ECE 344

MICROWAVE FUNDAMENTALS PART1-Lecture 3

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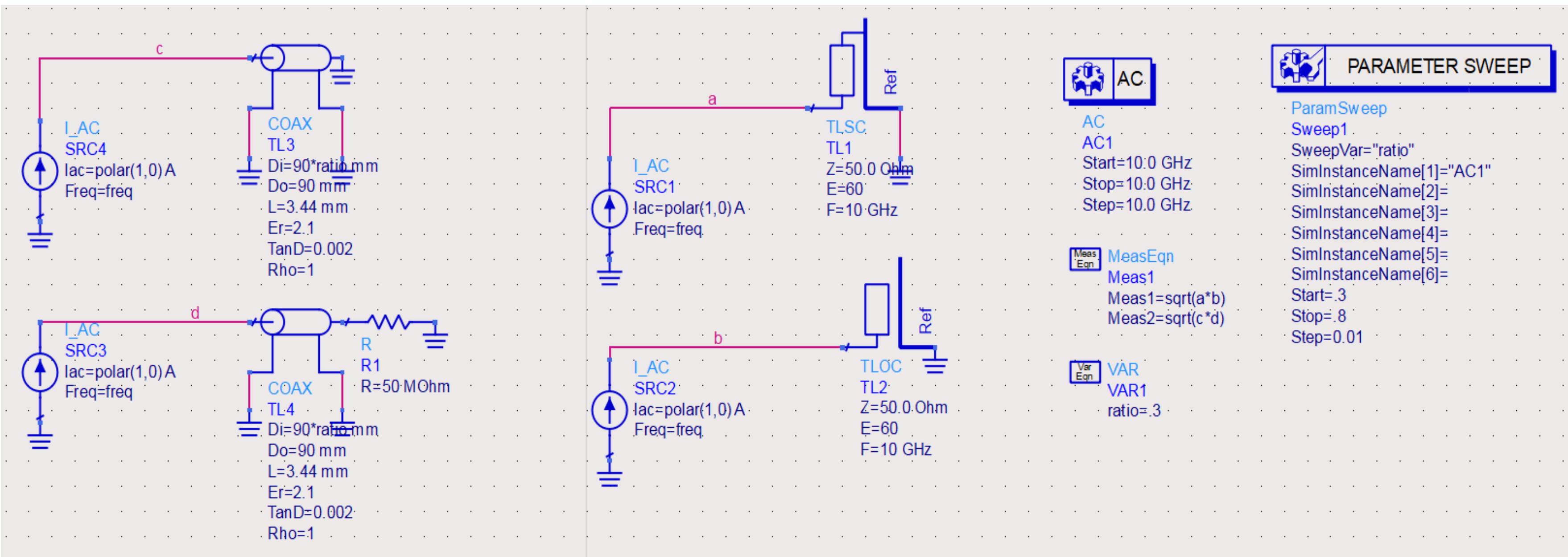
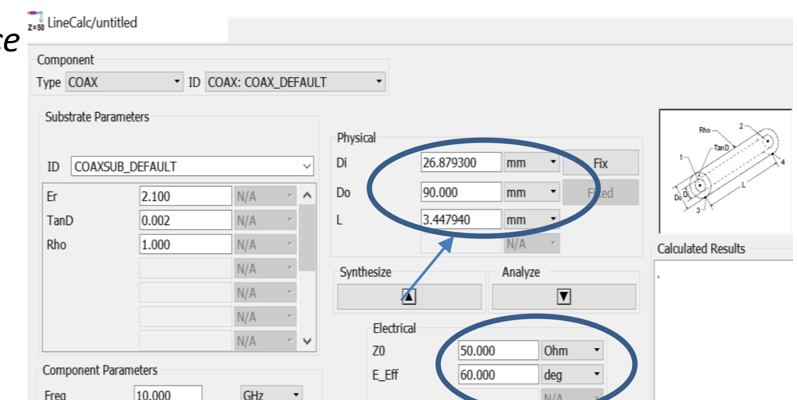
ADS Examples: Characteristic impedance depend on dimension only

