120)}$ =95Ω

B. Single Stub Tuner (Matching)



- When $Z_L \neq Z_0$, the load can be matched by using a single stub tuner.
- It consists of an open or shorted section of transmission line of length ***d*** connected in parallel with the main line at some distance ***l*** from the load.

Single Stub Tuner (Matching)



$Y_{tl} = Y_0 + jB$ [Input admittance of the terminated T-line section]

$Y_s = -jB$ [Input admittance of the stub (short or open circuit)]

$Y_{in} = Y_{tl} + Y_s = Y_0$ [Overall input admittannce] , $Y_0 = 1/Z_0$

Single Shunt Stub Tuner Design Procedure

1) Locate normalized load impedance and draw VSWR circle.

2) Convert to normalized load admittance yL. **(for the remaining steps consider the Smith Chart as admittance chart).**

3) From yL, rotate CW (toward generator) on the VSWR circle until it intersects the *1+jb* circle in two points.

4) Thus the distance ***l***, from the load to the stub, is given by either of these intersections.

5) Beginning at the stub end, rotate CW (toward generator) until the point at *0-jb* is reached. This rotation distance is the stub length ***d***.

Single Shunt Stub Tuner Design Procedure

Notes:

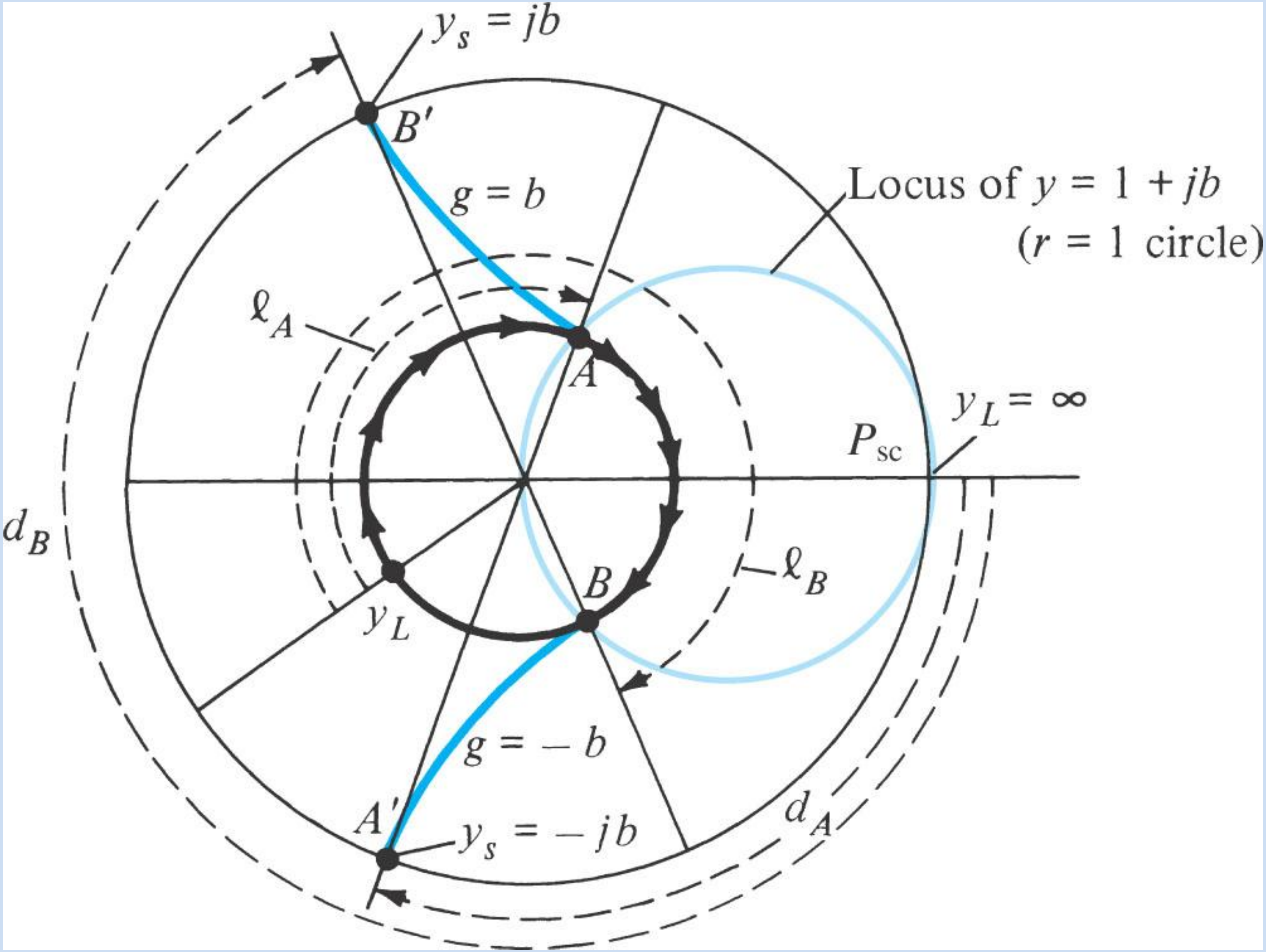
❑Rightmost Smith chart point is the admittance of a short-circuit.

❑Leftmost Smith chart point is the admittance of an open-circuit.

❑There are usually two possible solutions, we normally choose the shorter stub or one at a position closer to the load.

