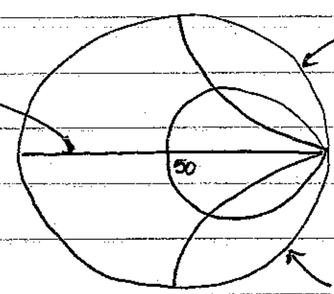
The Impedance chart was developed to map rectangular impedance to polar reflection coefficient

$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

Z_0 is the arbitrary characteristic impedance of the system (typically $Z_0 = 50\Omega$)

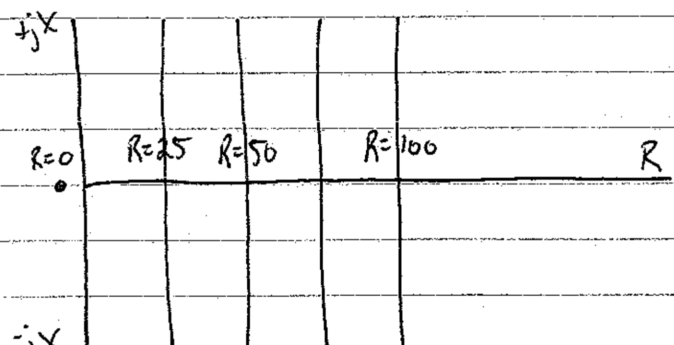
Impedances can vary from 0 to ∞, but Reflection coefficient can only vary from 0 to 1

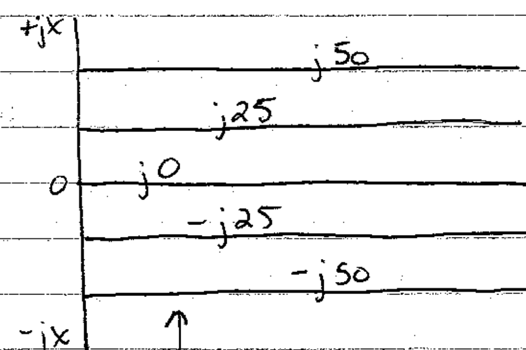
ideal resistors
No reactance



ideal inductors (no resistance, positive reactance)

ideal capacitors (no resistance, negative reactance)





varying reactance
constant resistance

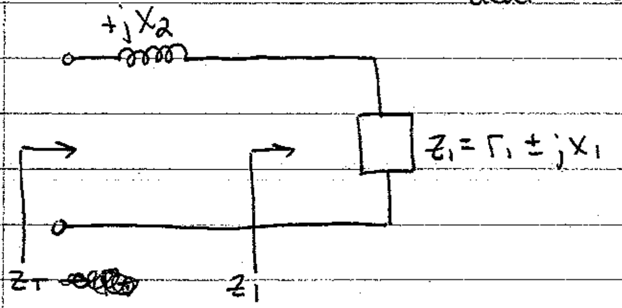
varying resistance
constant reactance.

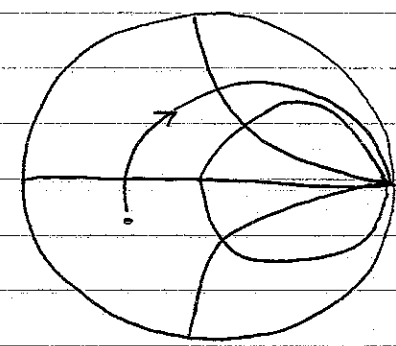
$$\Gamma = \frac{Z - Z_0}{Z + Z_0} = \frac{\frac{Z - Z_0}{Z_0}}{\frac{Z + Z_0}{Z_0}} = \frac{z - 1}{z + 1} \qquad z = \frac{Z}{Z_0}$$

This makes it possible to use the chart with any impedance.