$$Z_o = \sqrt{Z_{sc} Z_{oc}}$$



Note as I=1 V=Zin so points a,b,c,d measure input impedance

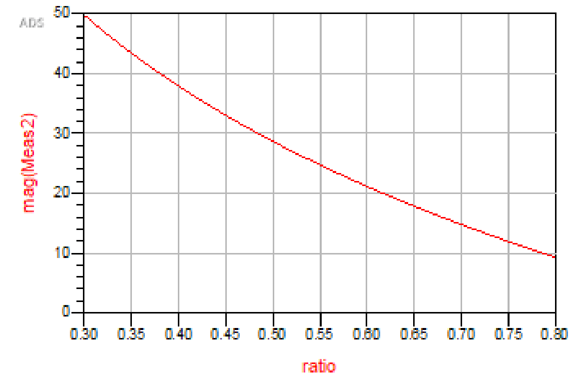
To get Zo=50Ω, a/b=26.87/90=.3



ratio	a	b	Meas1	Meas2	c	d
	freq=10.00 GHz	freq=10.00 GHz	freq=10.00 GHz	freq=10.00 GHz	freq=10.00 GHz	freq=10.00 GHz
300.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	49.81 / 56.60m	85.80 / 89.92 V	28.92 / -89.80 V
310.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	48.46 / 56.60m	83.47 / 89.92 V	28.13 / -89.80 V
320.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	47.14 / 56.60m	81.20 / 89.92 V	27.37 / -89.80 V
330.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	45.87 / 56.59m	79.01 / 89.92 V	26.63 / -89.80 V
340.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	44.64 / 56.59m	76.88 / 89.92 V	25.91 / -89.80 V
350.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	43.44 / 56.58m	74.82 / 89.92 V	25.22 / -89.80 V
360.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	42.27 / 56.57m	72.81 / 89.92 V	24.54 / -89.80 V
370.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	41.14 / 56.57m	70.86 / 89.92 V	23.88 / -89.80 V
380.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	40.03 / 56.56m	68.96 / 89.92 V	23.24 / -89.80 V
390.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	38.96 / 56.55m	67.11 / 89.92 V	22.62 / -89.80 V
400.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	37.91 / 56.54m	65.30 / 89.92 V	22.01 / -89.80 V
410.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	36.89 / 56.53m	63.54 / 89.92 V	21.42 / -89.80 V
420.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	35.89 / 56.52m	61.82 / 89.92 V	20.84 / -89.80 V
430.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	34.92 / 56.51m	60.15 / 89.92 V	20.27 / -89.80 V
440.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	33.97 / 56.50m	58.51 / 89.92 V	19.72 / -89.80 V
450.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	33.04 / 56.49m	56.91 / 89.92 V	19.18 / -89.80 V
460.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	32.13 / 56.48m	55.34 / 89.92 V	18.65 / -89.80 V
470.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	31.24 / 56.47m	53.81 / 89.92 V	18.14 / -89.80 V
480.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	30.37 / 56.45m	52.31 / 89.92 V	17.63 / -89.80 V
490.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	29.52 / 56.44m	50.84 / 89.92 V	17.14 / -89.80 V
500.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	28.68 / 56.42m	49.40 / 89.92 V	16.65 / -89.80 V
510.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	27.86 / 56.41m	47.99 / 89.92 V	16.17 / -89.80 V
520.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	27.06 / 56.39m	46.60 / 89.92 V	15.71 / -89.80 V
530.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	26.27 / 56.37m	45.25 / 89.92 V	15.25 / -89.80 V
540.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	25.49 / 56.36m	43.91 / 89.92 V	14.80 / -89.80 V
550.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	24.74 / 56.34m	42.61 / 89.92 V	14.36 / -89.80 V
560.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	23.99 / 56.32m	41.32 / 89.92 V	13.93 / -89.80 V
570.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	23.26 / 56.30m	40.06 / 89.92 V	13.50 / -89.80 V
580.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	22.54 / 56.27m	38.82 / 89.92 V	13.09 / -89.80 V
590.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	21.83 / 56.25m	37.60 / 89.92 V	12.67 / -89.80 V
600.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	21.14 / 56.23m	36.40 / 89.92 V	12.27 / -89.80 V
610.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	20.45 / 56.20m	35.23 / 89.92 V	11.87 / -89.80 V
620.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	19.78 / 56.17m	34.07 / 89.92 V	11.48 / -89.80 V
630.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	19.12 / 56.14m	32.93 / 89.92 V	11.10 / -89.80 V
640.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	18.47 / 56.11m	31.81 / 89.92 V	10.72 / -89.80 V
650.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	17.82 / 56.08m	30.70 / 89.92 V	10.35 / -89.80 V
660.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	17.19 / 56.05m	29.61 / 89.92 V	9.981 / -89.80 V
670.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	16.57 / 56.01m	28.54 / 89.91 V	9.620 / -89.80 V
680.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	15.96 / 55.97m	27.48 / 89.91 V	9.264 / -89.80 V
690.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	15.35 / 55.93m	26.44 / 89.91 V	8.913 / -89.80 V
700.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	14.76 / 55.88m	25.42 / 89.91 V	8.568 / -89.80 V
710.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	14.17 / 55.84m	24.41 / 89.91 V	8.227 / -89.80 V
720.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	13.59 / 55.78m	23.41 / 89.91 V	7.891 / -89.80 V
730.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	13.02 / 55.73m	22.43 / 89.91 V	7.560 / -89.80 V
740.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	12.46 / 55.67m	21.46 / 89.91 V	7.233 / -89.80 V
750.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	11.90 / 55.61m	20.50 / 89.91 V	6.910 / -89.80 V
760.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	11.35 / 55.54m	19.56 / 89.91 V	6.592 / -89.80 V
770.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	10.81 / 55.46m	18.63 / 89.91 V	6.278 / -89.80 V
780.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	10.28 / 55.38m	17.71 / 89.91 V	5.968 / -89.80 V
790.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	9.753 / 55.29m	16.80 / 89.91 V	5.662 / -89.80 V
800.0 m	86.60 / 90.00 V	28.87 / -90.00 V	50.00 / 3.127f	9.233 / 55.19m	15.90 / 89.91 V	5.360 / -89.80 V