❑We may have two stubs arrangement, this is called *double*-*stub matching*, allows for adjustment of the load impedance.

Single Stub Tuner – Design using Smith Chart



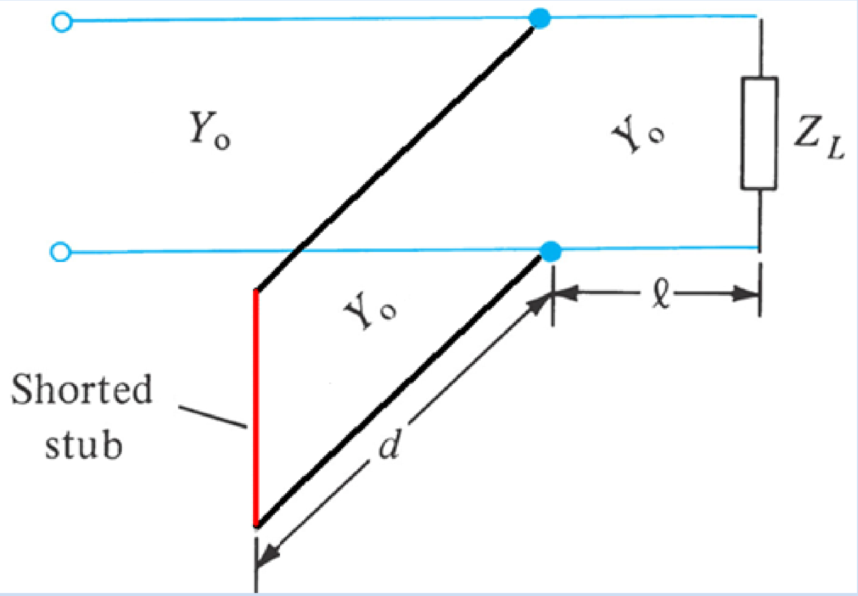
Example 11.7

An antenna with an impedance of 40+j30 Ω is to be matched to a 100 Ω lossless line with a shorted stub. Determine

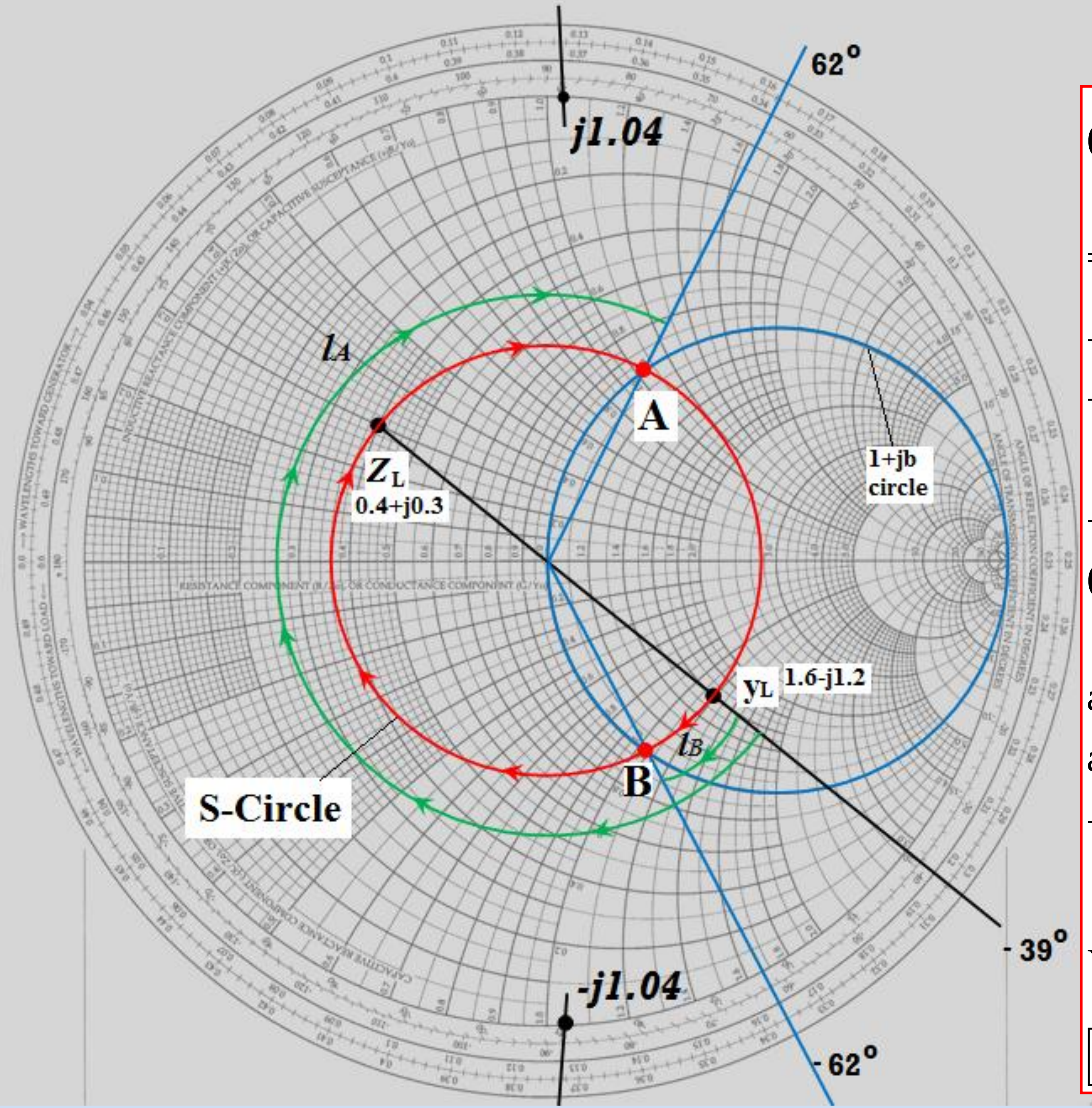
(a) The required stub admittance

(b) The distance between the stub and the antenna.

