Return loss

Power of the signal returned/reflected by discontinuity in transmission line is noming bar return loss.

$$RL(dB) = 10 \log_{10} \frac{P_i}{P_r}$$

$$\Gamma = \frac{V_r}{V_i} = \frac{\text{Amp. refle wave}}{\text{Amp. Incident wave}}$$

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S}$$

$$\underset{\text{in dB}}{RL} = -20 \log |\Gamma|$$

line were terminated $Z_L = 37\Omega$ $Z_0 = 37\Omega$ no matter
How many section are there

Inductance loading of Telephone cables

* In distortionless lines with distributed parameters which long lines suffered by frequency and delay distortion.
To achieve the distortionless condition to increase the $\frac{L}{C}$ by lumped inductor in the line. This use of inductance is called loading the line.

* In submarine cable the the loading is obtained by winding the cable with high permeability permalloy.

Physical significance of equation infinite line

Sending end current of a line of length has

$R = V/I$

$$I = I_R \cosh \sqrt{zy}\, s + \frac{E_R}{Z_0} \sinh \sqrt{zy}\, s$$

$$I_s = I_R \left(\cosh \sqrt{zy}\, l + \frac{Z_R}{Z_0} \sinh \sqrt{zy}\, l \right)$$

If line is terminated $Z_R = Z_0$

$$I_s = I_R \left(\cosh \sqrt{zy}\, l + \sinh \sqrt{zy}\, l \right)$$

$$\frac{I_s}{I_R} = e^{\sqrt{zy}\, l} = e^{\gamma l}$$

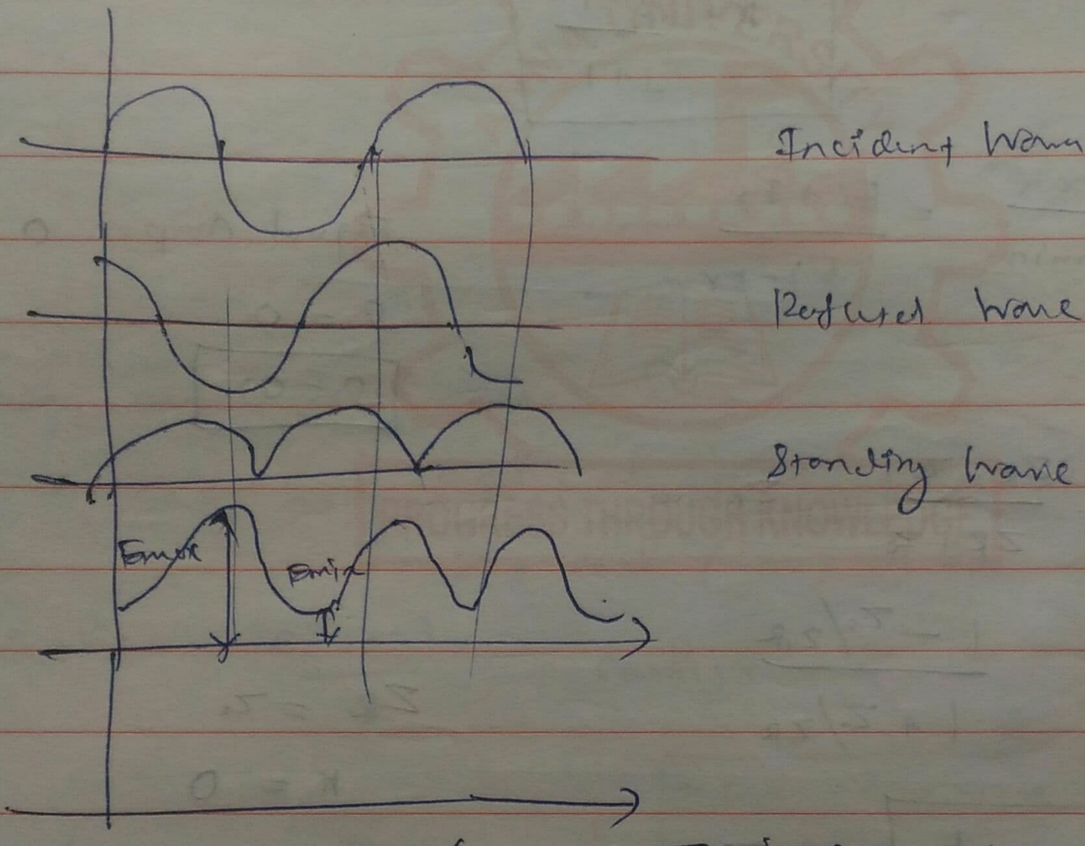
V & I on Dissipationless line at a dist s from the end

