ECE 344

Microwave Fundamentals

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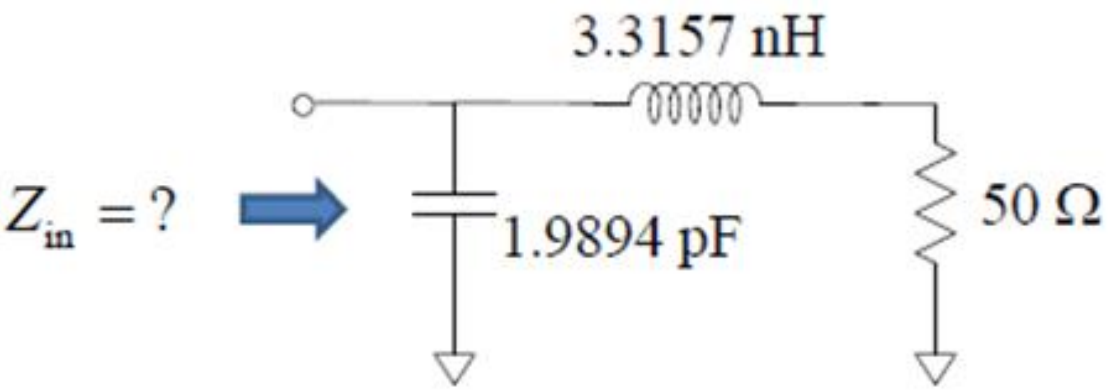
- Review :
- Smith chart example
- SWR meaning

- Quiz

Example 1



$$f = 2.4 \text{ GHz}$$

$$Z_0 = 50\ \Omega$$

$$Z_{in} = \frac{1}{j\omega C} \,\Big|\Big|\, (R + j\omega L)$$

$$= \frac{\frac{1}{j\omega C}(R + j\omega L)}{\frac{1}{j\omega C} + (R + j\omega L)}$$

$$= \frac{R + j\omega L}{1 - \omega^2 LC + j\omega RC}$$

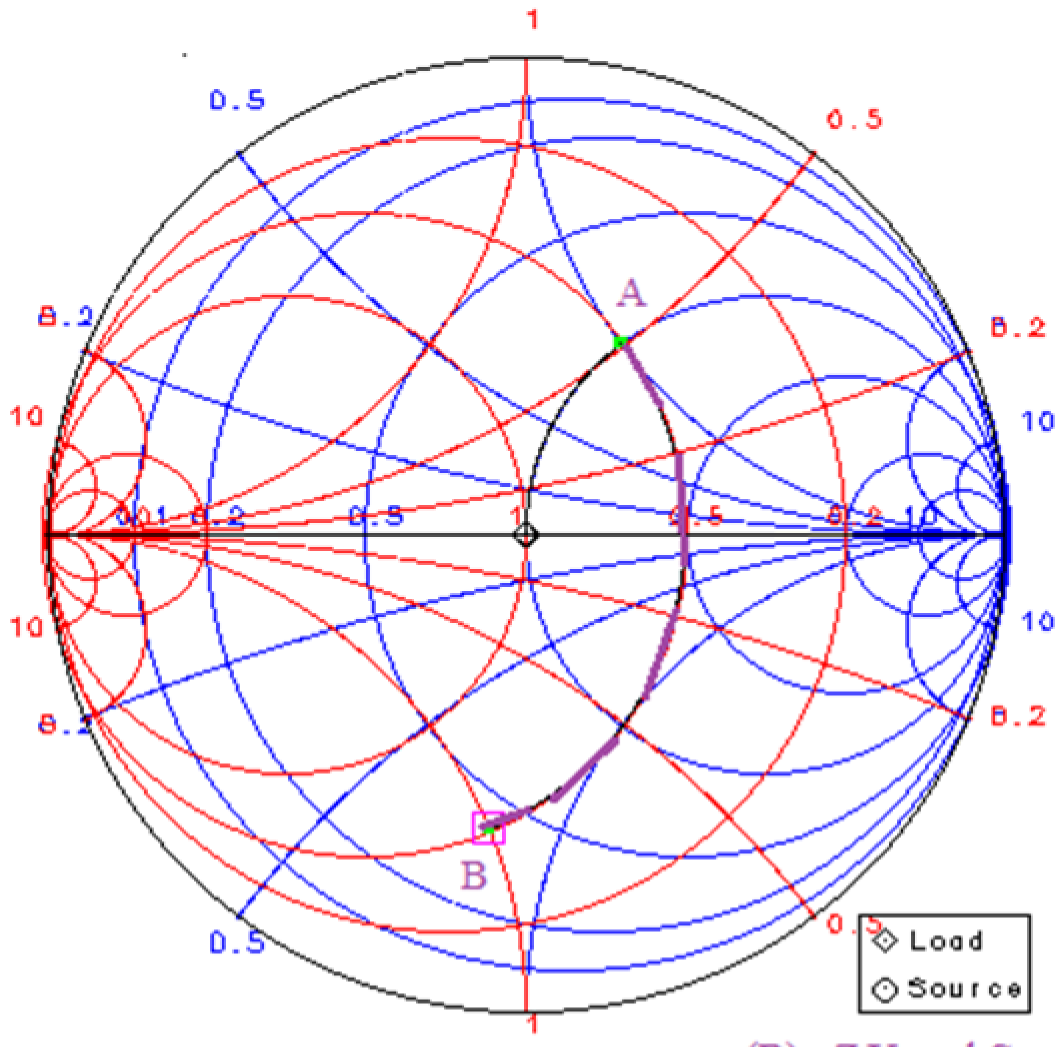
$$= \frac{50 + j\left(1.5080\times10^{10}\right)\left(3.3157\times10^{-9}\right)}{1-\left(1.5080\times10^{10}\right)^2\left(3.3157\times10^{-9}\right)\left(1.9894\times10^{-12}\right)+j\left(1.5080\times10^{10}\right)(50)\left(1.9894\times10^{-12}\right)}$$