(c) the stub length



Example 11.7



$(a)\ z_L = \dfrac{Z_L}{Z_0}$

$= \dfrac{40 + j30}{100} = 0.4 + j0.3$

→ Draw s-circle

→ Locate y_L

$y_L = 1.6 - j1.2$

→ Locate points A and B (where s-circle intersects the 1+jb circle)

at A(1+j1.04), $y_s = -j1.04$

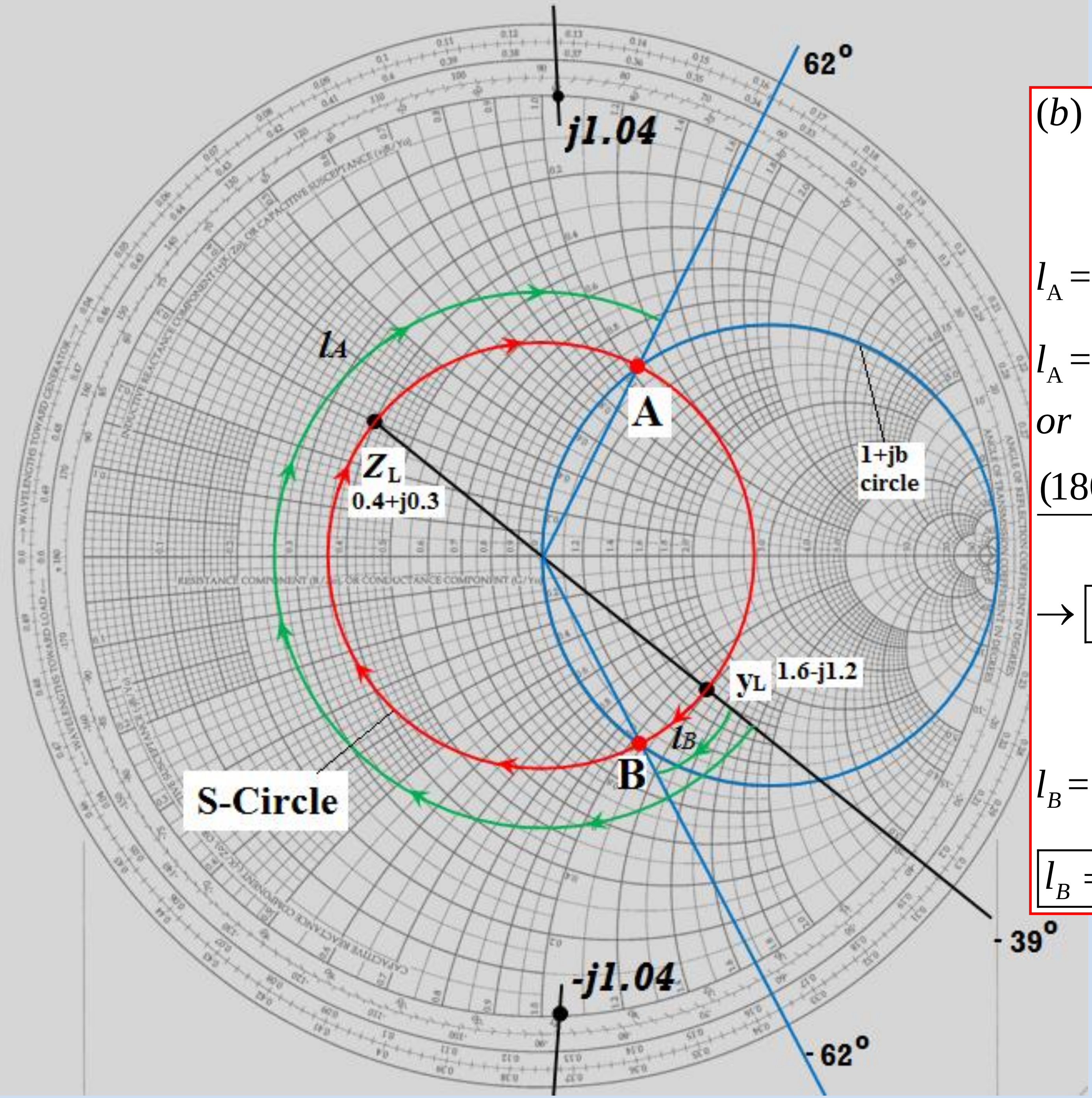
at B(1-j1.04), $y_s = +j1.04$

→ The required stub admittance is:

$Y_s = Y_0 y_s = \pm \dfrac{j1.04}{100}$

$\boxed{Y_s = \pm 10.4\ \text{mS}}$

Example 11.7



(*b*) Distance between y_L and stub is:

$$l_A = \frac{\lambda}{2} - \frac{(62^o + 39^o)\lambda}{720^o}$$

$$l_A = 0.36\lambda$$

or $l_A =$

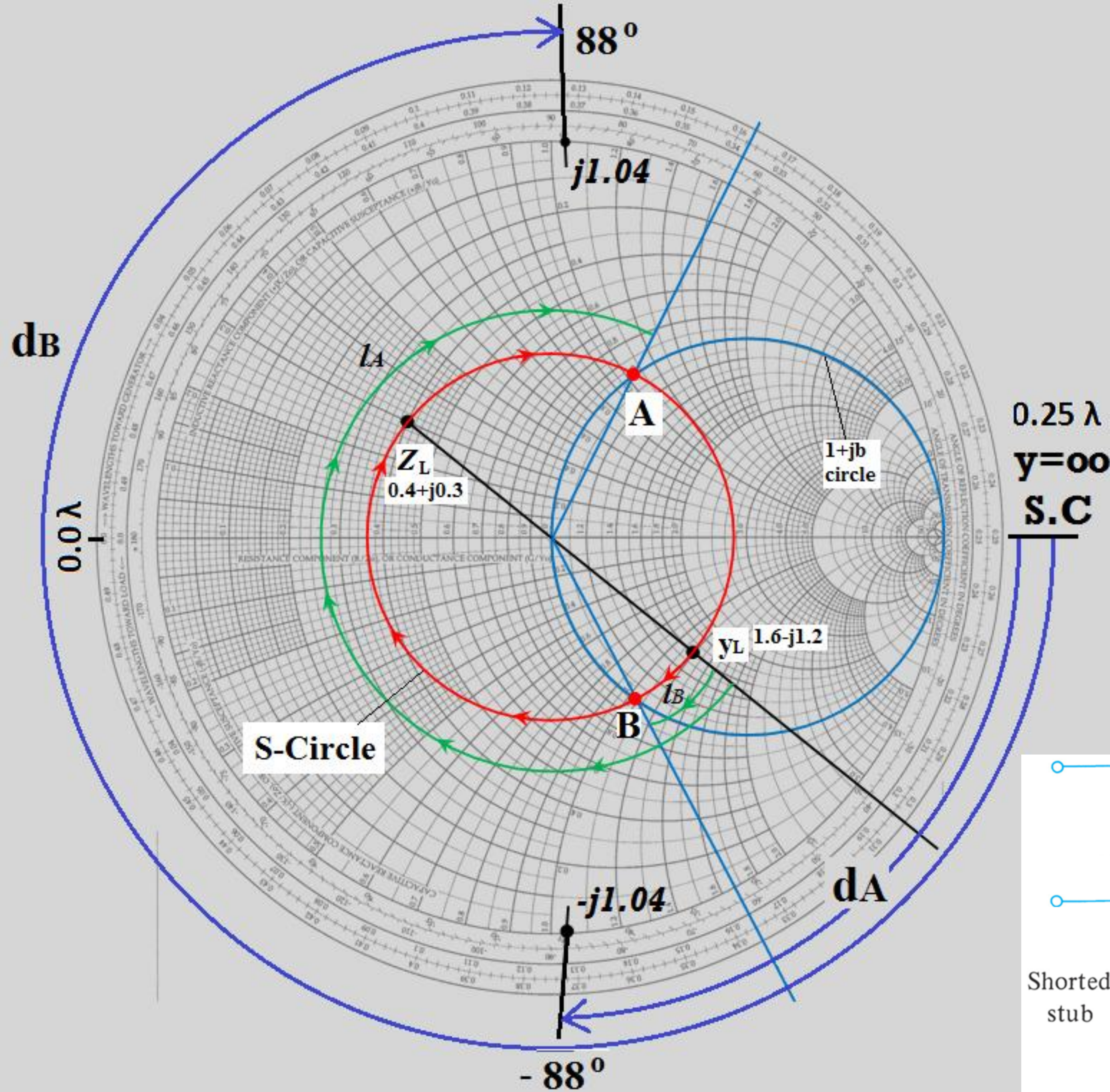
$$\frac{(180^o - 39^o) + (180^o - 62^o)}{(720^o)}\lambda$$