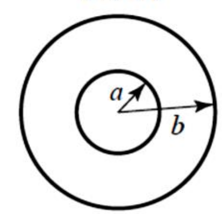
As ratio a/b increased ln(b/a) decreased

- R,L decreased.
- G,C increased.
- Zo decreased



$$z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

COAX



L	$\frac{\mu}{2\pi}\ln\frac{b}{a}$
C	$\frac{2\pi\epsilon'}{\ln b/a}$
R	$\frac{R_s}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$
G	$\frac{2\pi\omega\epsilon''}{\ln b/a}$

For b=90mm a=.3*90mm σcu=5.8x10^7 S/m

F=10GHz

L=2x10^{-7}ln(1/ratio)=2.4x10^{-7} H/m

Rs=.026 Ω/m R=0.199 Ω/m

G=.012 S/m C=96.98 pF/m

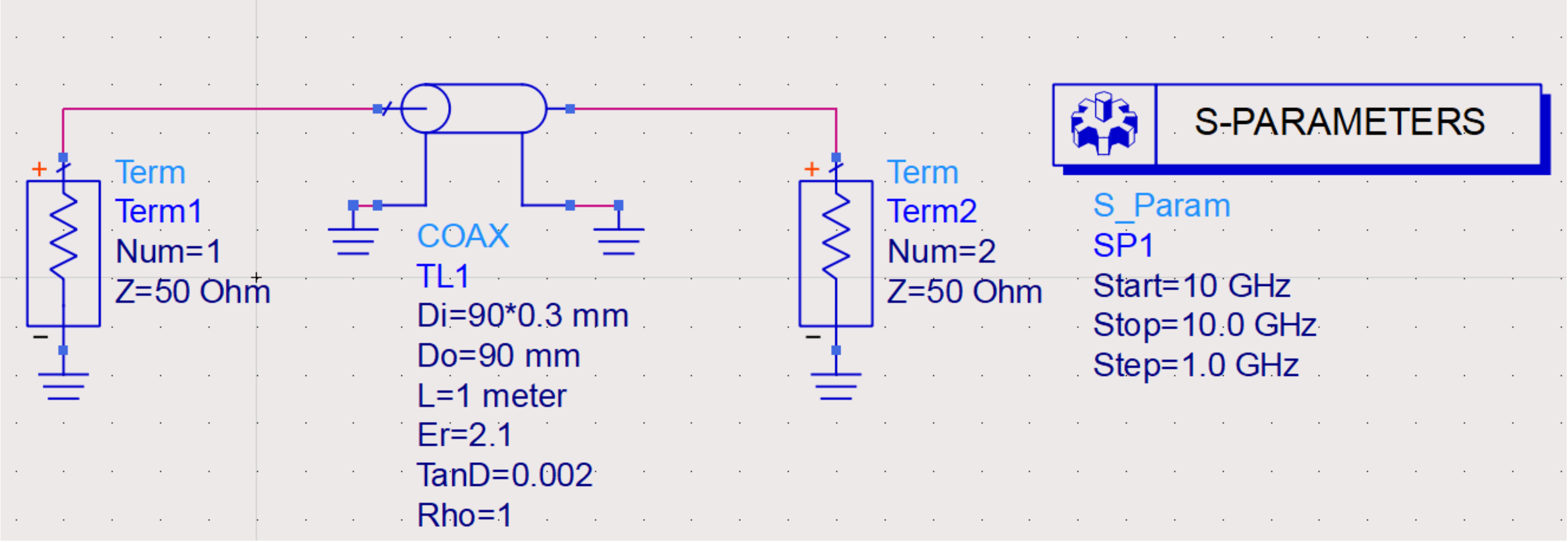
Zo=49.75

Compute Attenuation/m in Coaxial Using:

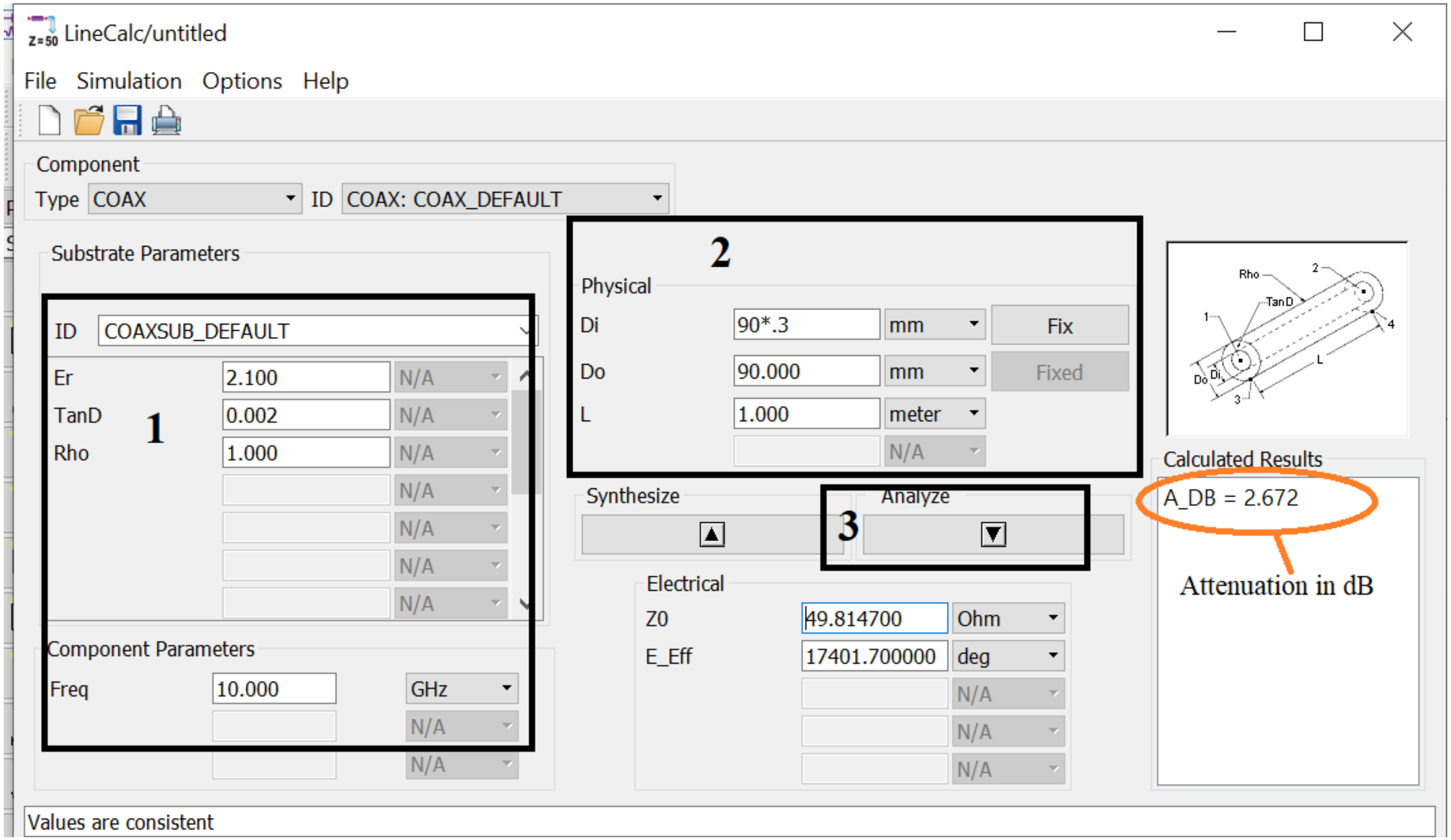
Line Calc.