$$E = \frac{E_R (Z_R + Z_0)}{2 Z_R} \left(e^{\gamma s} + K e^{-\gamma s} \right)$$

$$\gamma = \alpha + j\beta$$

$\alpha = 0$ $R = 0$ $G = 0$

$$E = \frac{E_R (Z_R + Z_0)}{2 Z_R} \left[e^{j\beta s} + K e^{-j\beta s} \right)$$



$\cos \pi + j \sin$

$\cos 0 + j \sin 0$

$$E_{max} = \frac{E_R (Z_R + Z_0)}{2 Z_R} \left[e^{j\beta s} + |K| e^{-j\beta s} \right]$$

max in phase

$$E_{max} = \frac{E_R (Z_R + Z_0)}{2 Z_R} \left(1 + |K| \right)$$

min occur Both out of phase

$$E_{min} = \frac{E_R (Z_R + Z_0)}{2 Z_R} \left(1 - |K| \right)$$

$$VSWR = \frac{E_{max}}{E_{min}} = \frac{1+|K|}{1-|K|}$$

$$S = \frac{1+K}{1-K}$$

$$S(1-K) = 1+K$$

$$S - SK = 1+K$$

$$S-1 = K+SK$$

$$\boxed{K = \frac{S-1}{S+1}}$$

$$RS = \frac{E_{max}}{E_{min}} = \frac{E_i + E_r}{E_i - E_r}$$

Equal Amp = 0

$S = 0$

$\boxed{S = \infty}$

Open

$$K = \frac{Z_R - Z_0}{Z_R + Z_0} \qquad Z_R = \infty$$

$$K = \frac{1 - Z_0/Z_R}{1 + Z_0/Z_R}$$

$Z_R = Z_0$

$K = 0$

$\boxed{K = 1}$

$Z_R = 0$

$\boxed{SWR = \infty}$

$S = 1$

$\boxed{S = 1}$

Short $Z_R = 0$

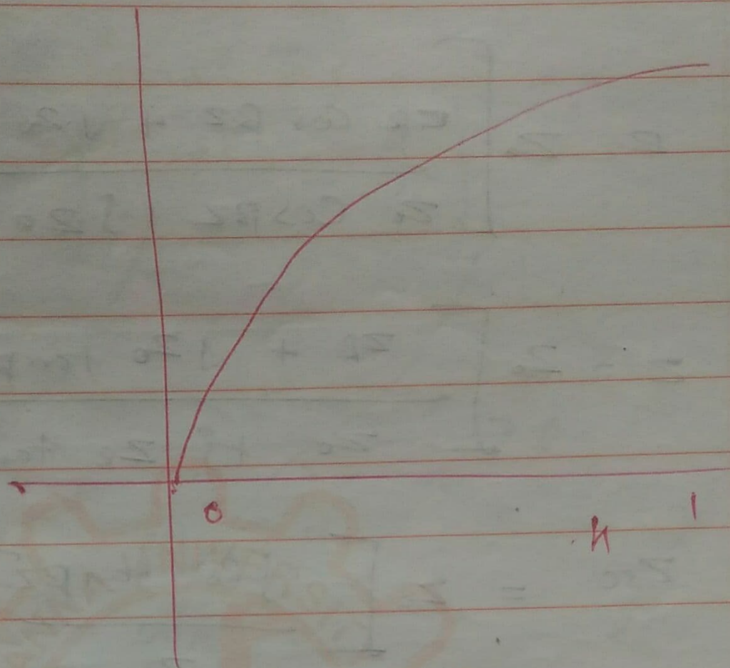
$$K = \frac{-Z_0}{Z_0}$$

$$\boxed{K = -1}$$

$\Gamma = 0 \to 1$

VSWR $\to$ $1 \to \infty$

'x'	VSWR
0	
0.1	1.22
0.2	1.5
0.3	1.85
0.4	2.3
0.5	3
0.6	4
0.7	5.6
0.8	9
0.9	19
1.0	∞