$$\rightarrow \boxed{l_A = 0.36\lambda}$$

$$l_B = \frac{(62^o - 39^o)\lambda}{720^o}$$

$$\boxed{l_B = 0.032\lambda}$$

Example 11.7



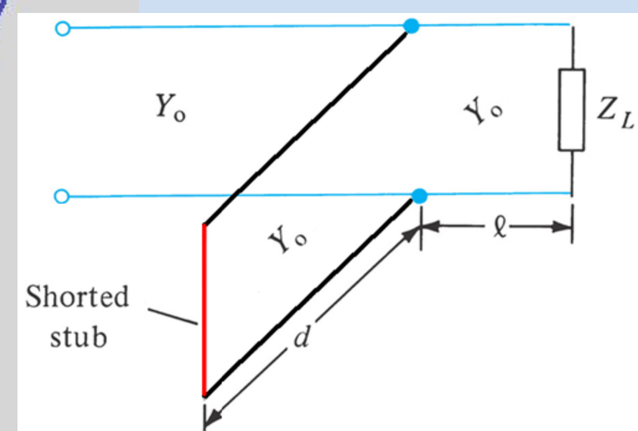
(c) Stub Length

$$d_A = \frac{88^o}{720^o}\lambda$$

$$d_A = 0.1222\lambda$$

$$d_B = \frac{(360^o - 88^o)}{720^o}\lambda$$

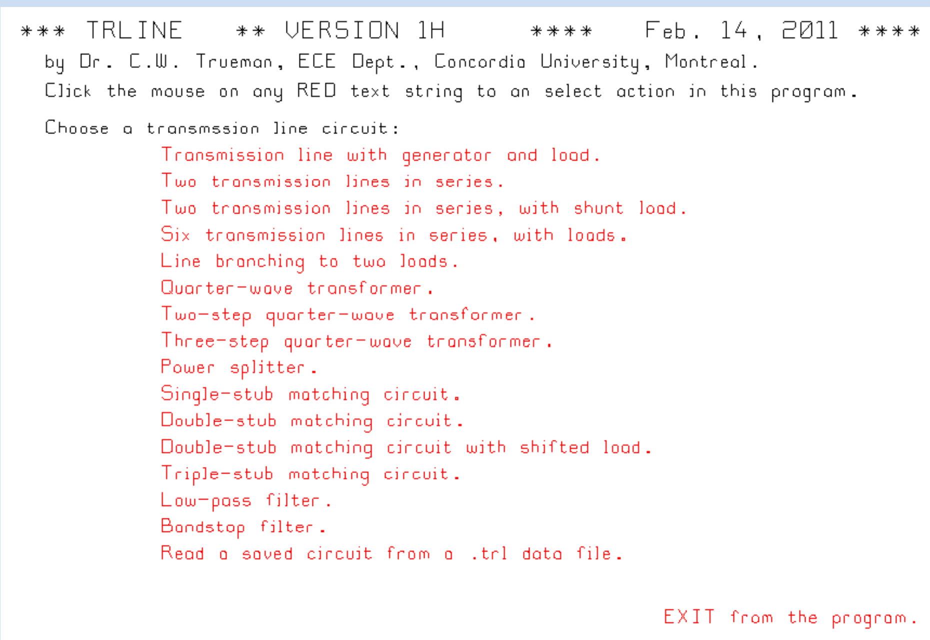
$$d_B = 0.3778\ \lambda$$

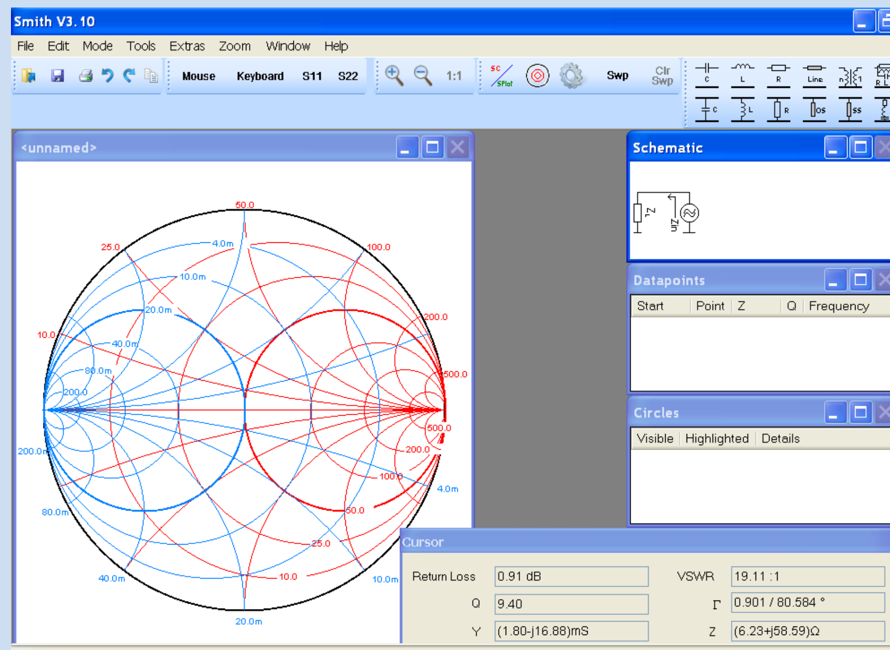


Transmission Line and Smith Chart - Tools

Software **TRLINE**

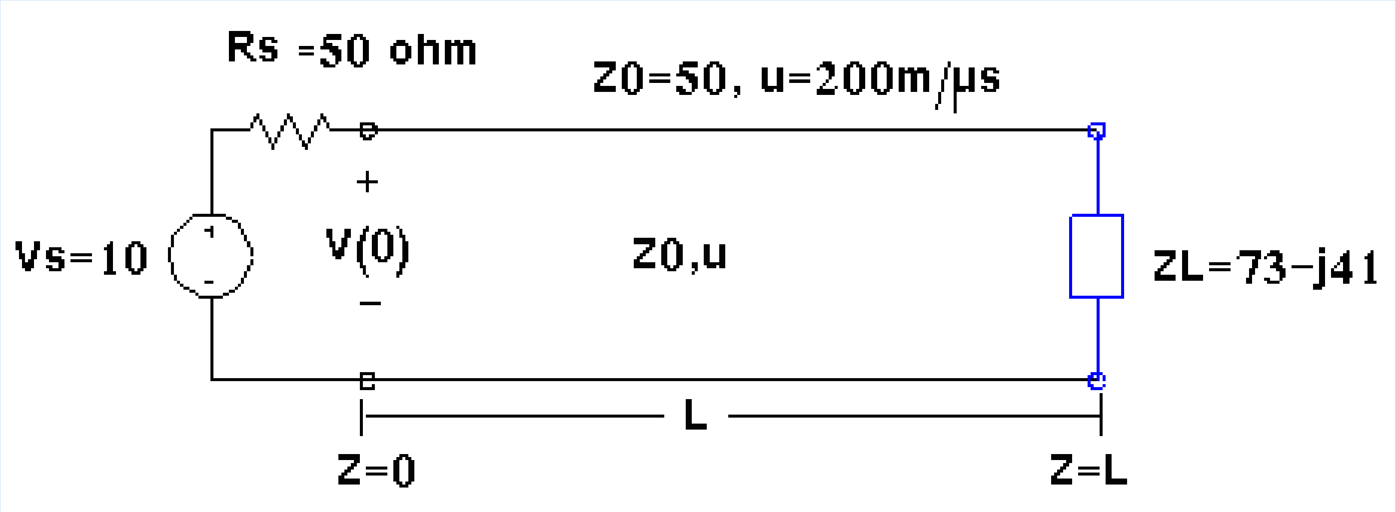