How can the chart be used for impedance matching

Series
Ideal Inductor



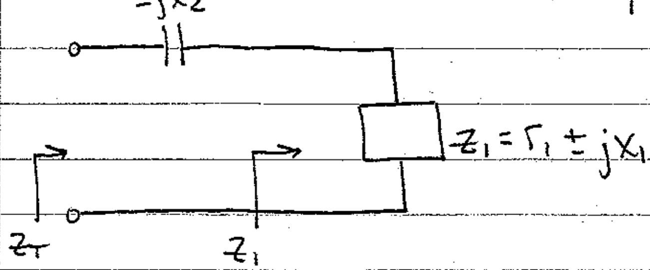


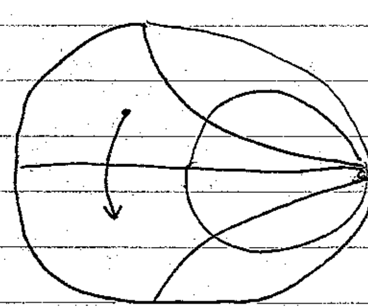
$$Z_T = Z_1 + jX_2 = (r_1 \pm jX_1) + jX_2$$
$$Z_T = r_1 + j(\pm X_1 + X_2)$$

Addition of an ideal inductor causes upward movement on a line of constant resistance towards infinity As $L \to \infty$ $Z \to \infty$

$$j\omega L = X_L$$
$$L = \frac{X_L}{\omega} = \frac{x_L \cdot Z_0}{\omega}$$

Series
Ideal Capacitor





$$Z_T = Z_1 - jX_2 = r_1 \pm jX_1 - jX_2$$
$$Z_T = r_1 + j(\pm X_1 - X_2)$$

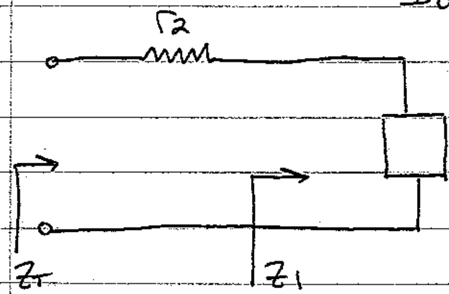
Addition of an ideal capacitor causes downward movement on a line of constant resistance towards infinity

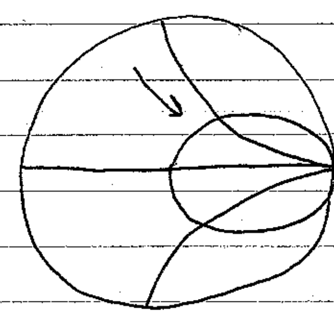
As $C \to 0$ $Z \to \infty$

$$\frac{1}{\omega C} = X_c$$

$$C = \frac{1}{\omega X_c} = \frac{1}{\omega x_c \cdot Z_0}$$

Ideal series Resistance





$Z_T = r_2 + r_1 \pm jX_1$

$Z_T = (r_2 + r_1) \pm jX_1$

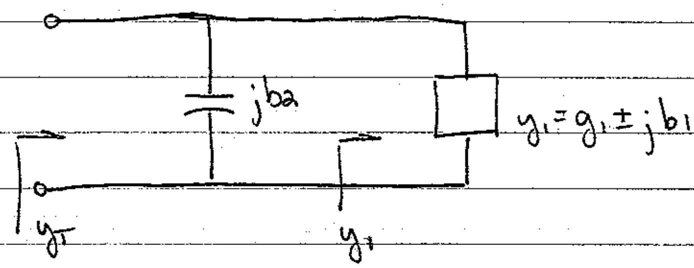
addition of a series resistance causes movement on a line of constant reactance towards infinity

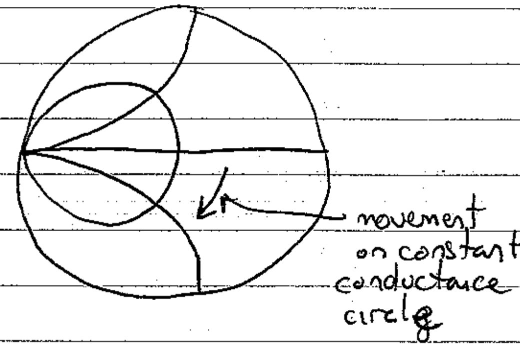
As $R \to \infty$ $\quad Z \to \infty$

Admittance Chart developent is similar to Impedance chart. Chart is rotated by 180° and then overlayed on Impedance chart, to form "Immitance" chart.

$$\Gamma = \frac{Y - Y_0}{Y + Y_0} = \frac{\frac{Y - Y_0}{Y_0}}{\frac{Y + Y_0}{Y_0}} = \frac{y-1}{y+1} \qquad y = \frac{Y}{Y_0}$$