open and short ckted line

$$Z_s = Z_0 \left[\frac{Z_R \cosh(j\beta z) + Z_0 \sinh(j\beta z)}{Z_0 \cosh(j\beta z) + Z_R \sinh(j\beta z)} \right]$$

$$\cosh x = \frac{e^x + e^{-x}}{2} \qquad \cosh jx = \frac{e^{jx} + e^{-jx}}{2}$$

$$\boxed{\cosh jx = \frac{2\cos x}{2} = \cos x}$$

$$\sinh jx = \frac{e^{jx} - e^{-jx}}{2}$$

$$= \frac{\cos x + j\sin x - \cos x + j\sin x}{2}$$

$$\boxed{\sinh jx = j\sin x.}$$

Q7.

$$Z = Z_0 \left[\frac{Z_R \cos\beta z + j Z_0 \sin\beta z}{Z_0 \cos\beta z + j Z_R \sin\beta z} \right]$$

$$Z = Z_0 \left[\frac{Z_R + j Z_0 \tan\beta z}{Z_0 + j Z_R \tan\beta z} \right] \quad Z_R \; Z_0$$

$$\Leftrightarrow \quad Z_{sc} = Z_0 \left[\frac{j Z_0 \tan\beta z}{Z_0} \right]$$

$Z_R = 0$

$$\boxed{Z_{sc} = j Z_0 \tan\beta z}$$

$$Z_{oc} = Z_0 \left[\frac{1 + j \frac{Z_0}{Z_R} \tan\beta z}{\frac{Z_0}{Z_R} + j \tan\beta z} \right]$$

Q8.

$$= \frac{1}{j \tan\beta z}$$

$$\boxed{Z_0 = -j Z_0 \cot\beta z}$$

Impedance of Dissipationless line

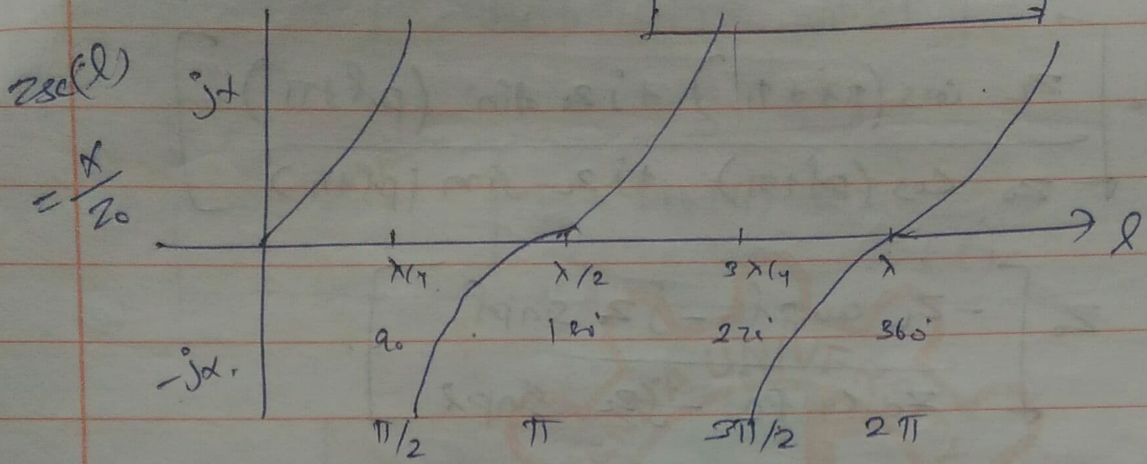
$$Z(l) = Z_0 \left[\frac{Z_R + j Z_0 \tan\beta l}{Z_0 + j Z_R \tan\beta l} \right]$$

$$Z_{sc}(l) = j Z_0 \tan(\beta l)$$

$$\boxed{Z = jx}$$

$Z_{sc}(l) \Rightarrow \quad Z_0 \tan \beta l = x$

$$\boxed{\tan \beta l = \frac{x}{Z_0}}$$



Short ckt

$\lambda/4$ line L

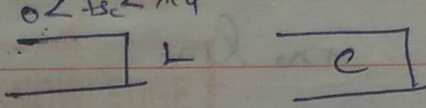
$\lambda/4$ line

$0 < l_{sc} < \lambda/4$

$\lambda = \frac{2\pi}{\beta}$

$\beta = \frac{2\pi}{\lambda} \times l$

$=$



$\lambda/4 < l_{sc} < \lambda/2$

Q 10.

