How does a Smith Chart work?

Microwave Engineering

http://sss-mag.com/pdf/smith_chart_basics.pdf

Smith Chart

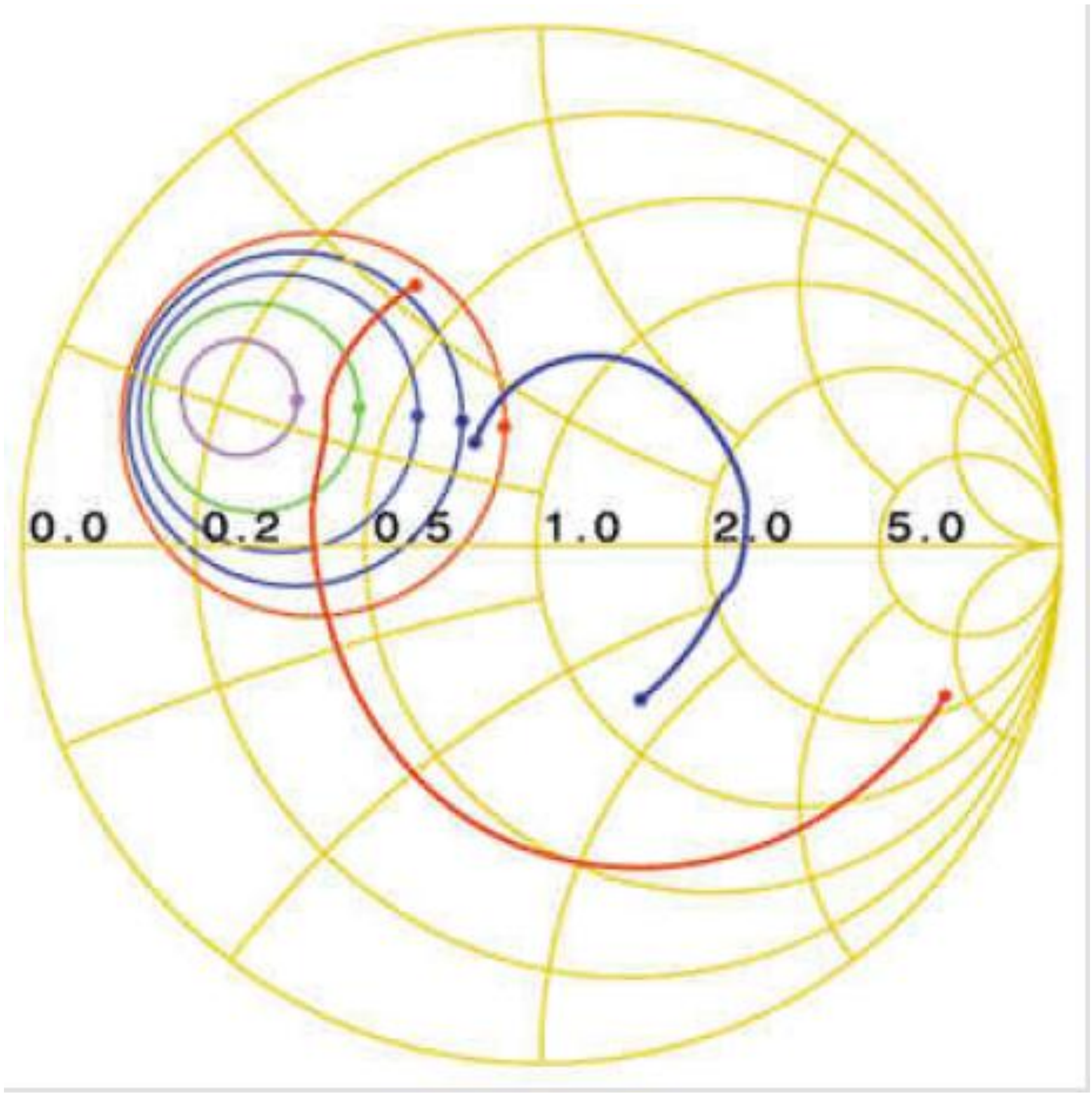


Fig. 1

Smith Chart

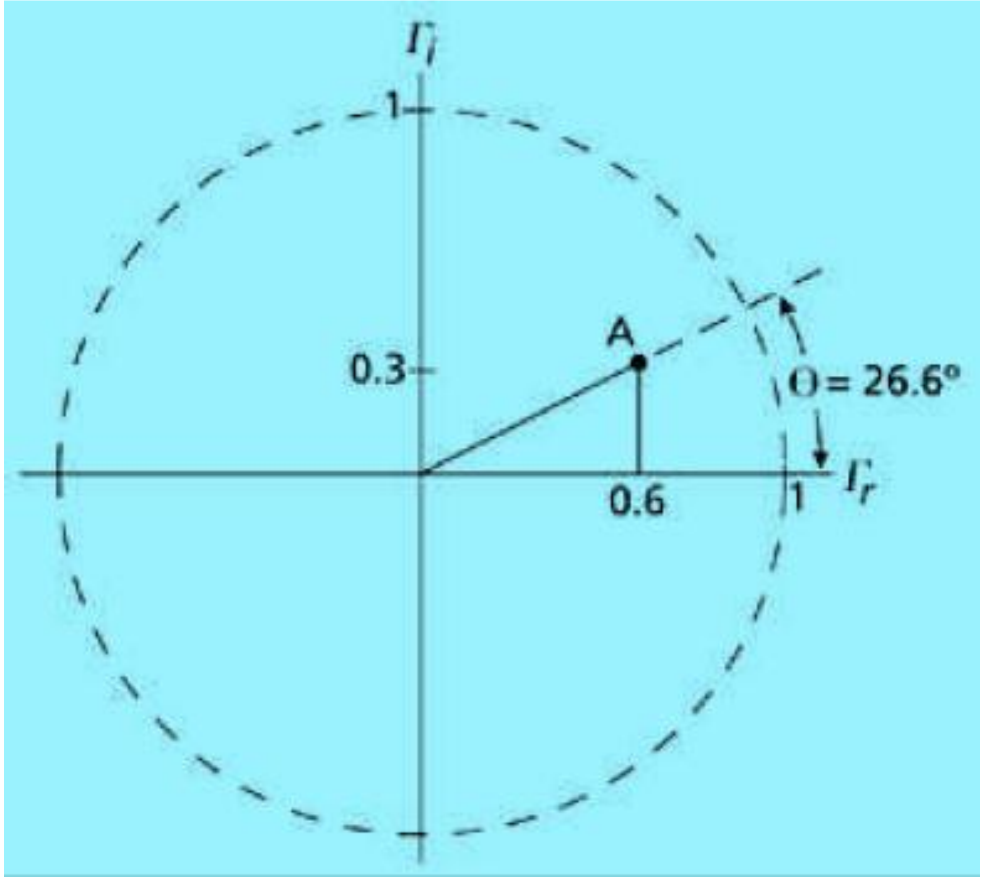


Fig. 2

Smith Chart

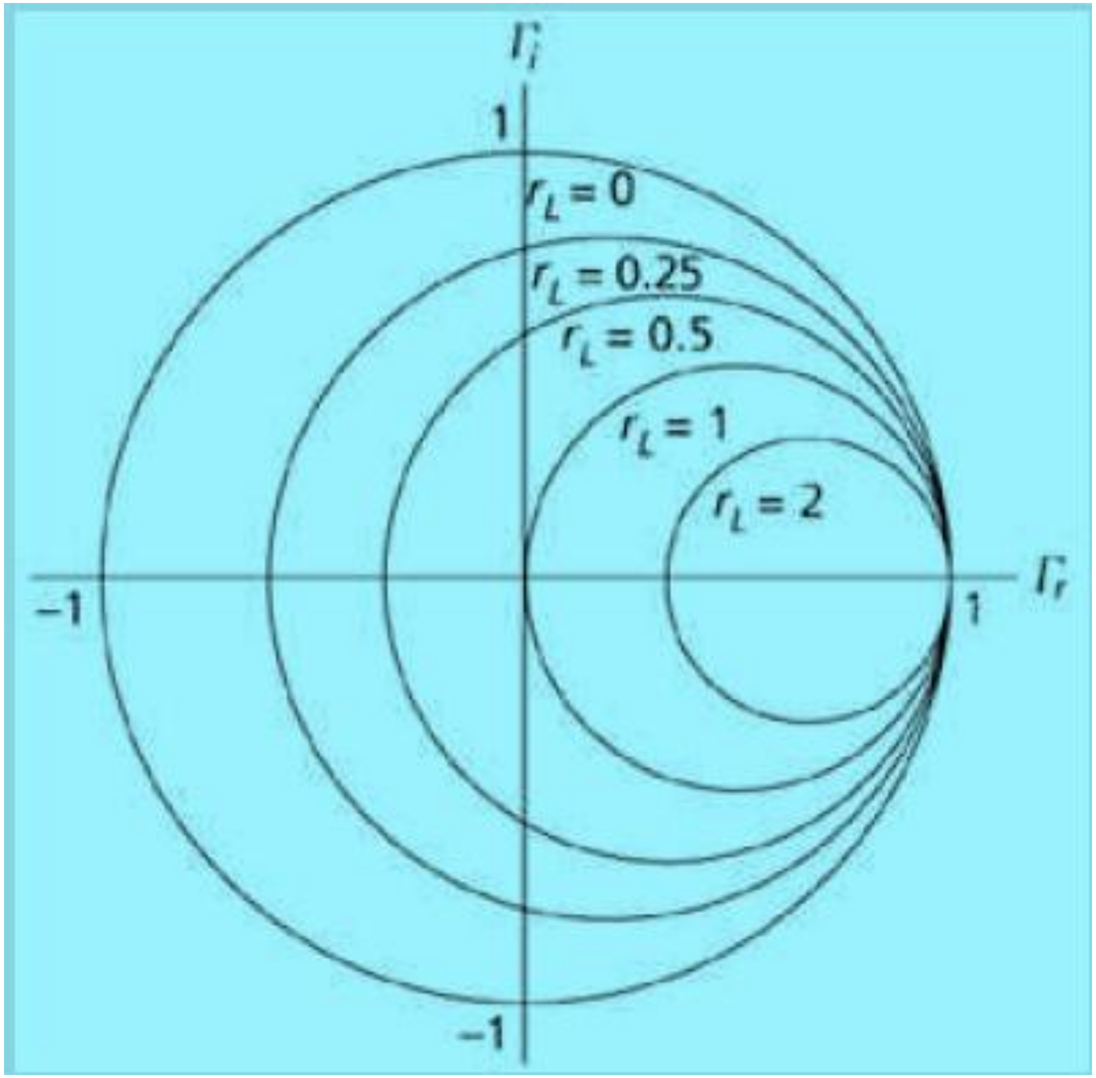


Fig. 3

SmithChart