Software **Smith V3.10**





TRLINE - Example

Example: A radio-frequency generator at 100 MHz produces an open-circuit voltage of 10 volts amplitude and has an internal resistance of 50 ohms. It drives an antenna through a length of L=7.7 m of coaxial cable with characteristic resistance R_0=50 ohms and speed of travel *u=20* cm/ns. The input impedance of the antenna is Z_L=73-j41 ohms.



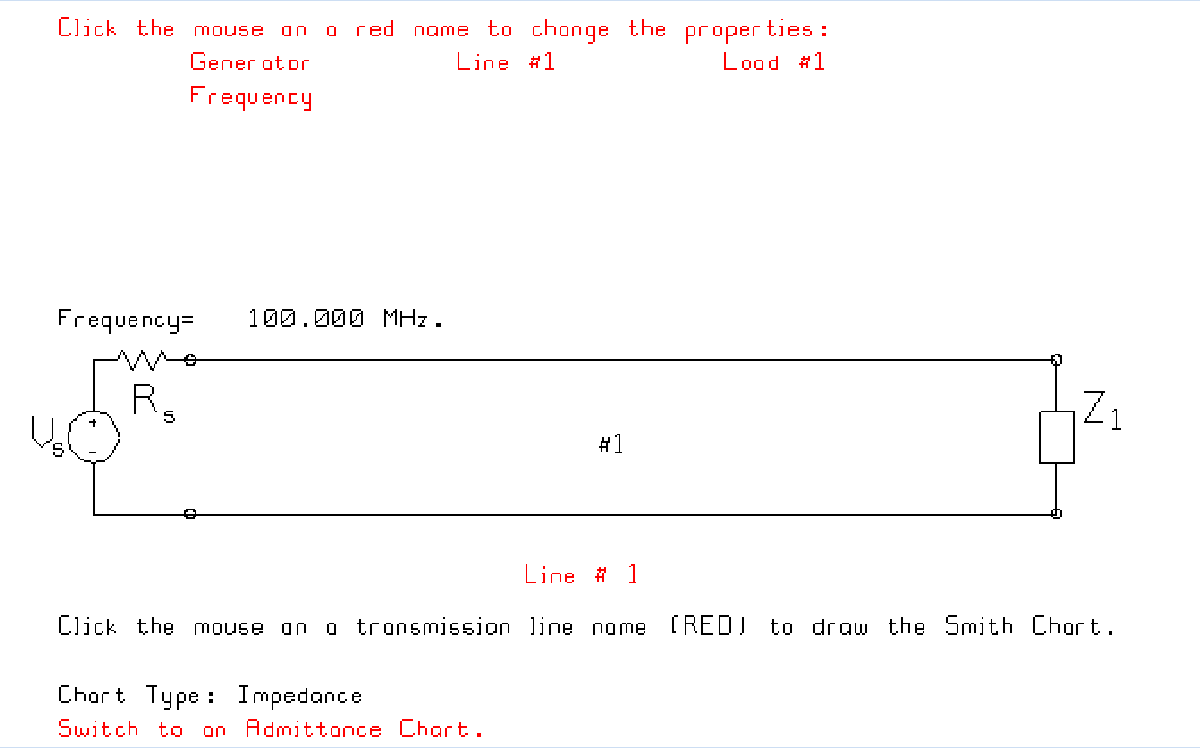
TRLINE - Example

(1) Run "TRLINE.EXE"

(2) Click the mouse on "Transmission line with generator and load".