l	βl	$\tan \beta l$	$Z_{sc}\, l$
0	0	0	0
$\lambda/4$	$\pi/2$	∞	∞
$\lambda/2$	π	0	0

$$z(l+\lambda/2) = z_0\left[\frac{z_L \cos\beta(l+\lambda/2) + jz_0 \sin(l+\lambda/2)}{z_0 \cos\beta(l+\lambda/2) + jz_L \sin\beta(l+\lambda/2)}\right]$$

$$= z_0\left[\frac{z_L \cos(\beta l+\pi) + jz_0 \sin(\beta l+\pi)}{z_0 \cos(\beta l+\pi) + jz_L \sin(\beta l+\pi)}\right]$$

$$\lambda/2 \quad = z_0\left[\frac{-z_L \cos\beta l - jz_0 \sin\beta l}{-z_0 \cos\beta l - jz_L \sin\beta l}\right]$$

$$\boxed{z(l+\lambda/2) = z(l)}$$

line characteristic repeat eg. $\lambda/2$ distance in the line.

Normalized Impedance inverse evry $\lambda/4$ distance

$$\beta(l+\lambda/4) = \beta l + \frac{2\pi}{\lambda} \times \lambda/4 = \beta l + \pi/2$$

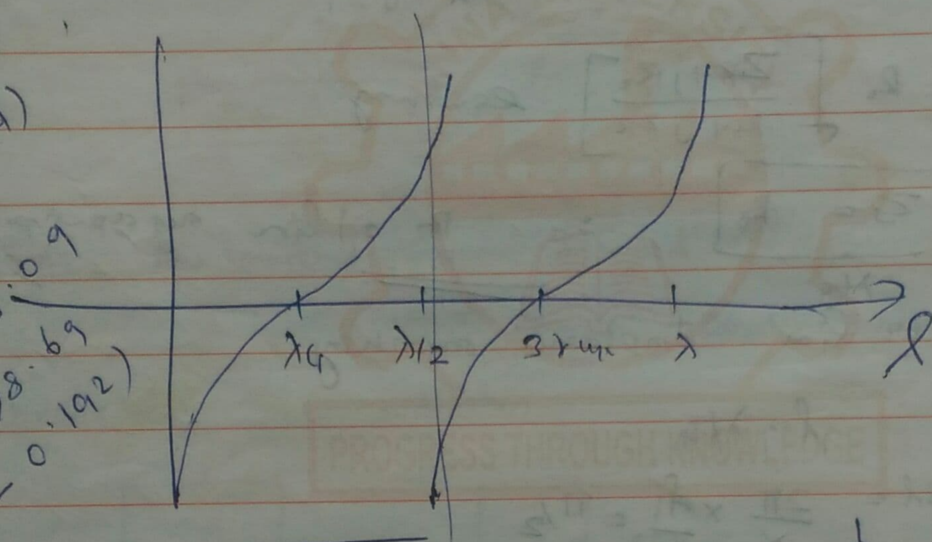
$$\cos\beta l = \cos(\beta l + \pi/2) = -\sin\beta l$$

$$\sin(\beta l + \pi/2) = \cos\beta l$$

$$\bar{z}(l+\lambda/4) = \frac{\bar{z}_L \cos(\beta l+\pi/2) + j\sin(\beta l+\pi/2)}{\cos(\beta l+\pi/2) + j\bar{z}_L \sin(\beta l+\pi/2)}$$

$$= Z_0 \left[\frac{-\bar{Z}_L \sin\beta l + j\cos\beta l}{-\sin\beta l + j\bar{Z}_L \cos\beta l} \right]$$