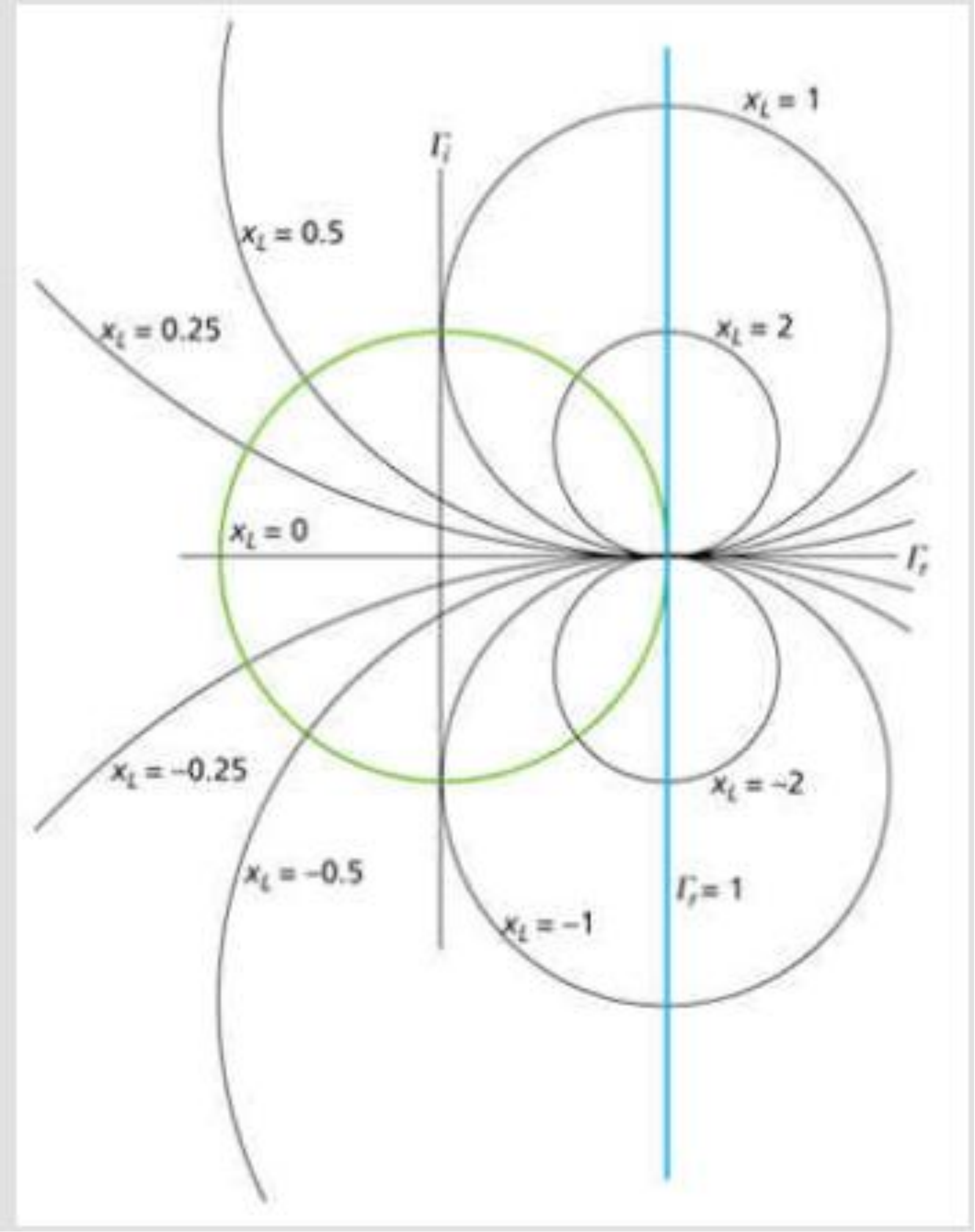


Fig. 4

Smith Chart

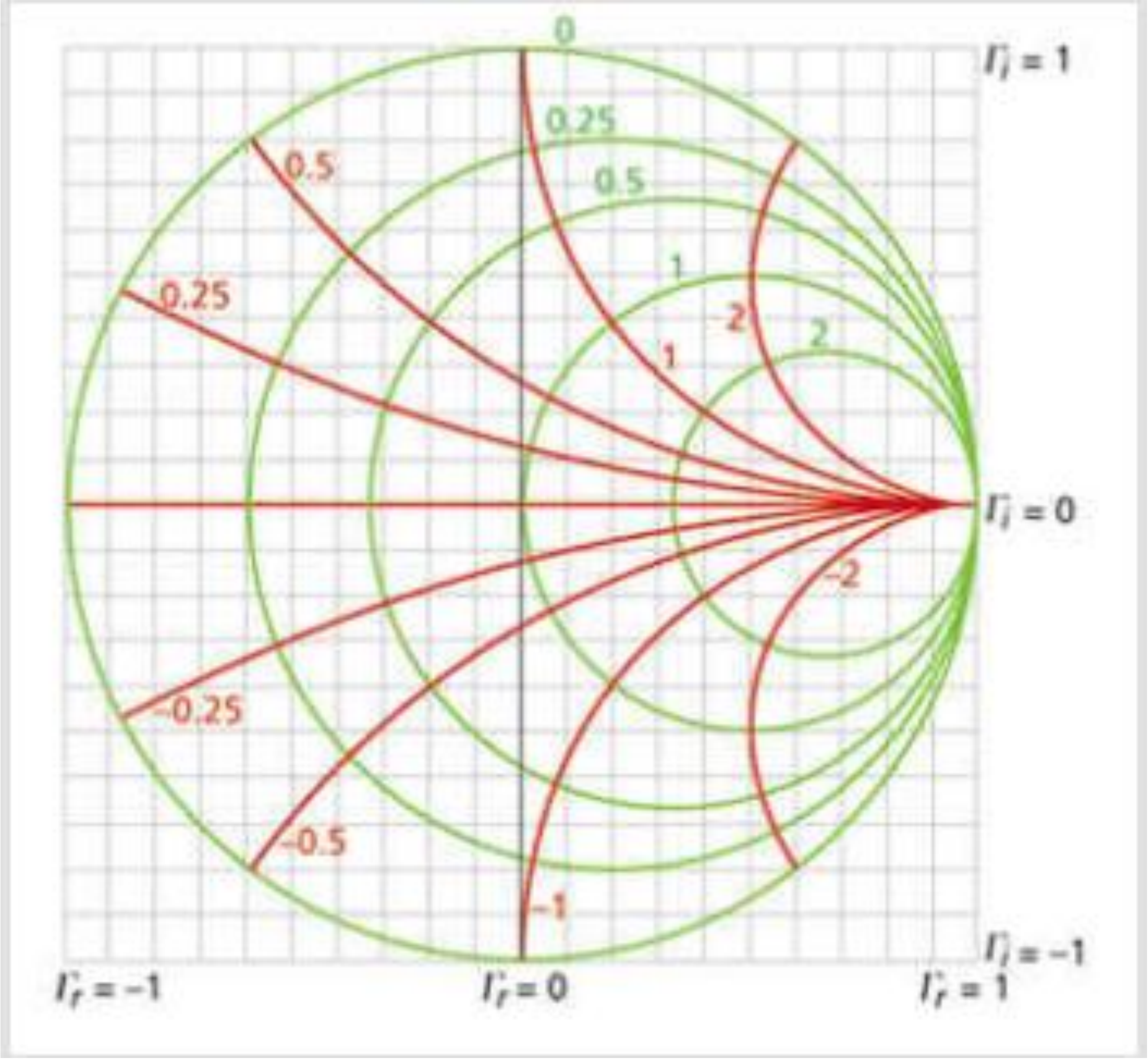


Fig. 5

Smith Chart

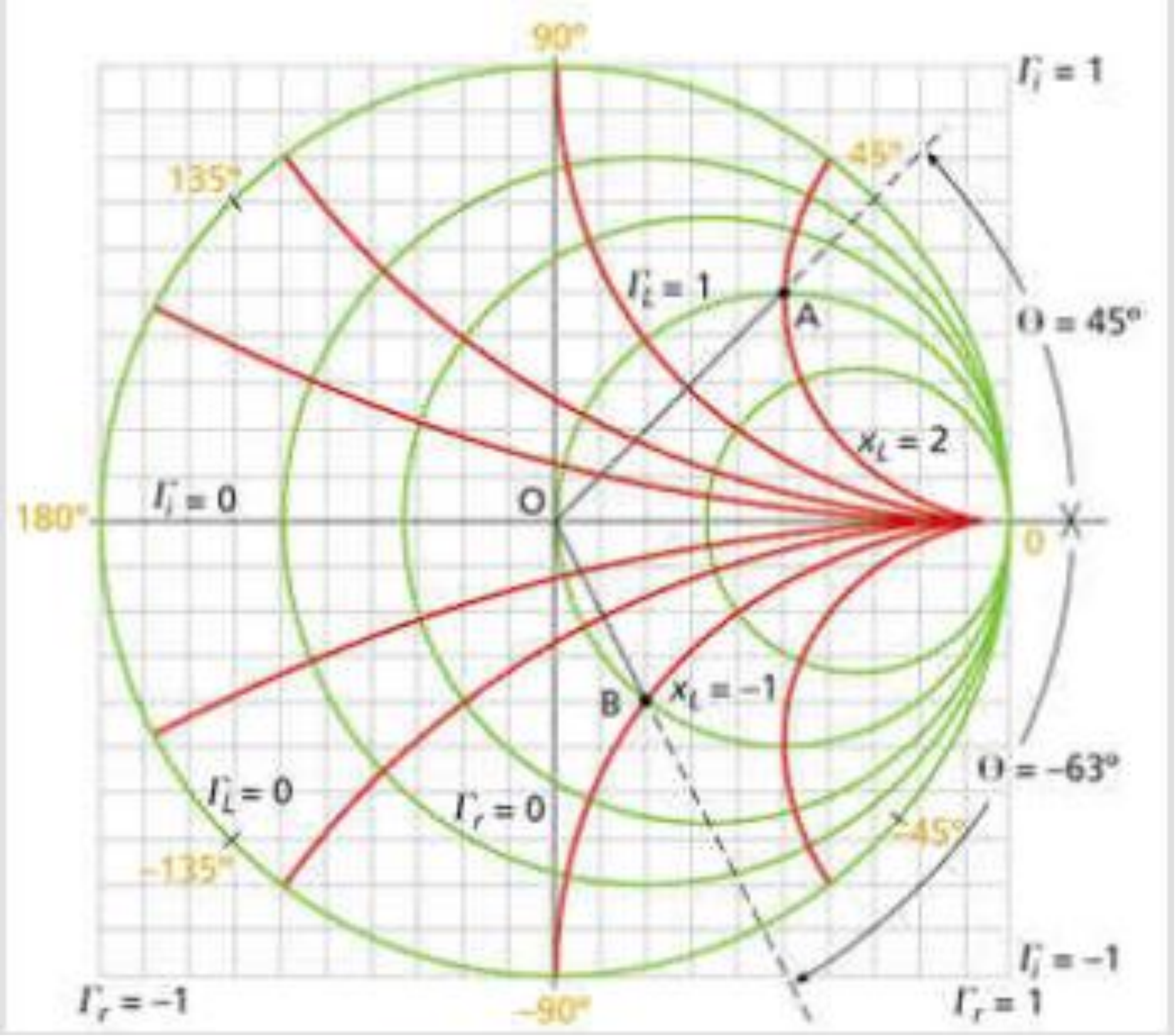


Fig. 6

Smith Chart

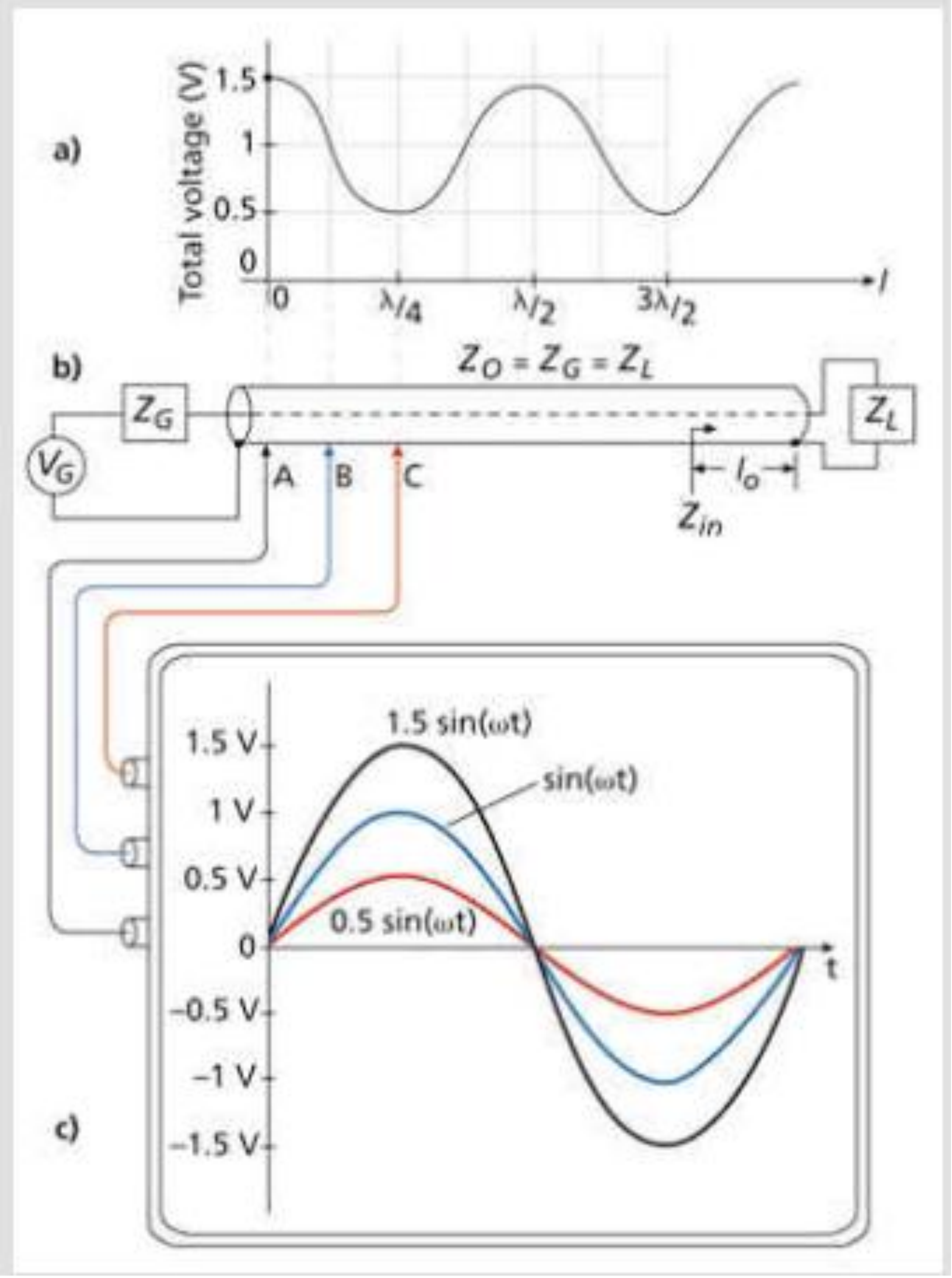


Fig. 7

Smith Chart

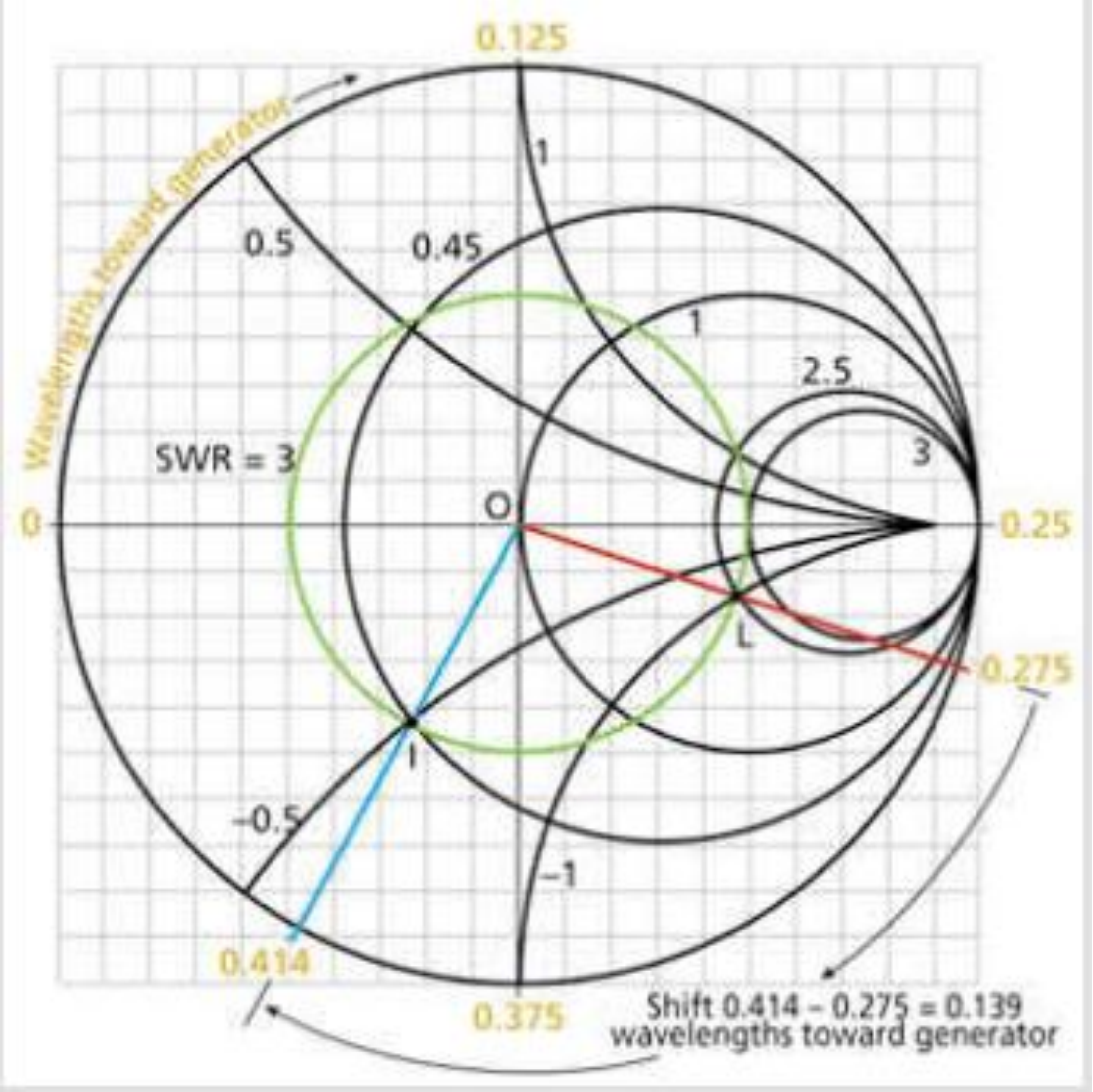
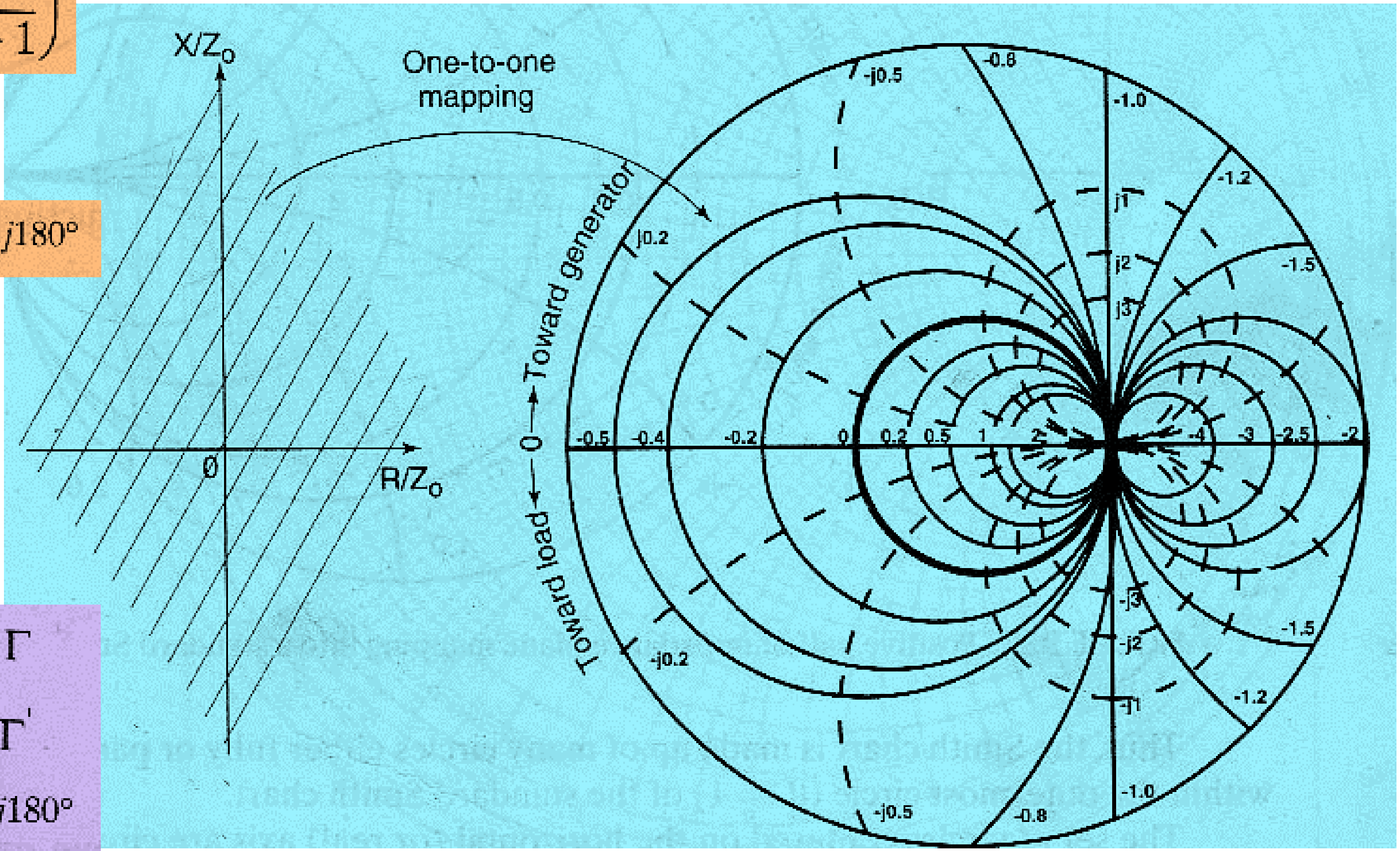