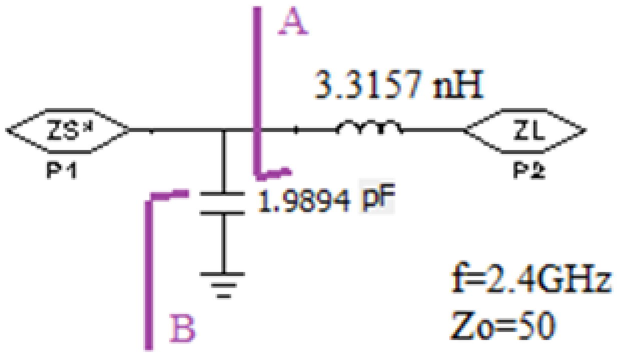
$$= 20 - j40\ \Omega$$

$$\Gamma = \frac{(20 - j40) - 50}{(20 - j40) + 50} = 0.62\measuredangle -98^\circ$$

$$\text{VSWR} = 4.2654$$

Normalized value is used in impedance admittance smith chart (also using ADS smithchart)





ZL=50

ZA=50+j 2*pi*2.4*3.3157

ZA/Zo=1+j1

Bcn=2*pi*2.4*10^9*1.9894*10^-12*50=1.5

(B) Z,Y, and Gamma

Gamma:	0.62016	<	-97.1237	Z:	0.40002	+j	-0.80001
VSWR:			4.26541	Y:	0.50000	+j	0.99997

← ZB/Zo

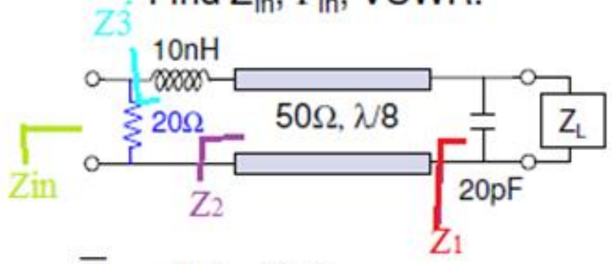
ZB=20-j40

Example 2 **with shunt C, G, series L and TL**

e.g. $Z_L = 20 - j25\ \Omega$

$f = 159$ MHz $(\omega = 10^9)$

Find Z_{in}, Γ_{in}, VSWR.