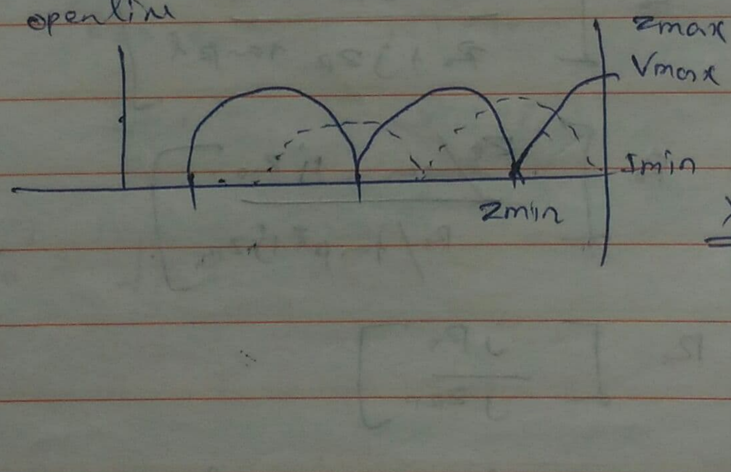
$$\boxed{= Z_0 [\ \ ] \quad \bar{Z}(l + \lambda/4) = \frac{1}{\bar{Z}(l)}}$$



op $\dashv\vdash$ $0 < l_{oc} < \lambda/4$

L $(\lambda/4 < l < \lambda/2)$

parallel resonance



λ =

Impedance

Inversion

$\lambda/4$ distance

Eight wave line

$$Z_S = Z_0 R \left[\frac{Z_R + jR_0 \tan\beta l}{R_0 + jZ_R \tan\beta l} \right]$$

$$l = \lambda/8$$

$$\beta l = \frac{2\pi}{\lambda} \times \frac{\lambda}{8} = \pi/4$$

$$\tan \pi/4 = 1$$

$$Z_S = R_0 \left[\frac{Z_R + jR_0}{R_0 + jZ_R} \right] \text{ eqnly}$$

$$\boxed{Z_S = R_0}$$

$Z_S = R_0$ of line not depend upon load

$\lambda/4$

Quarter line Impedence matching

$$l = \lambda/4$$

$$\beta l = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \pi/2$$

$$\tan\beta l = \tan \pi/2 = \infty$$

$$Z_S = R_0 \left[\frac{Z_R + jR_0 \tan\beta l}{R_0 + jZ_R \tan\beta l} \right]$$

$$= R_0 \left[\frac{Z_R/\tan + jR_0}{R_0/\tan\beta l + jZ_R} \right]$$

$$= R_0 \left[\frac{jR_0}{jZ_R} \right]$$

$$Z_S = \frac{R_0^2}{Z_R} \qquad R_0^2 = \sqrt{Z_S Z_R}$$

Low Imped to high Impedance

~~Half wave line~~

$l = \lambda/2$

$\tan \beta l = 2\pi/\lambda \times \lambda/2 = \pi$

$\tan \pi = 0$

$$Z_s = R_0 \left(\frac{Z_R + j R_0 \tan \pi}{R_0 + j Z_R \tan \pi} \right)$$

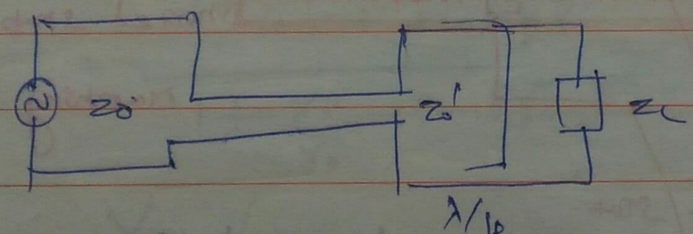
$$= R_0 \frac{Z_R}{R_0}$$

$$\boxed{Z_s = Z_R}$$

Half wave line act as one to one transformer

$Z_0 \neq Z_L$ not matched SWave formed

↳ Causes, power loss, dielectric breakdown, noise, radiation,



$\lambda/4$ act as transformer

$R_L = Z_0$ — 1:1 turn

$R_L > Z_0$ — Step up

$R_L < Z_0$ — step down

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

Determine the physical length and Z_0
for $\lambda/4$ transformer that is used to match a section
($Z_0 = 50\,\Omega$) to $150\,\Omega$ Resistive load, The freq
of operation is 150MHz and the velocity factor
$V_f = 1$