Fig. 8

Smith Chart

$$\Gamma' = \left(\frac{Y_N - 1}{Y_N + 1}\right)$$

$$\Gamma' = -\Gamma = \Gamma\, e^{j180°}$$

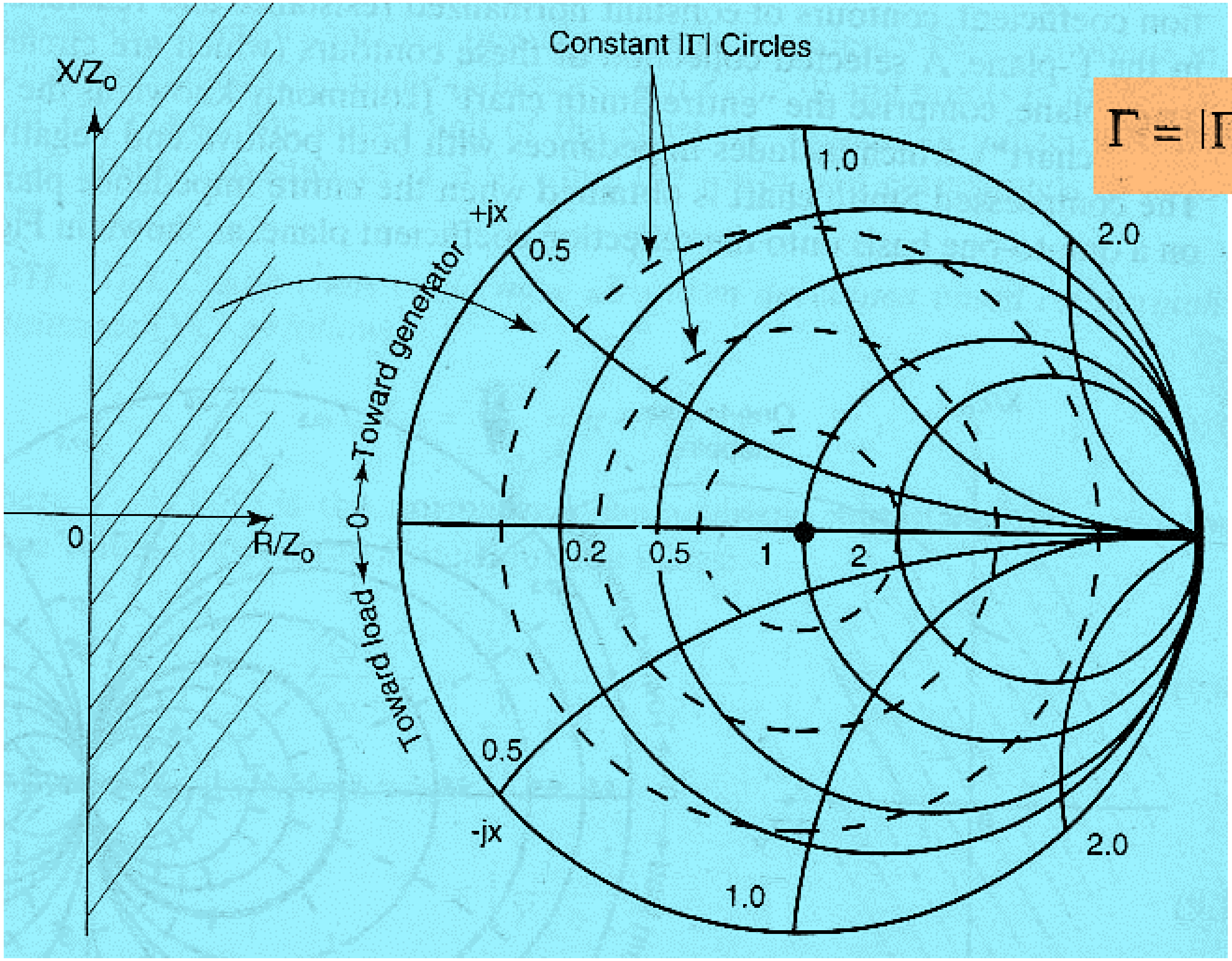


$$Z_N \leftrightarrow \Gamma$$

$$Y_N \leftrightarrow \Gamma'$$

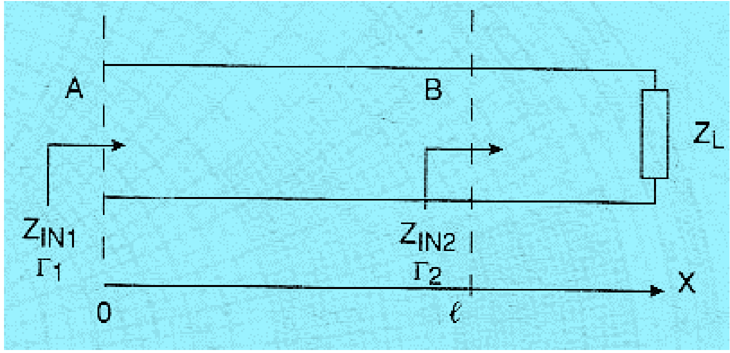
$$\Gamma' \leftrightarrow \Gamma\, e^{j180°}$$

Smith Chart

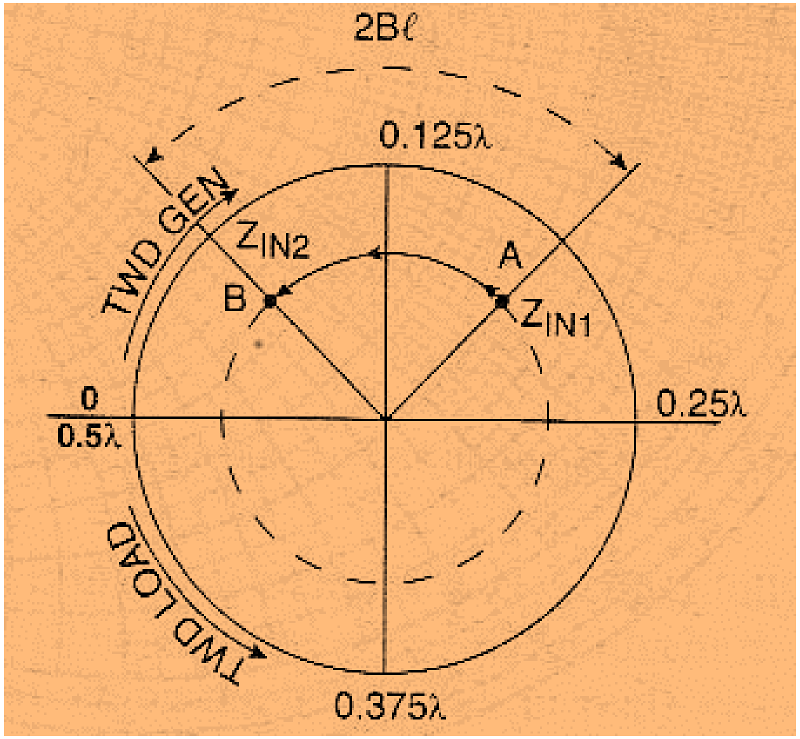


$$\Gamma = |\Gamma| e^{j\theta}, \quad 0 \leq \theta \leq 180^\circ$$

Smith Chart



A
B
Z_L
Z_{IN1}
Γ_1
Z_{IN2}
Γ_2
X
0
ℓ



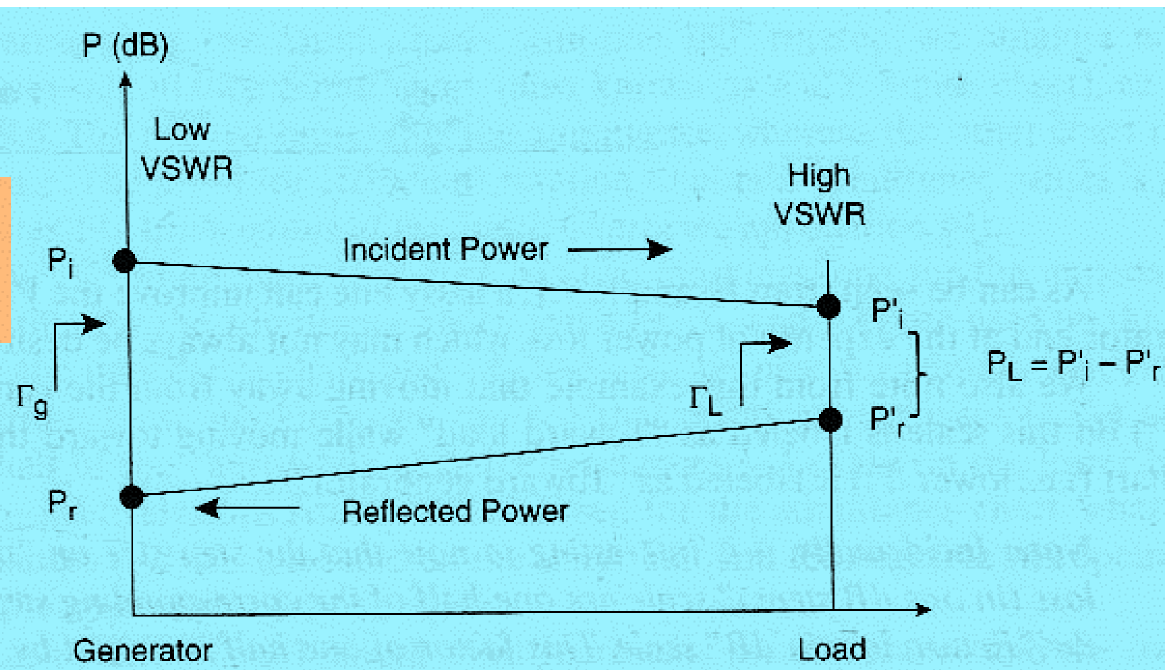
$2B\ell$
0.125λ
TWD GEN
Z_{IN2}
A
B
Z_{IN1}
0
0.5λ
0.25λ
TWD LOAD
0.375λ

Smith Chart: Scale

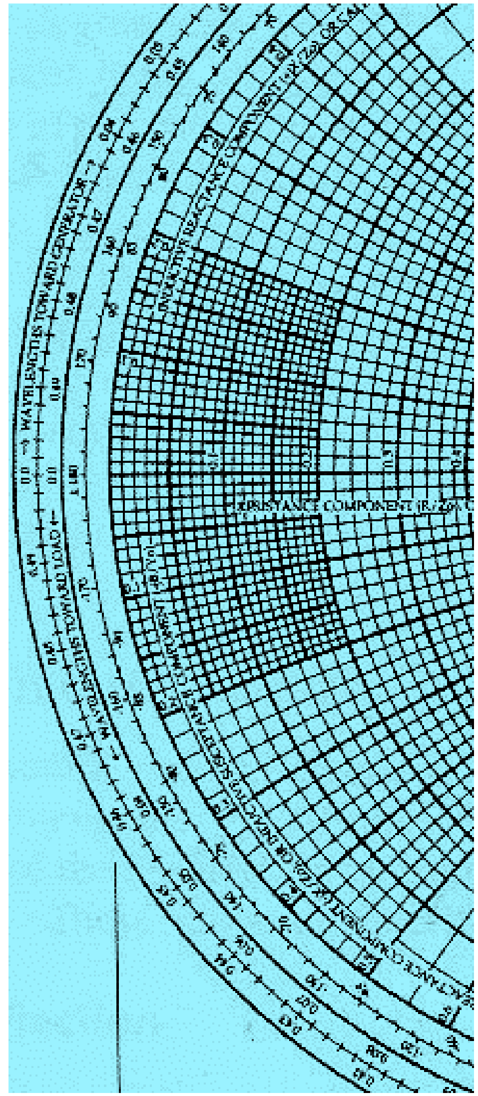
- Wavelength Scale
- Degree Scale
- Reflection: REFL. COEF (VOL, PWR); Loss in dB (RETN, REFL)
- Transmission Loss: LOSS COEF., 1 dB steps
- Standing Wave: VOL. RATIO, IN DB