$\bar{Z}_L = 0.4 - j0.5$

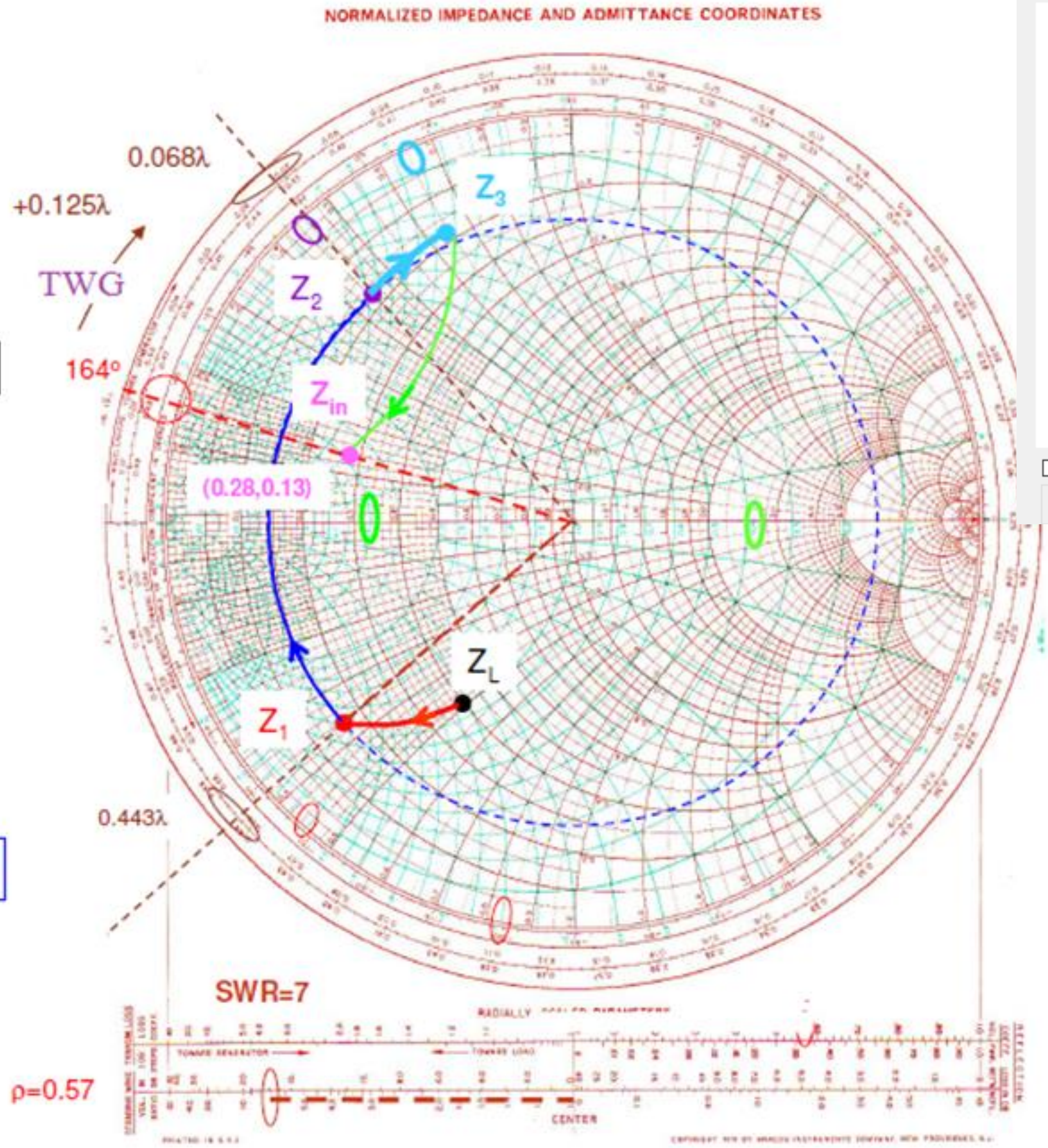
$\bar{B} = \omega C / Y_o = 0.02 Z_o = 1$