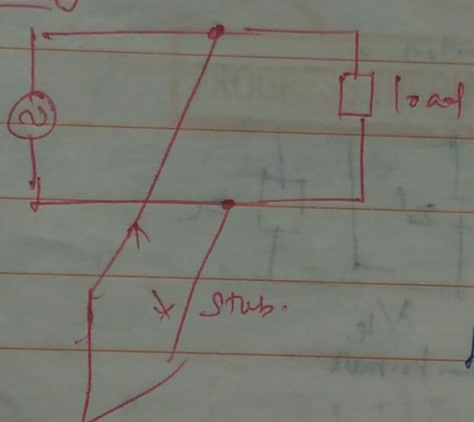
$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\,m/s}{100\times10^{6}} = 2m$$

$$\lambda/4 = \frac{2}{4} = 0.5m.$$

Z_0 of $(0.5m)$ transformer

$$Z_0' = \sqrt{Z_0 Z_L} = \sqrt{50\times150} = 86.6\,\Omega$$

Stub matching



Shorted stub input matching.

Load L, C

$K = 1$ $\quad$ SWR $= \infty$

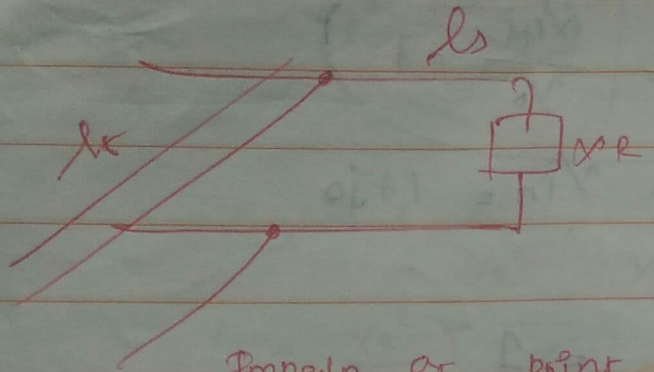
only L, C

reactive component of load is cancelled by the stub whose reactance.

Stub matching

Stub match by open Ckt stub (or) short Ckt stub.

Smaller than $\lambda/2$ (or) $\lambda/2$ used as a stub.



Impedn at point of tx line

$$Z_{in} = Z_0 \frac{Z_R + Z_0 \tanh \gamma l}{Z_0 + Z_R \tanh \gamma l}$$

$$Y_{in} = Y_0 \frac{Y_R + Y_0 \tanh \gamma l}{Y_0 + Y_R \tanh \gamma l}$$

$\alpha = 0$ High freq application / transmission line

$$\frac{Y_{in}}{Y_0} = \frac{Y_R/Y_0 + \tanh \gamma l}{1 + \frac{Y_R}{Y_0} \tanh \gamma l}$$

$\tanh jx = j \tan x$

$\boxed{y_{in} = \frac{Y_{in}}{Y_0}}$ = Normalised Input Impedance

$y_r = \frac{Y_R}{Y_0}$ = Normalised load admittance

$$Y_{in} = \frac{y_r + j \tan \beta l}{1 + j y_r \tan \beta l} \times \frac{(1 - j y_r \tan \beta l)}{1 - j y_r \tan \beta l}$$

$$Y_{in} = \frac{y_r - j y_r^2 \tan \beta l + j \tan \beta l + y_r \tan^2 \beta l}{1 + y_r^2 \tan^2 \beta l}$$

* For No reflection */

$Y_{IN} = Y_0$ $\qquad y_{in} = \dfrac{Y_{IN}}{Y_0} = 1$

$y_{in} = 1 + j0$

$$\frac{y_r (1 + \tan^2 \beta l_s)}{1 + y_r^2 \tan^2 \beta l_s} = 1$$

$$y_r (1 + \tan^2 \beta l_s) = 1 + y_r^2 \tan^2 \beta l_s$$

$$\tan^2 \beta l_s (y_r - y_r^2) = 1 - y_r$$

Stub located at l_s

$$y_r \tan^2 \beta l_s (1 - y_r) = (1 - y_r)$$

$$y_r \tan^2 \beta l_s = 1$$

$$\tan \beta l_s = \frac{1}{\sqrt{y_r}} = \sqrt{\frac{Y_0}{Y_R}}$$

$$\beta l_s = \tan^{-1} \sqrt{\frac{Y_0}{Y_R}}$$

$$\frac{2\pi}{\lambda} l_s = \tan^{-1} \sqrt{\frac{Z_R}{Z_0}}$$

$$l_s = \frac{\lambda}{2\pi} \tan^{-1} \sqrt{\frac{Z_R}{Z_0}}$$

The suceptance at the location of stub will be

$$\frac{b_s}{Y_0} = \frac{(1 - y_r^2) \tan \beta l_s}{1 + y_r^2 \tan^2 \beta l_s}$$