Ideal Parallel Capacitors





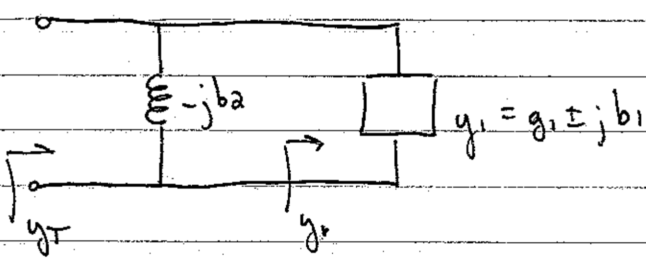
$y_T = y_1 + jb_1 = (g_1 \pm jb_1) + jb_2$

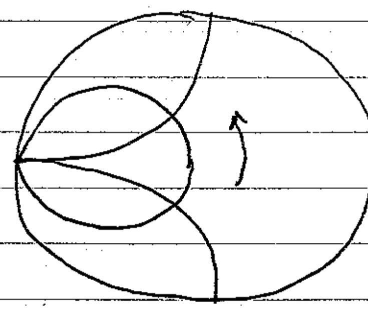
$y_T = g_1 + j(\pm b_1 + b_2)$

$\omega C = B \quad C = \frac{B}{\omega}$

Addition of parallel capacitor causes downward movement on chart toward $y = \infty$ $\quad C \to \infty \quad y \to \infty$

Ideal Parallel Inductors



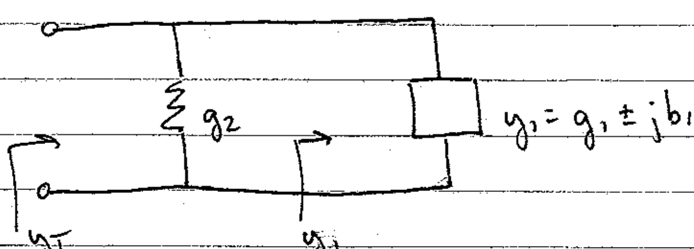


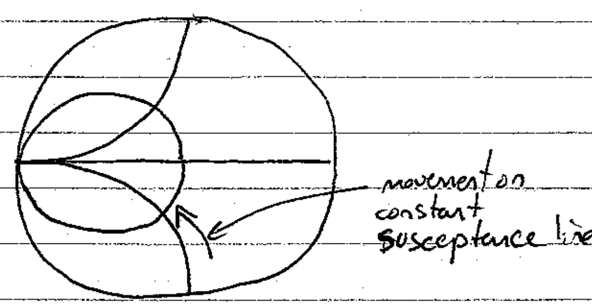
$y_T = y_1 - jb_2 = g_1 \pm jb_1 - jb_2$

$y_T = g_1 + j(\pm b_1 - b_2)$

Addition of parallel inductance causes upward movement on chart toward $y = \infty$ $\quad L \to 0 \quad y \to \infty$

Ideal Parallel Resistors





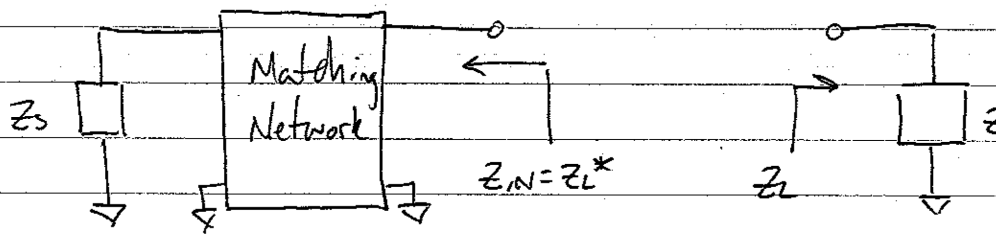
$y_T = g_1 \pm jb_1 + g_2$

$y_T = (g_1 + g_2) \pm jb_1$

Addition of parallel resistance causes movement on chart toward $y = \infty$

$R \to 0 \quad y \to 0$

Matching objective: transform an impedance from a source to the complex conjugate of the load.



Why complex conjugate: for maximum power transfer, the real parts of impedance must be equal, and ~~the phase~~ the voltage must be in phase with current.

What does this mean?