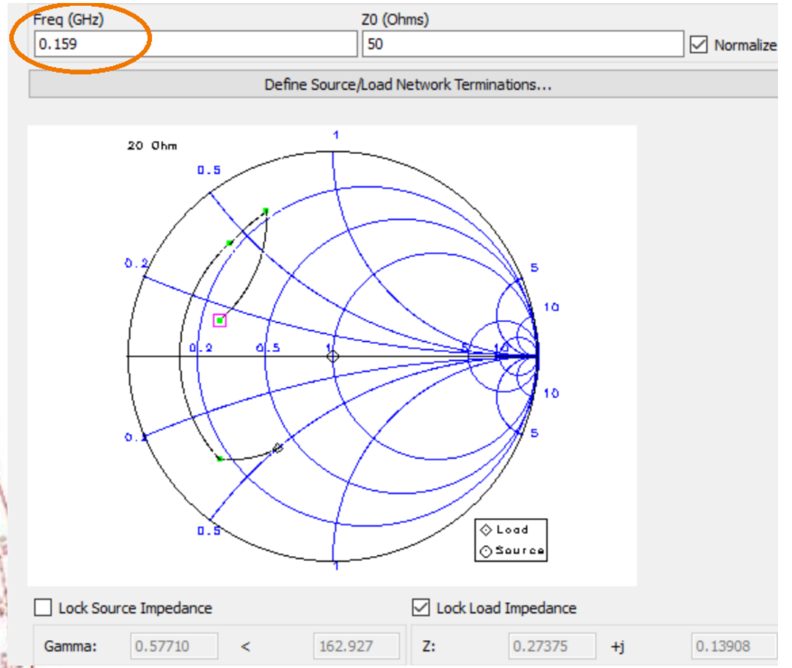
$\bar{X} = \omega L / Z_o = 10/Z_o = 0.2$

$\bar{G} = G/Y_o = Z_o/R = 50/20 = 2.5$

$Z_{in} = 50(0.28+j0.13) = 14 + j7\ \Omega$

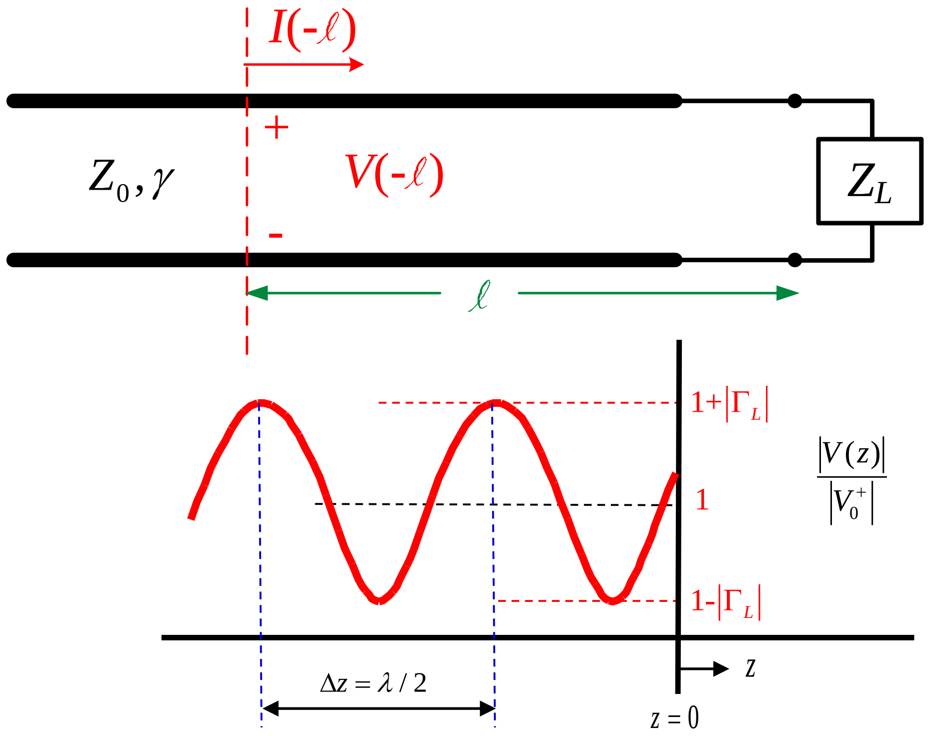
$\Gamma_{in} = 0.57\ (164^o)$





Voltage Standing Wave Ratio

$$V(-\ell) = V_0^+ e^{j\beta\ell}\left(1+\Gamma_L e^{-2j\beta\ell}\right)$$
$$= V_0^+ e^{j\beta\ell}\left(1+|\Gamma_L| e^{j\phi_L} e^{-2j\beta\ell}\right)$$