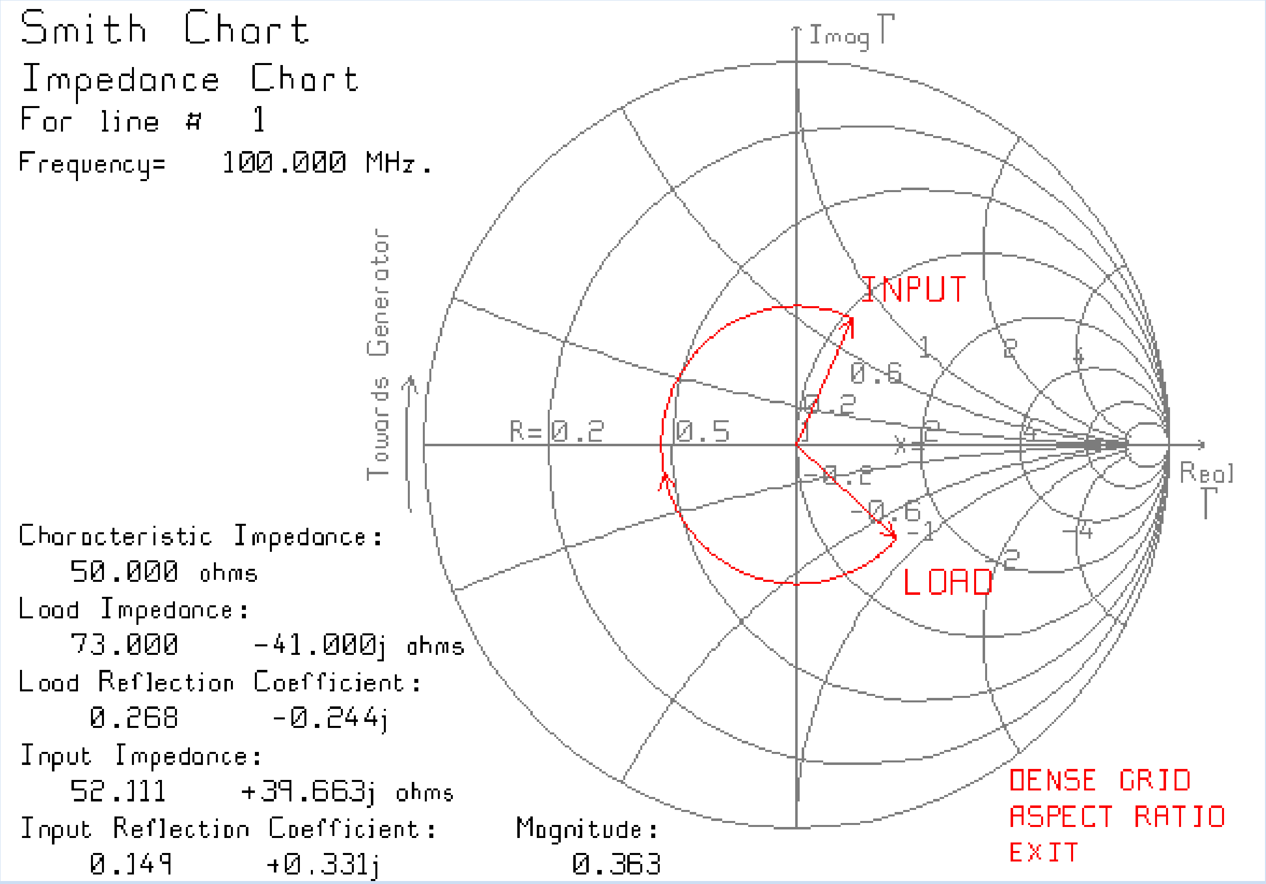
(3) Enter Parameters of Generator, Line #1, Load #1.

(4) Click the mouse on "Draw a Smith Chart"



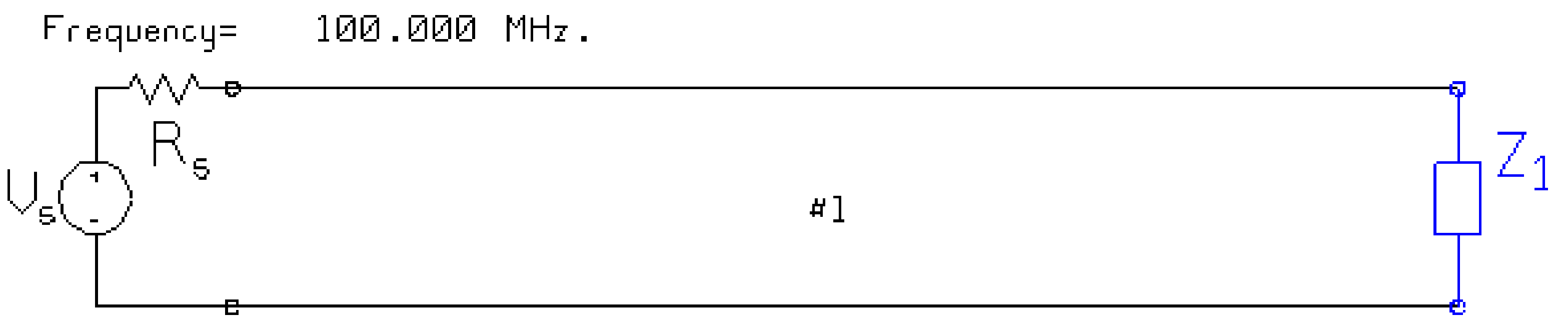
TRLINE - Example

(5) Let the chart type "Impedance Chart", then to find the input impedance for the transmission line, click the mouse on “Line #1”.



TRLINE - Example

(6) Exit Smith Chart, then click the mouse on “Find voltages, currents, and power”, then click “Load #1”



Load # 1:

Resistance = 73.00 ohms.

Reactance = -41.00 ohms.