Match always occurs from an impedance to the complex conjugate of another impedance

$Z_s \rightarrow Z_L^*$ or $Z_L \rightarrow Z_s^*$

- Constant Q ~~circles~~ curves

$Q = \frac{X}{R}$

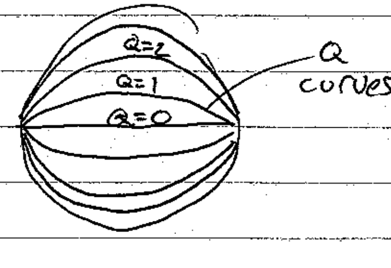
a Q curve is defined for a series of Impedance points where ratio between X and R is steady.

i.e. $Q = 5$ when $X = 5R$

$Q = 4$ when $X = 4R$

⋮

$Q = 0$ when $X = 0$

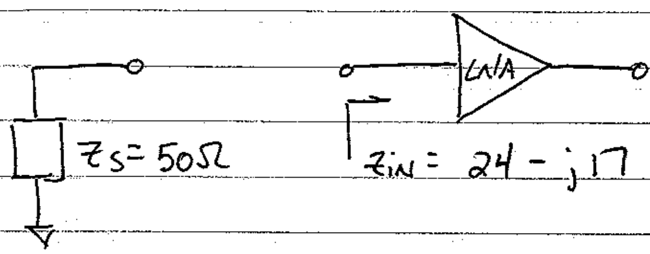


Matching Procedure:

1.) Normalize source and load impedance to Z_0
2.) Plot impedance of starting point and complex conjugate of ending point (i.e. Z_S and Z_L^*)
3.) Choose topology
4.) Follow rules for adding passive components to the network. (i.e. shunt components move on constant conduct. circle)
5.) Calculate component values.

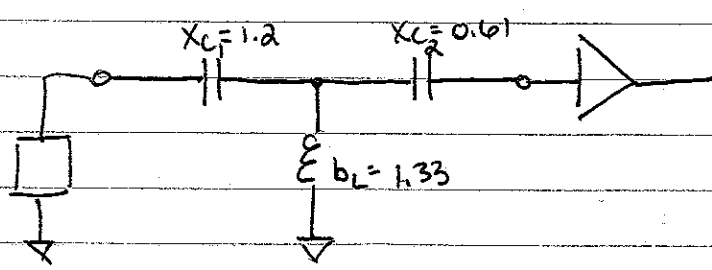
Example

Smith chart on next page: Match @ 2.4 GHz



Use highpass topology:

plot $Z_S = 1$ plot $Z_{in}^* = 0.48 + j0.34$

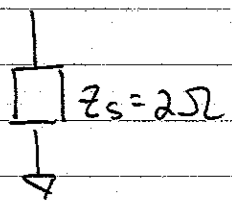


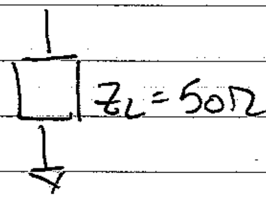
$C_1 = 1.1\,pF$
$L = 2.49\,nH$
$C_2 = 2.17\,pF$

$$C_{pF} = \frac{3.183}{f_{GHz}\cdot X_C} = \frac{3.183\, b_C}{f_{GHz}}$$

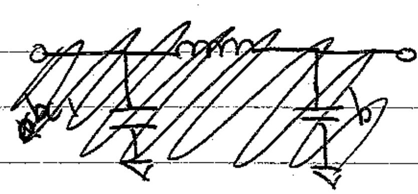
$$L_{nH} = \frac{7.96\, X_L}{f_{GHz}} = \frac{7.96}{f_{GHz}\, b_L}$$

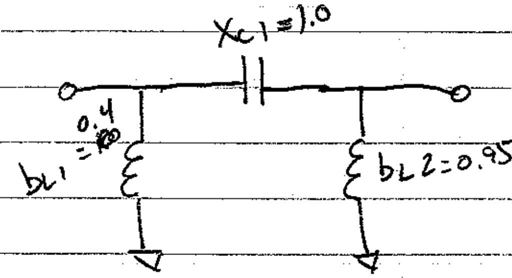
Class HW 1 examples





High pass π ~~model~~ match :





Normalize to $10\,\Omega$

$Z_s = 0.2\Omega$ $\qquad$ $Z_L^* = 5\Omega$

$L_{nH} = \dfrac{1.59}{1.9 \cdot 0.95} = 0.881\,nH$ $\qquad$ $C_{pF} = 8.44\,pF$

$b_L = \dfrac{.159 \cdot Z_0}{f_{GHz}\, L_{nH}}$ $\qquad$ $X_C = \dfrac{159 / Z_0}{f_{GHz} \cdot C_{pF}}$