$$|V(-\ell)| = |V_0^+|\left|1+|\Gamma_L| e^{j\phi_L} e^{-j2\beta\ell}\right|$$

$$V_{\max} = |V_0^+|\left(1+|\Gamma_L|\right)$$
$$V_{\min} = |V_0^+|\left(1-|\Gamma_L|\right)$$

$$\text{Voltage Standing Wave Ratio (VSWR)} = \frac{V_{\max}}{V_{\min}}$$

$$\text{VSWR} = \frac{1+|\Gamma_L|}{1-|\Gamma_L|}$$

Standing Waves -Matched

Matched Line ($Z_L = Z_o$), we had

$$Z_{in} = Z_o\,, \quad \Gamma_L = 0, \quad s = 1$$

- So substituting in $V(z)$

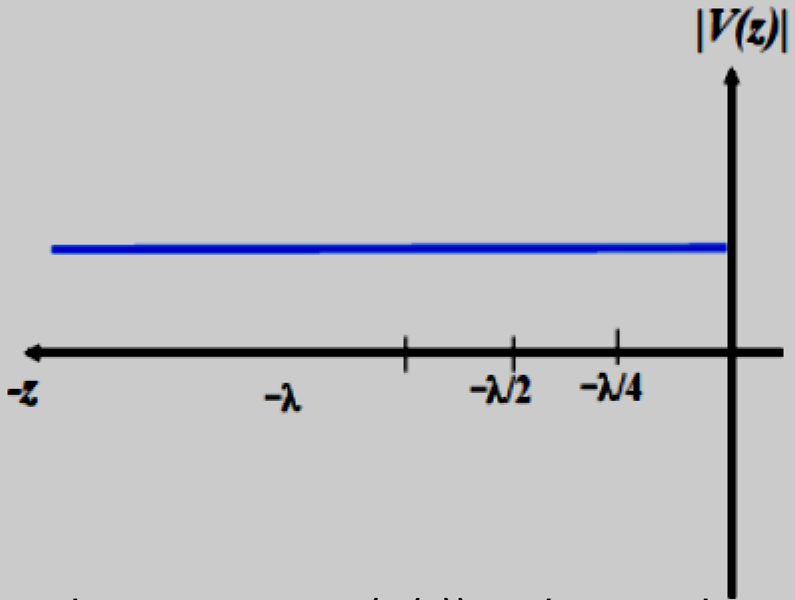
$$V(z) = V^+[e^{j\beta l} + (0)e^{-j\beta l}]$$