$$|\Gamma_g|^2 = P_r/P_i \quad \text{(at the source end)}$$

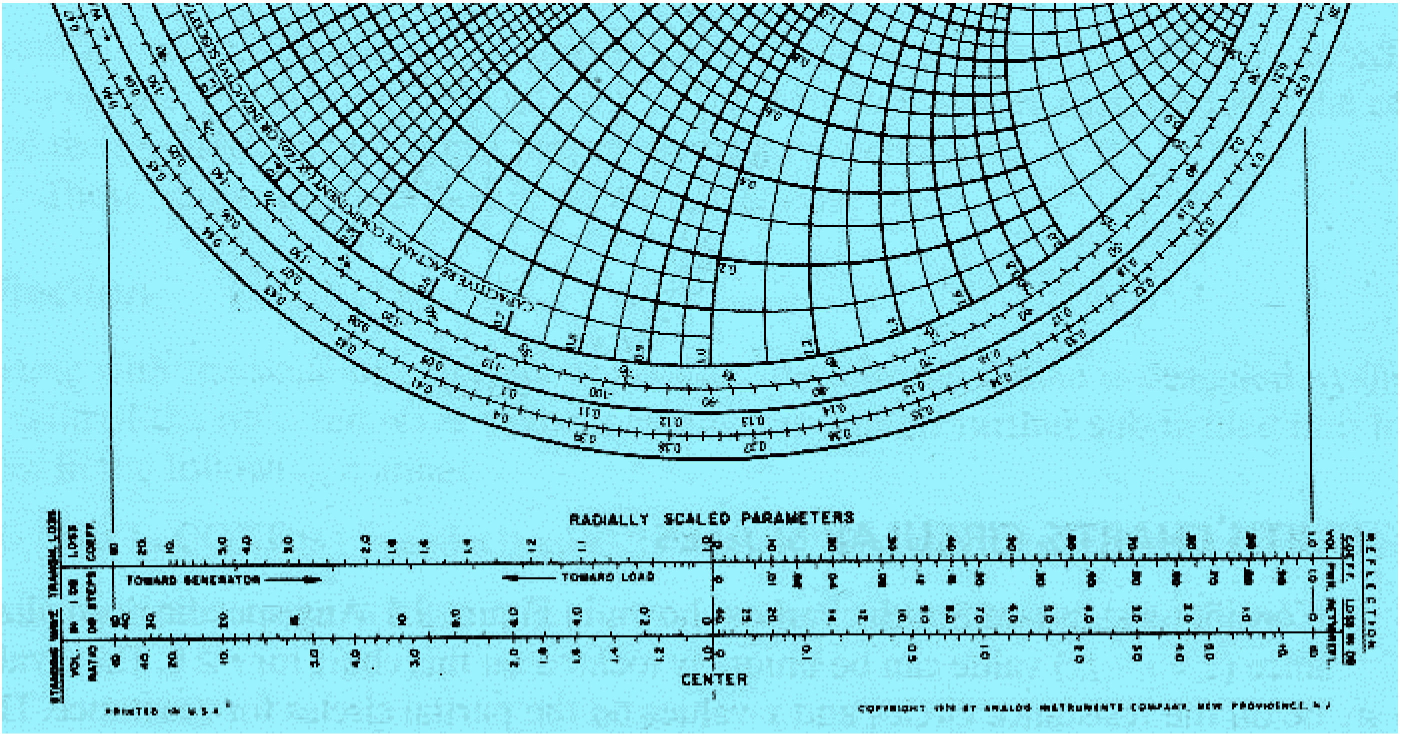
$$|\Gamma_L|^2 = P_r'/P_i' \quad \text{(at the load end)}$$



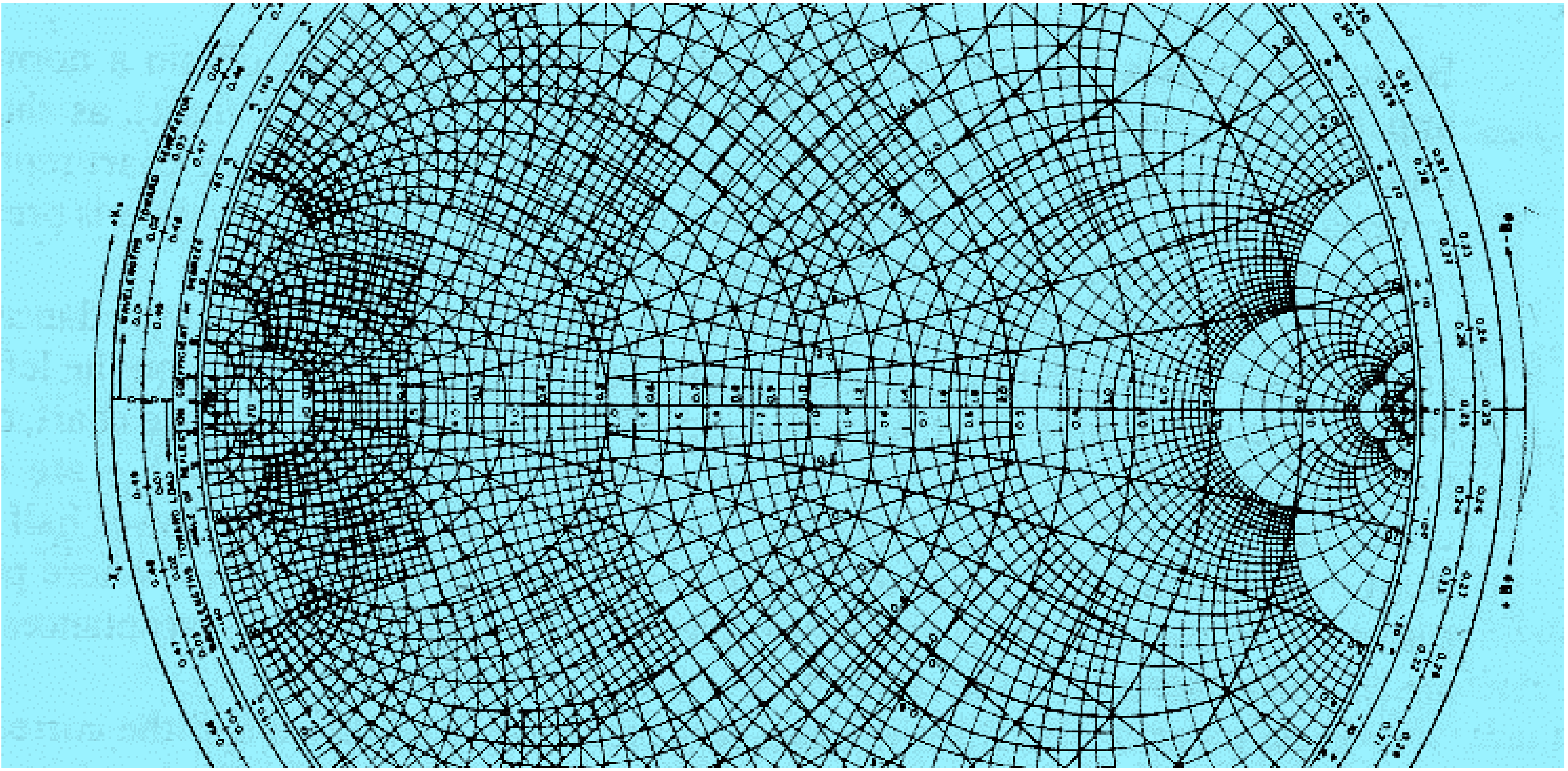
Smith Chart



Smith Chart: Radial Scale



Smith Chart: ZY



Applications of Smith Chart

- I/P Imp Z_IN using a known load Z_L
- I/P Imp using I/P reflection coeff<1
- I/P Imp using I/P reflection coeff>1

- Admittance from Imp
- Value and location of Z_max and Z_min from known Z_L
- Imp using single stubs

- Lumped: Series & Shunt

Applications of Smith Chart

- Admittance from Impedance

$$Z_N(x)=[1+\Gamma(x)]/[1-\Gamma(x)]$$

and

$$Y_N(x) = 1/Z_N(x) = [1-\Gamma(x)]/[1+\Gamma(x)]$$

where

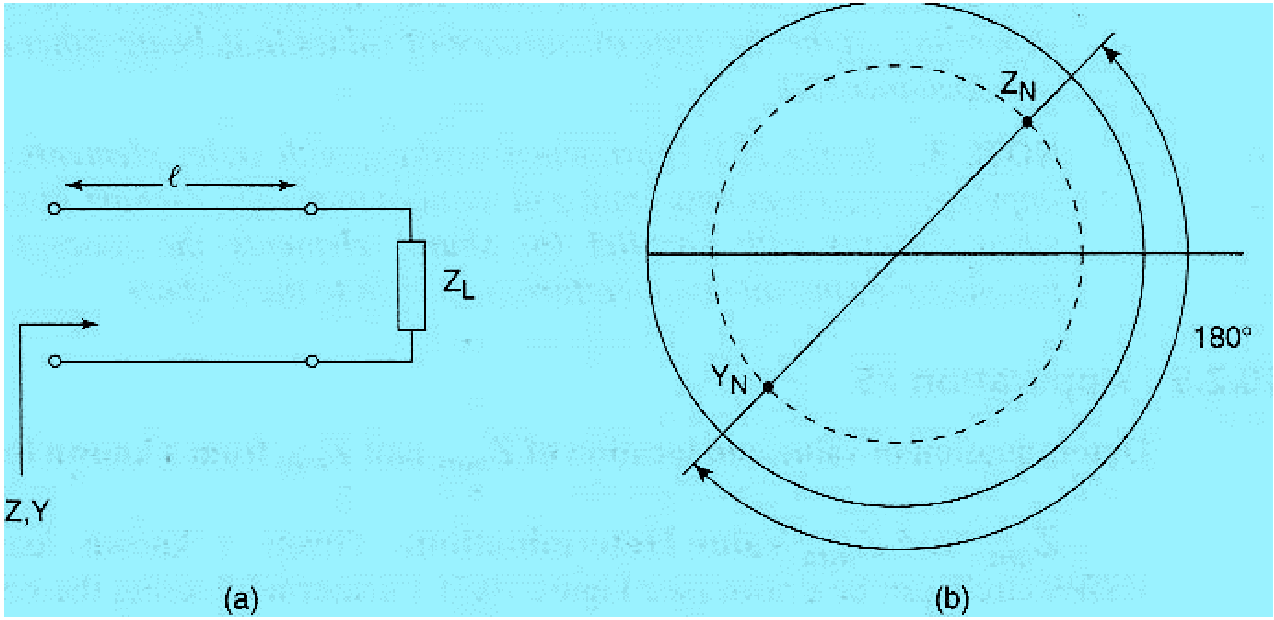
$$\Gamma(x) = \Gamma_L\, e^{j2\beta x}$$

- Y_N is located 180 deg opposite to Z_N on VSWR circle

Find the admittance value for an impedance value of $Z = 50 + j50\ \Omega$, in a 50 Ω system.

Applications of Smith Chart

$$Z_o = 50\ \Omega \Rightarrow Y_o = 1/50 = 0.02\ S$$



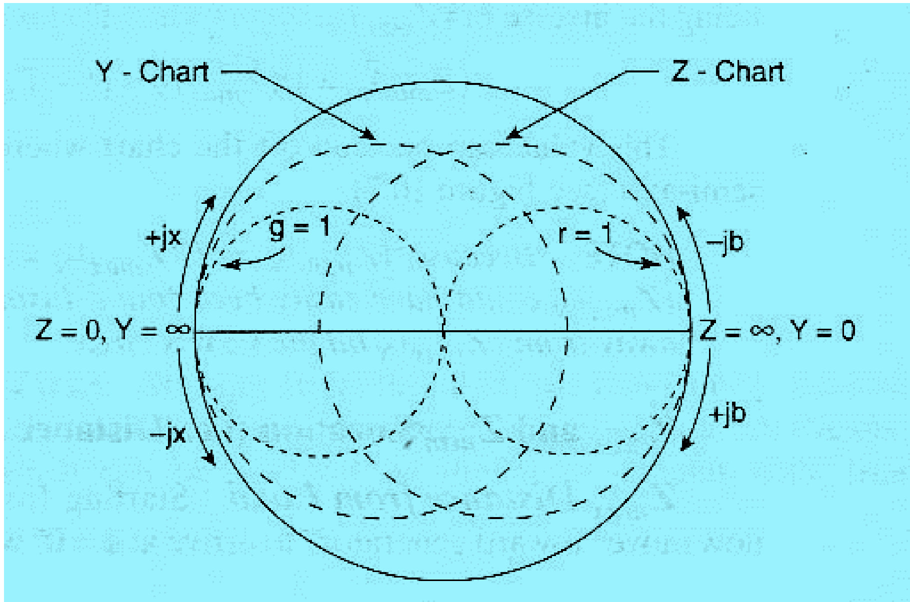
Applications of Smith Chart

$$Z_N = Z/Z_o = 1 + j1$$

$$Y_N = 0.5 - j0.5$$

$$Y = Y_o Y_N \Rightarrow Y = 0.01 - j0.01 \text{ S}$$

- Z-Y Conversion



Applications of Smith Chart

- Value and Location of Z_max and Z_min from a known load Z_L.