S parameter calc.

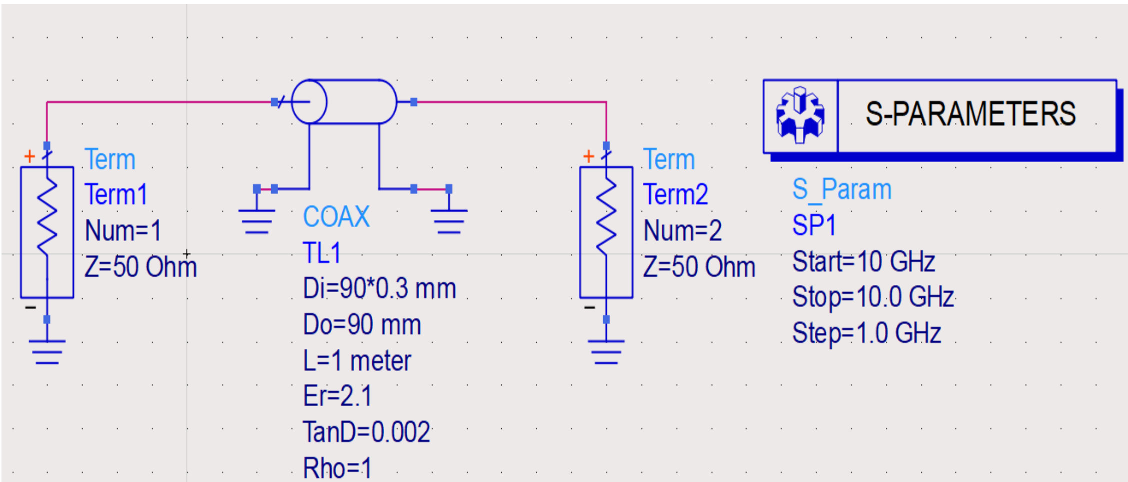
Equations



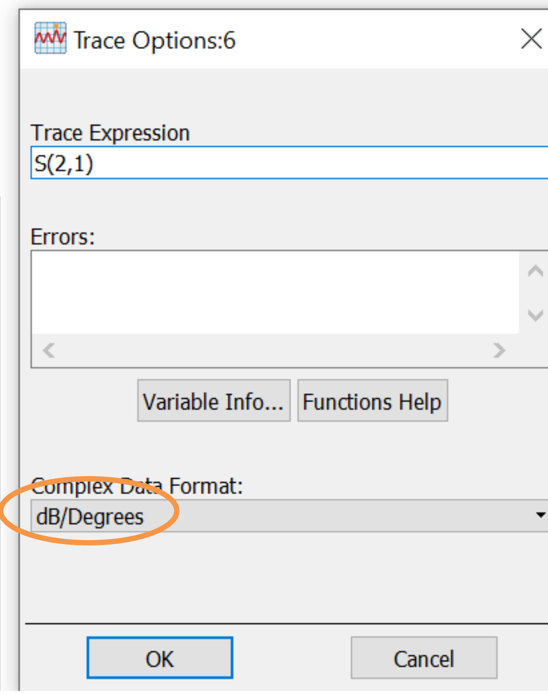
Compute Attenuation/m in Coaxial Using: Line Calc.