$$\tan\beta l_s = \sqrt{\frac{Y_0}{Y_R}}$$

$$\frac{b_s}{Y_0} = \frac{\left(1 - \frac{Y_R^2}{Y_0^2}\right)\sqrt{\frac{Y_0}{Y_R}}}{1 + \frac{Y_R^2}{Y_0^2} \cdot \frac{Y_0}{Y_R}}$$

$$= \frac{\left(1 - \frac{Y_R^2}{Y_0^2}\right)\sqrt{\frac{Y_0}{Y_R}}}{1 + \frac{Y_R}{Y_0}} \qquad \frac{\frac{1}{Y_0^2}\,\frac{(Y_0^2 - Y_R^2)}{}}{1/Y_0}$$

$$\frac{b_s}{Y_0} = \frac{1}{Y_0}(Y_0 - Y_R)\sqrt{\frac{Y_0}{Y_R}}$$

$$b_s = (Y_0 - Y_R)\sqrt{\frac{Y_0}{Y_R}} \qquad \left(\frac{1}{Z_0} - \frac{1}{Z_R}\right)\left(\sqrt{Z_0 Z_R}\right)$$

$$\cot\beta l_t = Y_0 - Y_R\sqrt{\frac{Y_0}{Y_t}} \qquad \frac{Z_R - Z_0}{Z_0 Z_R}\sqrt{Z_0 Z_R}$$

$$\cot\beta l_t = (Y_0 - Y_R)\sqrt{\frac{1}{Y_0 Y_R}} \qquad \frac{Z_R - Z_0}{\sqrt{Z_0 Z_R}}$$

$$\beta l_t = \tan^{-1}\frac{\sqrt{Z_R Z_0}}{Z_R - Z_0}$$

$$\boxed{l_t = \lambda/2\pi \, \tan^{-1}\frac{\sqrt{Z_R Z_0}}{Z_R - Z_0}}$$

Smith chart

$$K = \frac{Z_R - Z_0}{Z_R + Z_0} \qquad \frac{Z_R/Z_0 - 1}{Z_R/Z_0 + 1}$$

$$K = \frac{Z_r - 1}{Z_r + 1}$$

$$K Z_r + K = Z_r - 1$$

$$1 + K = Z_r (1 - K)$$

$$Z_r = \frac{1+K}{1-K}$$

Z, K are Complex No's.

$$R_r + jx = \frac{1 + K_r + jK_x}{(1 - K_r) - jK_x}$$

$$= \frac{(1+K_r) + jK_x}{(1-K_r)^2 + K_x^2} \times (1-K_r) + jK_x$$

$$= (1+K_r)(1-K_r) + (1+K_r)jK_x + jK_x(1-K_r) - K_x^2$$

$$1 - K_r^2 + jK_x + \cancel{jK_r K_x} + jK_x - \cancel{jK_r K_x} - K_x^2$$

$$jx = \frac{1 - K_r^2 + 2jK_x - K_x^2}{(1-K_r)^2 + K_x^2}$$

$$R_r = \frac{1 - K_r^2 - K_x^2}{(1-K_r)^2 + K_x^2}$$

$$X = \frac{2K_x}{(1-K_r)^2 + K_x^2}$$

The Const R-circle

$$R\{1 + k_r^2 - 2k_r + k_x^2\} = 1 - k_r^2 - k_x^2$$

$$R + Rk_r^2 - 2Rk_r + Rk_x^2 = 1 - k_r^2 - k_x^2$$

$$k_r^2(1+R) + k_x^2(1+R) - 2Rk_r = 1 - R$$

$$k_r^2 + k_x^2 - \frac{2R}{1+R}k_r = \frac{1-R}{1+R}$$

Add $\frac{R^2}{(1+R)^2}$ both sides.