$$\Gamma(x) = \Gamma_L \, e^{j2\beta x},$$

where $\Gamma_L = |\Gamma_L| \, e^{j\theta}$. Therefore, we can write:

$$\Gamma(x) = |\Gamma_L| \, e^{j\phi(x)}, \quad \phi(x) = 2\beta x + \theta$$

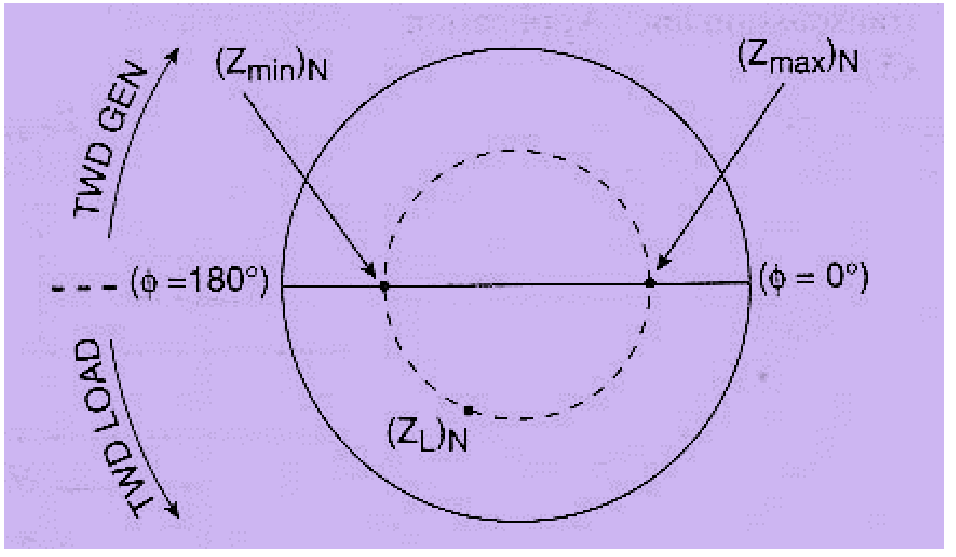
and

$$[Z_{IN}(x)]_N = Z_{IN}(x)/Z_o = [1 + \Gamma(x)]/[1 - \Gamma(x)]$$

- Max I/P Z_max occurs when Numerator is max and denominator is min

$\Gamma(x) = |\Gamma_L| \, e^{j\phi(x)}$ is a positive real number, i.e., $\phi(x) = 0$,