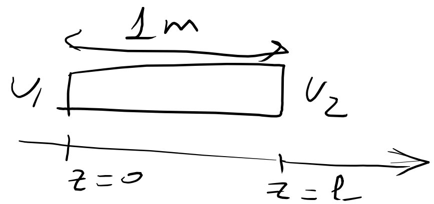
Compute Attenuation/m in Coaxial Using: S parameter Calc.



freq	S(2,1)
10.00 GHz	-2.673 / -121.697



Using Equations



$v_1 = v_0^+ \qquad v_2 = v_0^+ e^{-\alpha l} e^{-j\beta l}$

$$S_{21} = \frac{V_2}{V_1}$$

$$= e^{-\alpha l} \, e^{-j\beta l} \xrightarrow[20 \log]{\text{in dB}} \checkmark$$

$a = 0.3 \times \frac{90}{2}$ mm

$b = \frac{90}{2} = 45$ mm

$\epsilon_r = 2.1 \quad f = 10$ GHz

$\tan\delta = 0.002$

$\sigma_{copper} = 5.8 \times 10^7$

Get α, β from $\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$

$$R = \frac{1}{2\pi \delta \sigma_{copper}} \left(\frac{1}{a} + \frac{1}{b}\right), \quad \delta = \frac{1}{\alpha} = \frac{1}{\sqrt{\pi f \mu \sigma}} = 6.6 \times 10^{-7}$$

$$R = \frac{1}{2\pi \times 6.6 \times 5.8} \left(\frac{1000}{0.3 \times 45} + \frac{1000}{45}\right) = 0.3994 \ \Omega/m$$

$$G = \frac{2\pi \times 2\pi \times 10^{10} \times 0.002 \times 8.85 \times 10^{-12} \times 2.1}{\ln\left(\frac{10}{3}\right)} = 0.012 \ S/m$$

$\tan\delta = \frac{\epsilon''}{\epsilon'}$

$\epsilon'' = \tan\delta \times \epsilon'$

$$L = \frac{4\pi \times 10^{-7}}{2\pi} \ln\left(\frac{10}{3}\right) = 2.4 \times 10^{-7} \ H/m$$

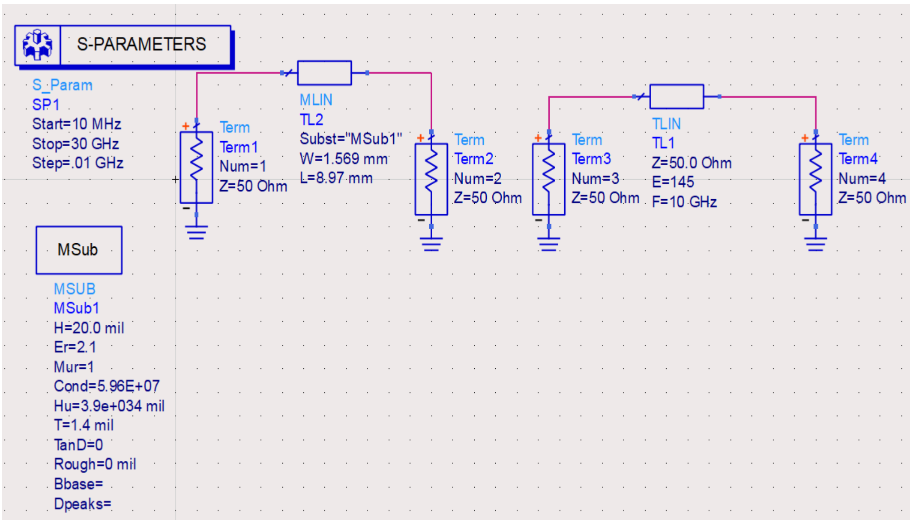
$$C = \frac{2\pi \times 8.85 \times 10^{-12} \times 2.1}{\ln(10/3)} = 96.98 \times 10^{-12} \ F/m$$