Voltage = 6.458 volts R.M.S., with phase 43.1 degrees.

Current = 77.13 milliamps R.M.S., with phase 72.4 degrees.

Power = 434.3 milliwatts.

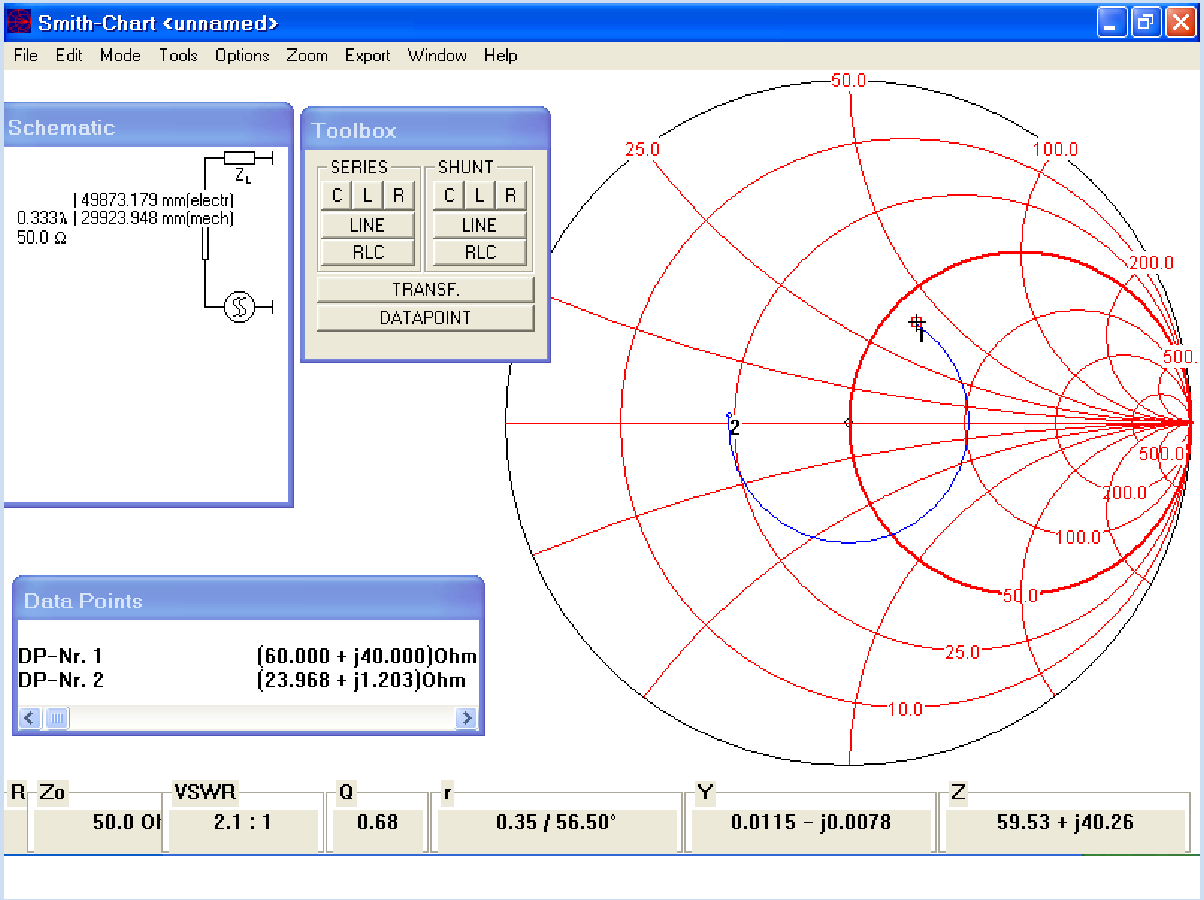
Smith Chart software - Example

Example: A 30m long lossless transmission line with Z_0=50 Ω operating at 2MHz is terminated with a load Z_L=60+j40 Ω, u=0.6c on the line. Use Smith software to find: The reflection coefficient, standing wave ratio and the input impedance.

1) run **Smith v2.00** software.
2) Choose DATAPOINT from Toolbox and then choose Keyboard, Fill in the Load Impedance ZL=60+j40 and the frequency=2MHz then press OK to return to the main screen.
3) From the Toolbox choose series LINE, and fill the characteristic impedance of the line=50 Ω, and εr=2.777 then press OK.
4) Note that $u = 0.6c = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\varepsilon_0\varepsilon_r}} = \frac{1}{\sqrt{\varepsilon_r}}c \Rightarrow \frac{1}{\sqrt{\varepsilon_r}} = 0.6 \Rightarrow \varepsilon_r = 2.7777$

Smith Chart software - Example

5) move clockwise a distance toward generator equals 0.333 λ. Note:($\lambda = u/f = 0.6 * 3 * 10^8 / 2 * 10^6 = 90m$, then the length of line=30m=0.333 λ).



Smith Chart software - Example

<u>Now, Record the results:</u>

❖the input impedance is that at data point #2, Zin = 23.968+j1.203.

❖to know the value of VSWR, put the mouse on any point in the circle, then VSWR=2.1.

❖To know the reflection coefficient, put the mouse pointer on data point #1, then record the reflection coefficient, or double click on data point # 1 then choose reflection coefficient, Γ_L = $0.2+j0.29 = 0.35/56^0$.