$$k_r^2 + k_x^2 - \frac{2R}{1+R}k_r + \frac{R^2}{(1+R)^2} = \frac{(1-R)}{(1+R)} + \frac{R^2}{(1+R)^2}$$

$$k_x^2 + \left(k_r - \frac{R}{1+R}\right)^2 = \frac{(1-R)(1+R) + R^2}{(1+R)^2}$$

$$k_x^2 + \left(k_r - \frac{R}{1+R}\right)^2 = \frac{1 - R^2 + R^2}{(1+R)^2}$$

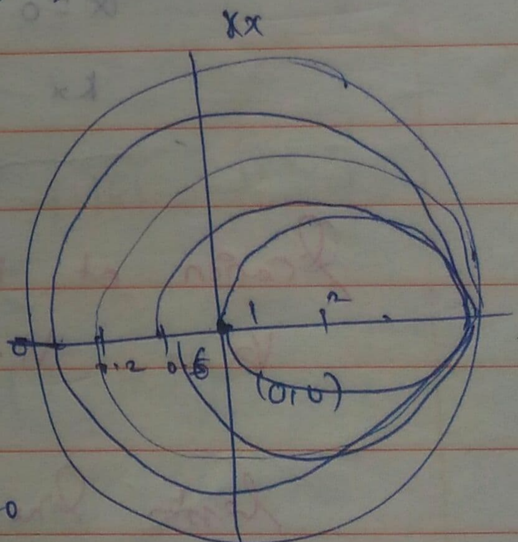
$$k_x^2 + \left(k_r - \frac{R}{1+R}\right)^2 = \left(\frac{1}{1+R}\right)^2$$

Constant R circles.

Radius $\left(R/_{1+R}\right)$

centre $\left[\frac{R}{1+R} \quad 1\,0\right]$

Come $(0,0)$
$k_r \; k_x$



$k_r, k_x = 0$

$R = \underline{1}$

Constant Reactance Circle

$$(1-K_r)^2 + K_x^2 = \frac{2K_x}{x}$$

$$(1-K_r)^2 + K_x^2 - \frac{2K_x}{x} = 0$$

$$(1-K_r)^2 + K_x^2 - \frac{2K_x}{x} + \left(\frac{1}{x}\right)^2 = \left(\frac{1}{x}\right)^2$$

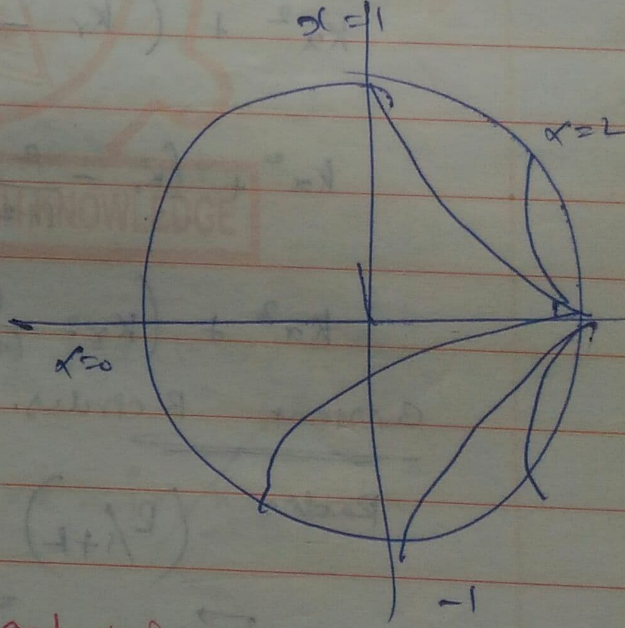
$$(1-K_r)^2 + (K_x - 1/x)^2 = (1/x)^2$$

$$(K_r-1) + (K_x - 1/x)^2 = (1/x)^2$$

$(1, 1/x)$

x positive above Hz axis

x -ve below Hz axis.



$K_x, K_r = 0$

$x = 0$

K_x K_r Vary

x Vary

Location of voltage max and minimum

V_x : $V_i + V_r$ Inphase V_{max}

V_{min}

lossless line $\alpha = 0$ β

$$V_x = b e^{j\beta y} + a e^{-j\beta y}$$