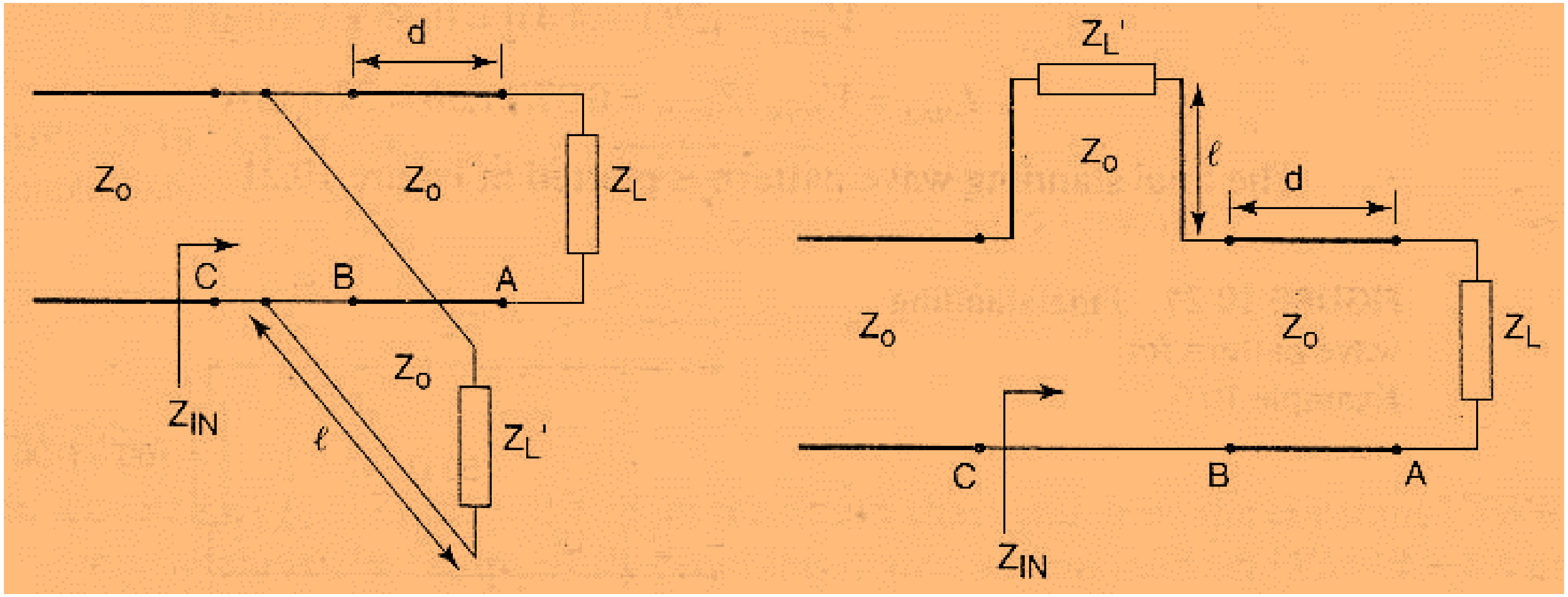
Applications of Smith Chart



$$(Z_{min})_N = 1/(Z_{max})_N = [1 - |\Gamma_L|]/[1 + |\Gamma_L|]$$

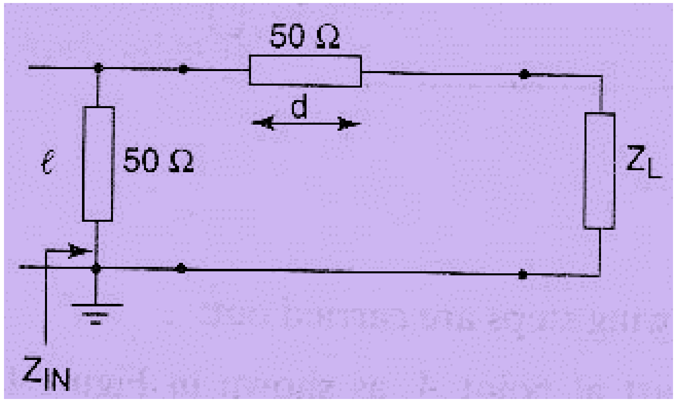
Applications of Smith Chart

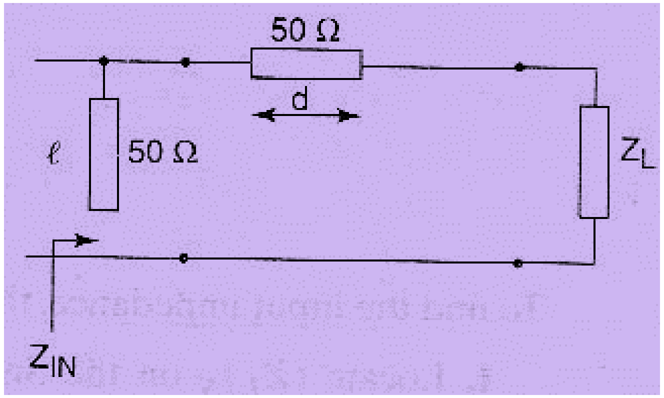
- Input Impedance using single Stubs

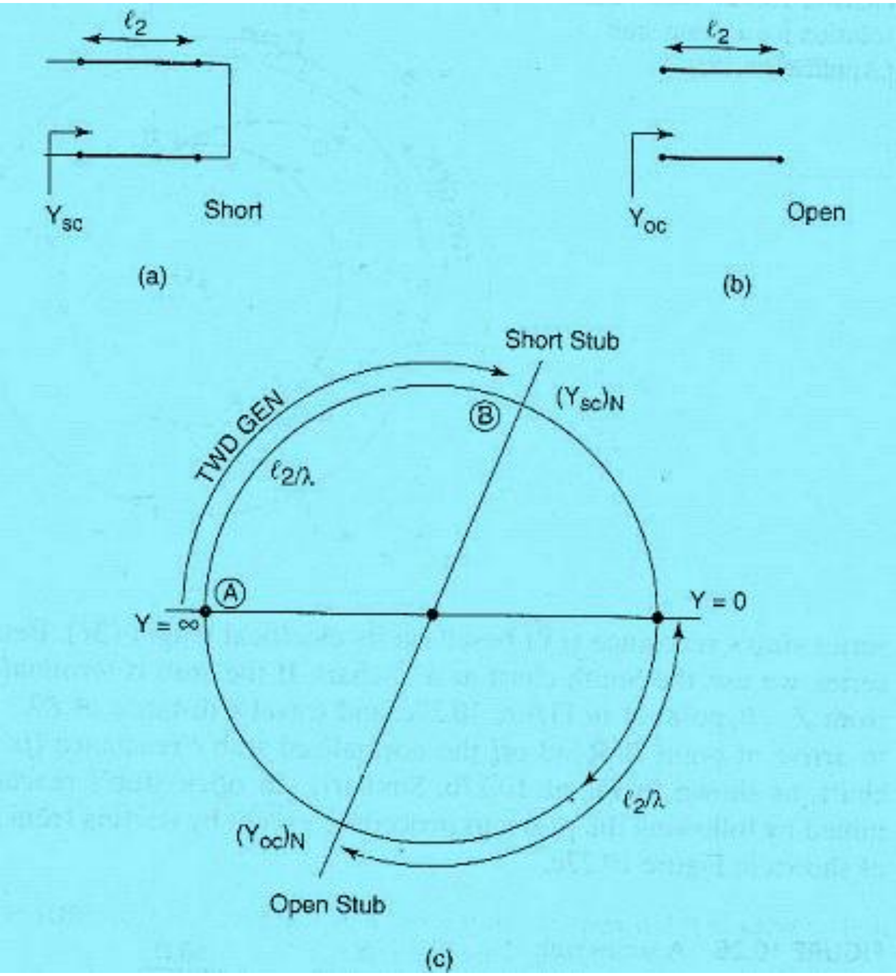


Applications of Smith Chart

- For parallel Stubs



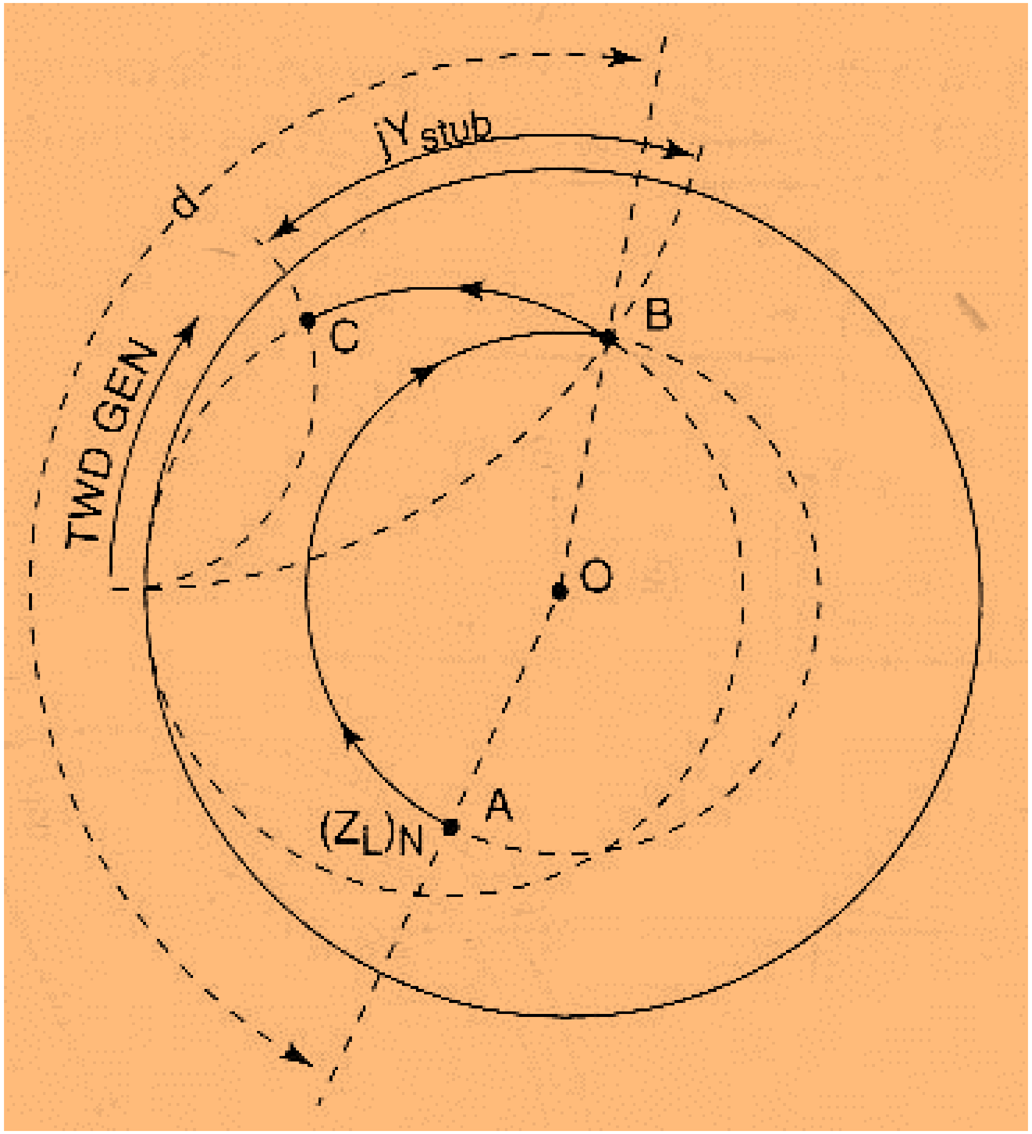




Applications of Smith Chart

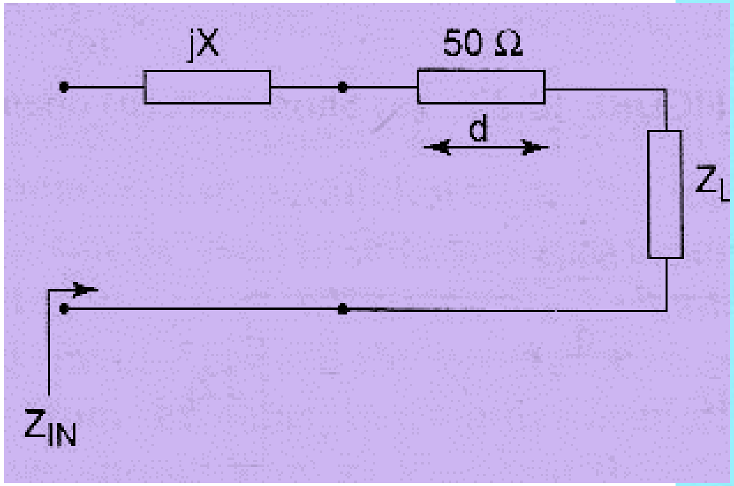
1. Locate Z_L on the Smith chart (use a ZY chart) at point A in Figure 10.25.
2. Draw the constant $VSWR$ circle.
3. Travel a distance (d) toward the generator on the $VSWR$ circle to arrive at point B.
4. Now because we are adding the parallel stub, we must switch to the Y-chart and travel on a constant conductance circle an amount equal to the susceptance of the stub to arrive at point C, as shown in Figure 10.25.