$$V(z) = V^+ e^{j\beta l}$$

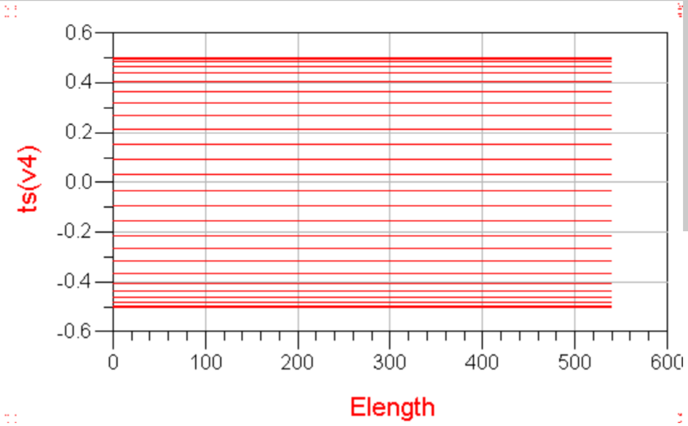
$$|V(z)| = |V^+||e^{j\beta l}|$$

$$|V(z)| = |V^+|$$

$|V(Z)|$ *does not depend on z*



Simulation ADS mag(V(z)) with time changing



Standing Waves -Short

Shorted Line ($Z_L=0$), we had

$$Z_{in} = jZ_o \tan\beta l\,,\quad \Gamma_L = -1,\quad s = \infty$$

- So substituting in $V(z)$

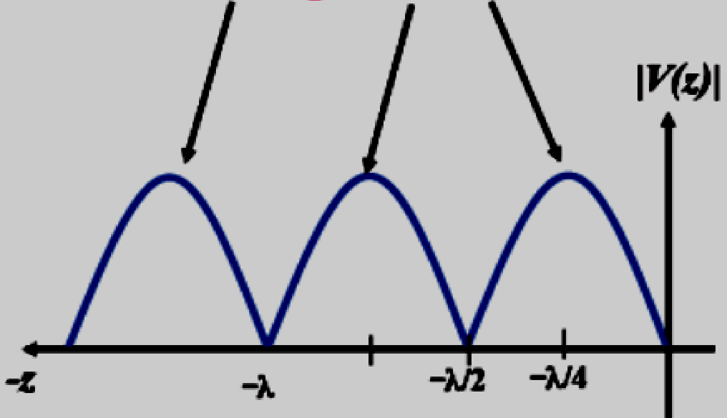
$$V(z) = V^+[e^{j\beta l} + (-1)e^{-j\beta l}]$$

$$V(z) = V^+(2j\sin\beta l)$$

$$|V(z)| = |V^+||2\sin(\beta l)|$$

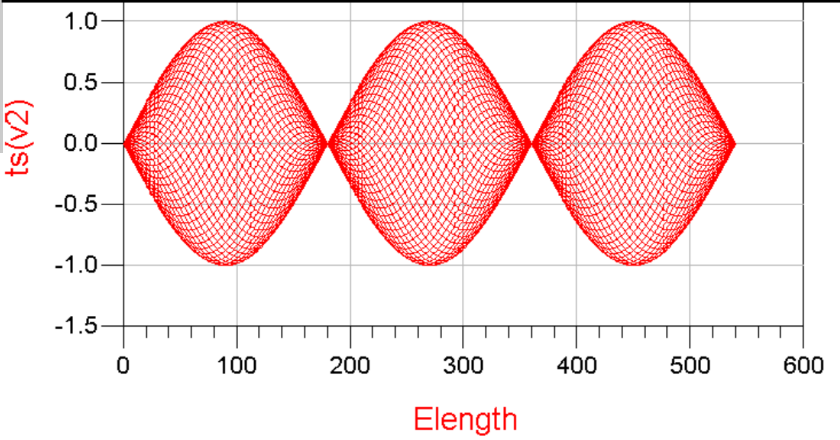
$$|V(z)| = |V^+|\left|2\sin\left(\frac{2\pi}{\lambda}l\right)\right|$$

Voltage maxima



*Voltage minima occurs at same place that impedance has a minimum on the line

Simulation with ADS time signal vs length



Standing Waves -Open

Open Line ($Z_L=\infty$) ,we had

$$Z_{in} = -jZ_o \cot \beta l, \quad \Gamma_L = +1, \quad s = \infty$$

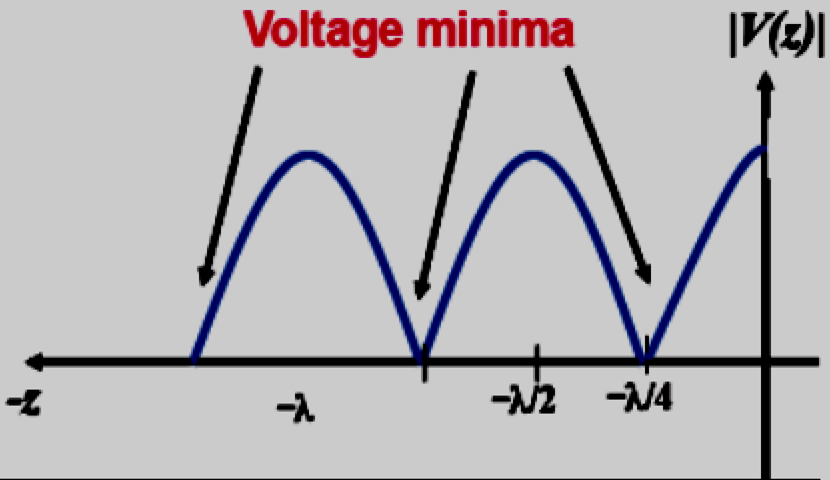
- So substituting in $V(z)$

$$V(z) = V^+[e^{j\beta l} + (+1)e^{-j\beta l}]$$

$$V(z) = V^+(2\cos \beta l)$$

$$|V(z)| = |V^+||2\cos(\beta l)|$$

$$|V(z)| = |V^+|\left|2\cos\left(\frac{2\pi}{\lambda} l\right)\right|$$



Simulation with ADS time signal vs length