$C_{pF} = \dfrac{15.9}{1.9 \cdot 1.0} = 8.44\,pF$

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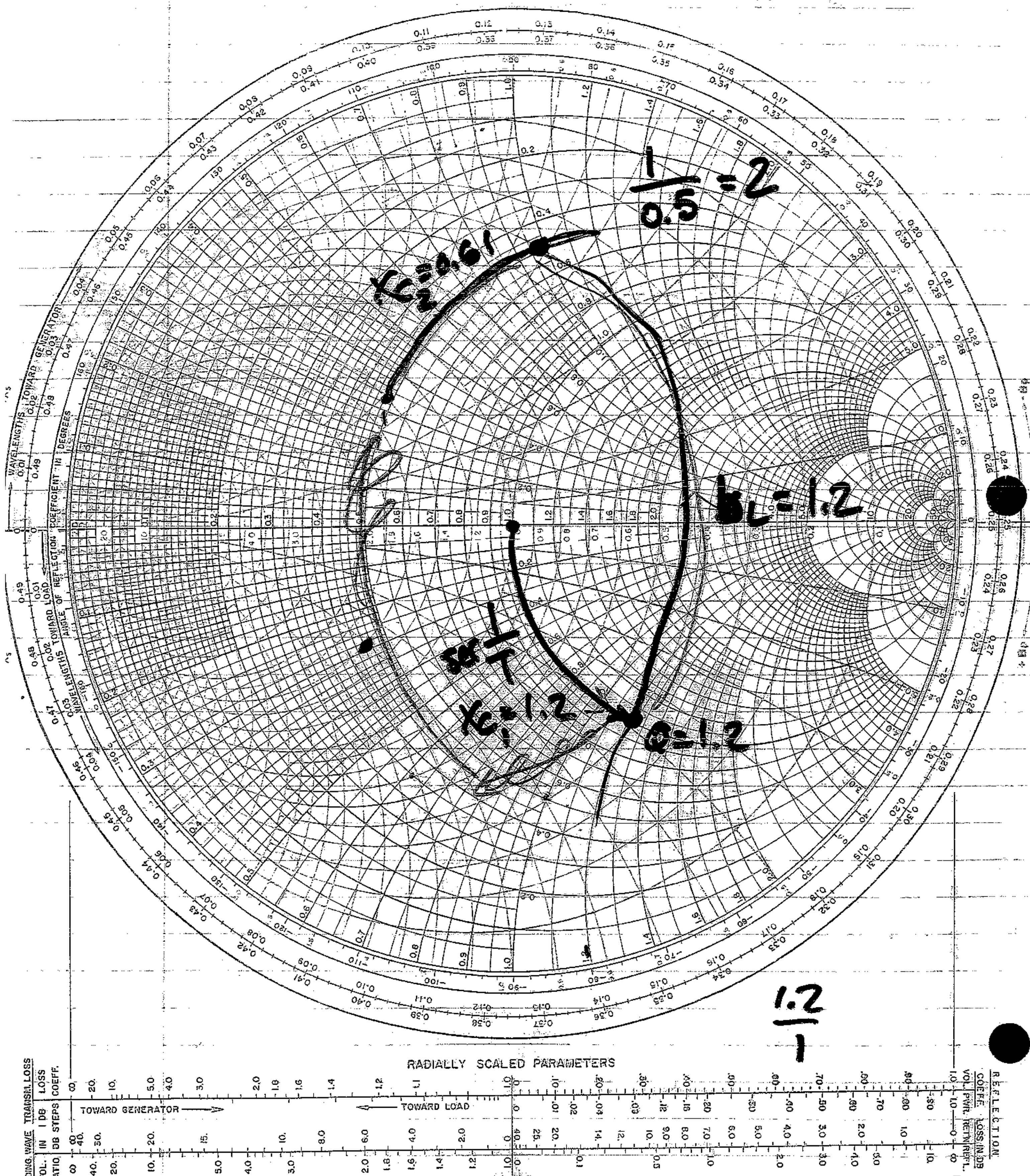
NORMALIZED IMPEDANCE AND ADMITTANCE COORDINATES



$\frac{1.2}{1}$