5. To find the input impedance, we switch back to the Z-chart and read off the normalized values (r, x) at point C corresponding to $(Z_{IN})_N$. The total input impedance is given by:

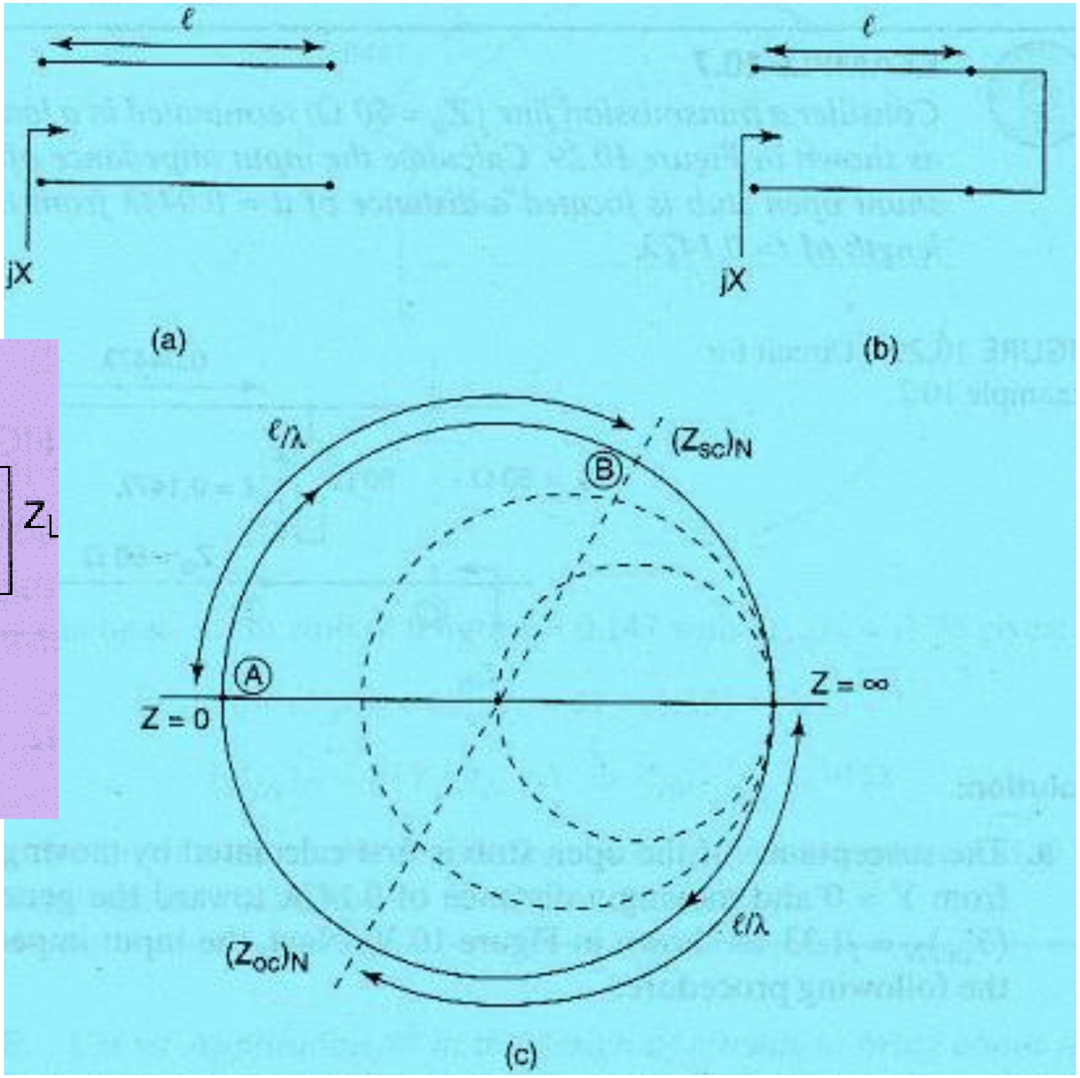
Applications of Smith Chart



Applications of Smith Chart

- Series Stubs:

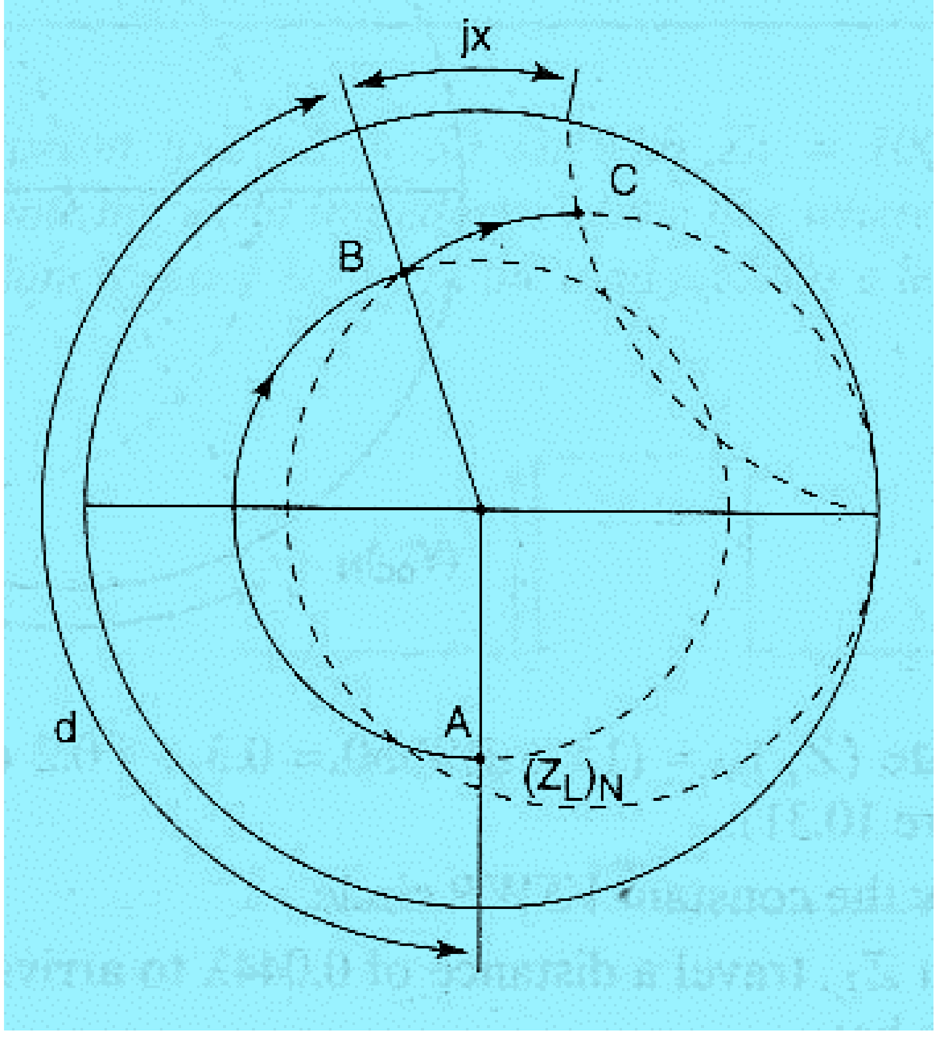




Applications of Smith Chart

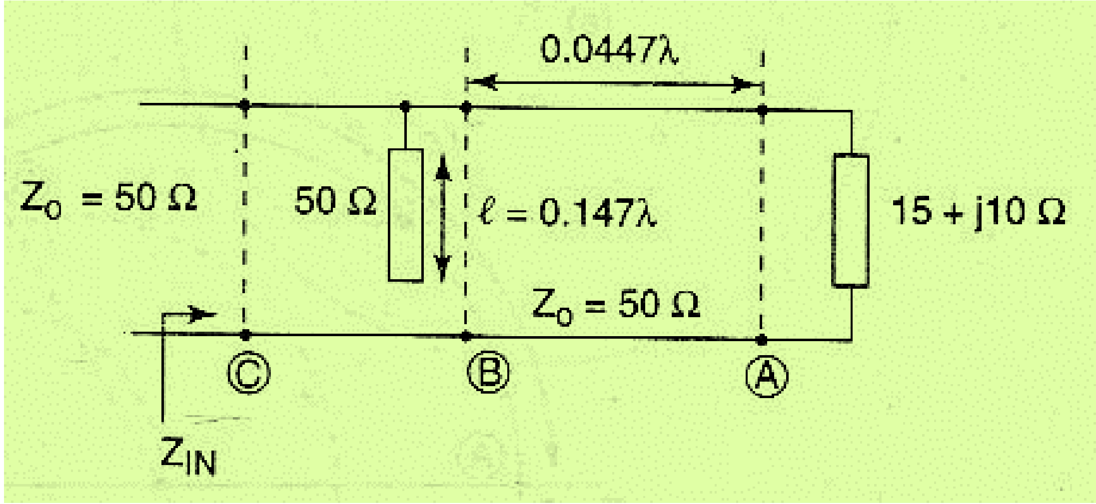
1. Locate $(Z_L)_N$ on the Smith chart at point A, as shown in Figure 10.28 (use a Z-chart).
2. Draw the constant $VSWR$ circle.
3. From $(Z_L)_N$, travel a distance (d) toward the generator on the $VSWR$ circle to arrive at point B.
4. Now, because we are adding the series stub, we travel on a constant resistance circle an amount equal to the reactance of the stub, jx, to arrive at point C.
5. The input impedance is read off at point C in Figure 10.28.

Applications of Smith Chart



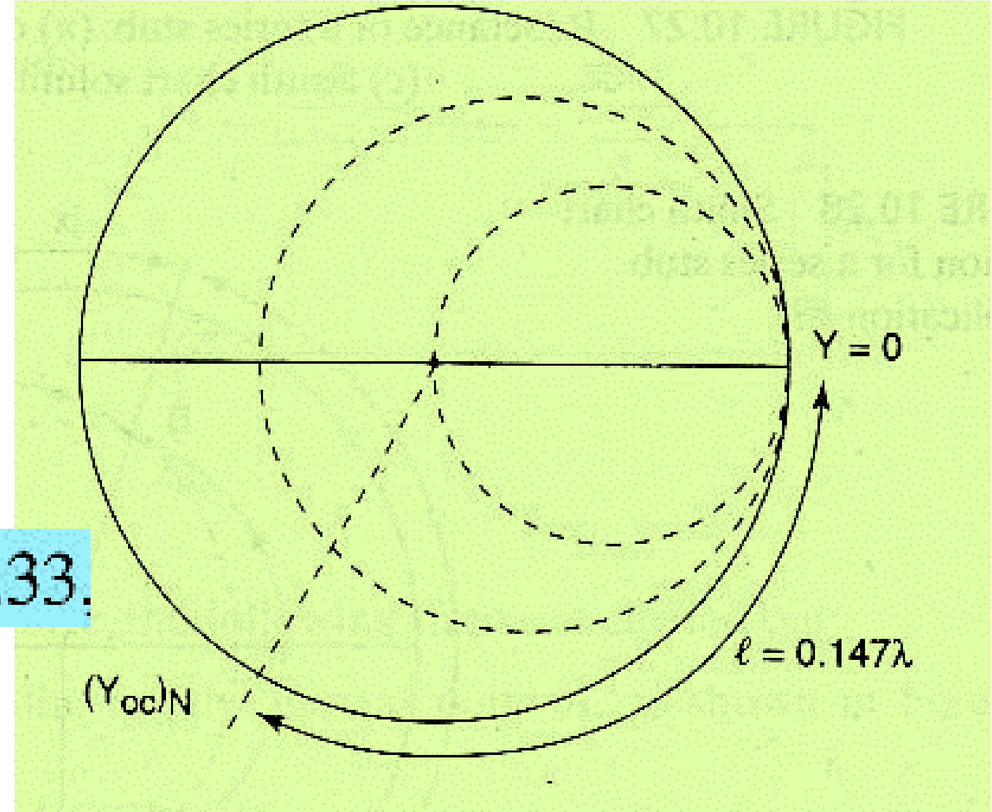
Applications of Smith Chart

Consider a transmission line ($Z_o = 50\ \Omega$) terminated in a load $Z_L = 15 + j10\ \Omega$, as shown in Figure 10.29. Calculate the input impedance of the line where the shunt open stub is located a distance of $d = 0.044\lambda$ from the load and has a length of $\ell = 0.147\lambda$.



Applications of Smith Chart

$(Y_{oc})_N = j1.33.$



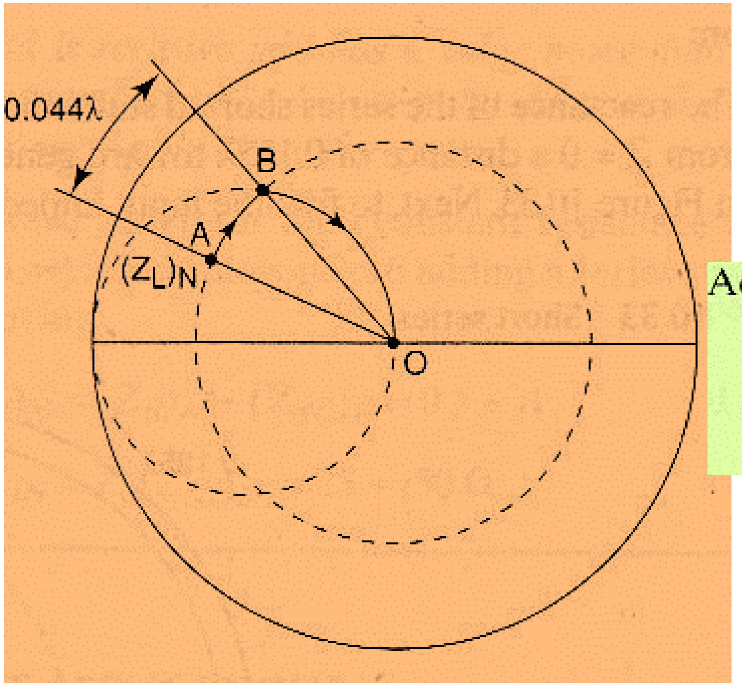
Applications of Smith Chart

b. Locate $(Z_L)_N = (15 + j10)/50 = 0.3 + j\,0.2$ on the Smith chart (see point A in Figure 10.31).

c. Draw the constant $VSWR$ circle.

d. From Z_L, travel a distance of 0.044λ to arrive at point B. The admittance is read off to be:

$$(Y_B)_N = 1 - j1.33 \text{ (point } B \text{ in Figure 10.31)}$$



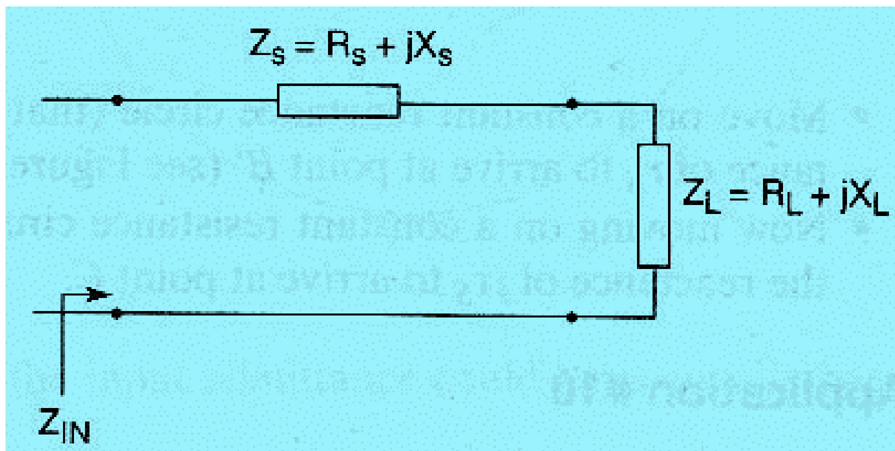
Adding an open shunt stub of length $\ell = 0.147$ with $(Y_{oc})_N = j1.33$ gives:

$$(Y_{IN})_N = (Y_B)_N + (Y_{oc})_N = (1 - j1.33) + j1.33 = 1$$

$$(Z_{IN})_N = 1/(Y_{IN})_N = 1 \Rightarrow Z_{IN} = Z_o = 50\ \Omega$$

Applications of Smith Chart

- Smith Ch for Lumped Elements CKT
- I/P Imp for a series lumped element



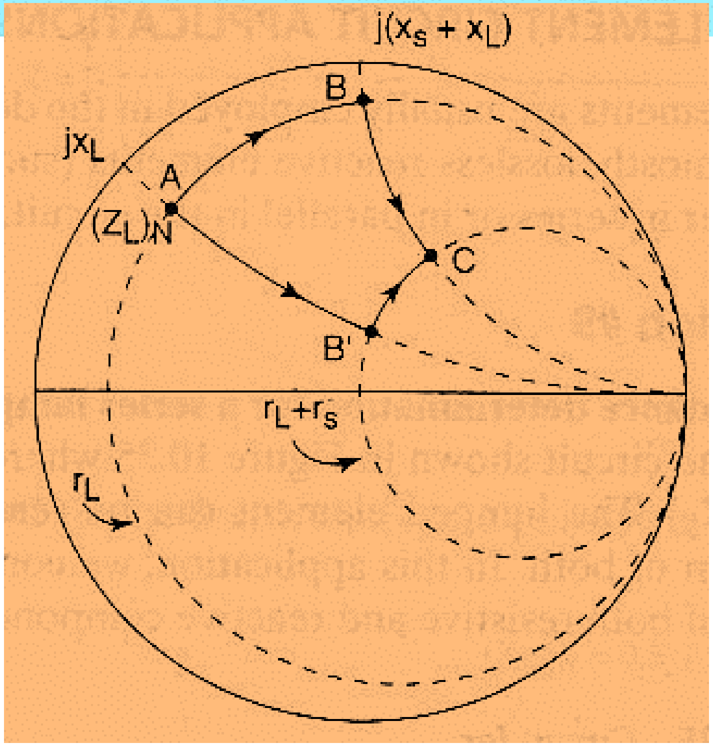
$$Z_{IN} = Z_L + Z_S$$

$$(Z_{IN})_N = (r_L + r_S) + j(x_L + x_S)$$

Z Chart, since series

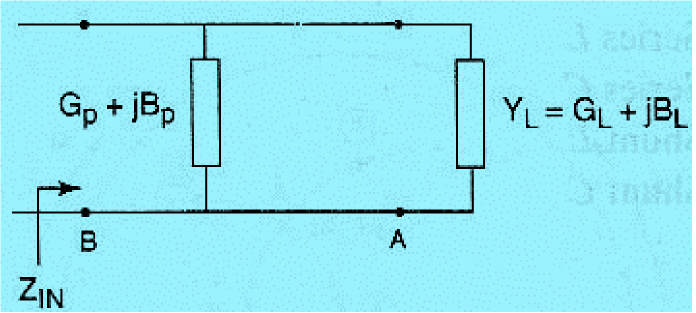
Applications of Smith Chart

1. Locate $(Z_L)_N$ on the Smith chart (see point A in Figure 10.36).
2. Moving on the constant resistance circle that passes through Z_L, add a reactance of jx_S to arrive at point B.
3. Now moving on a constant reactance circle that passes through point B, add a resistance of r_S to arrive at point C.
4. The input impedance value is read off at point C, using the Z-chart markings.



Applications of Smith Chart

- I/P Admittance For a shunt lumped element



$$Y_{IN} = Y_L + Y_P$$

$$(Y_{IN})_N = (g_L + g_P) + j(b_L + b_P)$$

1. Locate $(Y_L)_N$ on the Y-chart at point A in Figure 10.38.
2. Move on the constant conductance circle that passes through $(Y_L)_N$ and add a susceptance of jb_P to arrive at point B.
3. Move on the constant susceptance circle (passing through B) by adding a conductance of g_P to arrive at point C.
4. The input admittance is read off at point C using the Y-chart markings.

Applications of Smith Chart