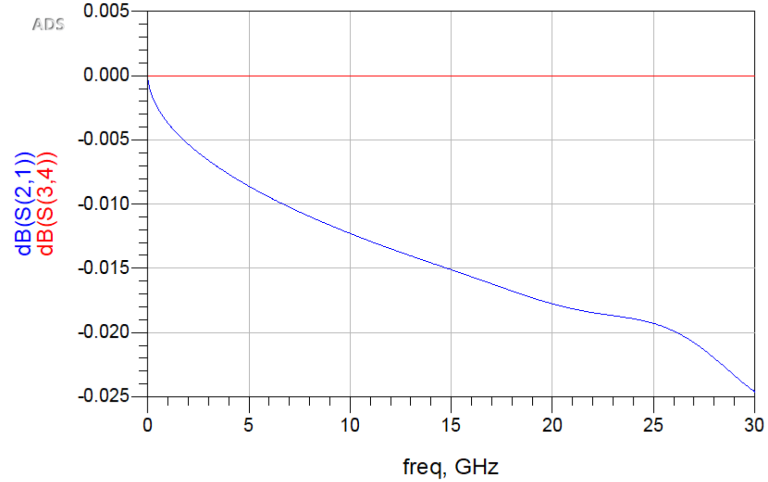
$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} = 0.3 + j303.12 \quad , \quad l = 1$$

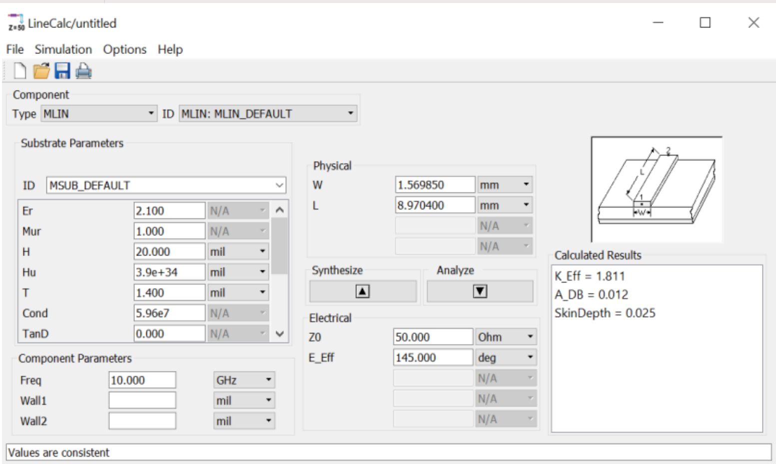
$$\therefore |S_{21}| = |e^{-\alpha l} e^{-j\beta l}| = e^{-0.3}$$

$$\therefore S_{21 \text{ in dB}} = 20\log e^{-0.3} = -2.61$$

Assume loss due to skin depth only







dbS21=-.025 dB

20logS21=-.025

S21=.997

As the frequency increase losses increase

And S21 decreased

$v_{ph} = \omega/\beta$ — for T.L. have ε_{reff}: $v_{ph} = \dfrac{3\times10^8}{\sqrt{1.8}} = 2.236\times10^8$

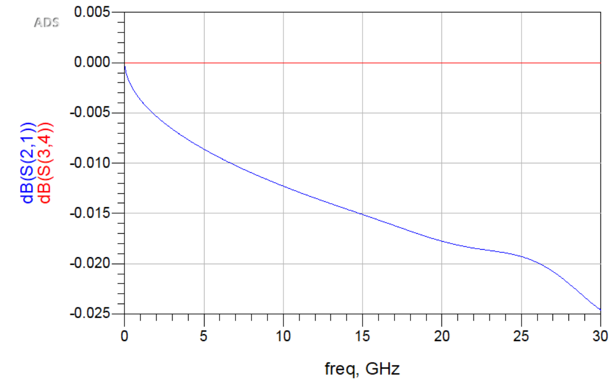
- ideal T.L. $v_{ph} = 3\times10^8$

Given in exam

The attenuation due to conductor loss is given approximately by

$$\alpha_c = \frac{R_s}{Z_0 W} \text{ Np/m},$$

$R_{s\text{tot}} = 0.5\sqrt{\omega\mu_0/2\sigma}$ surface resistivity of the conductor



The T.L. are matched so $|S_{21}| = e^{-\alpha L}$ $\xrightarrow{\text{in dB}}$ $|S_{21}| = 20\log e^{-\alpha\ell}$

The losses due to dielectric is neglected as we consider $\tan\delta = 0$

@ f = 5 GHz

$$R_s = \sqrt{\frac{5\times 2\pi\times 10^9 \times 4\pi\times 10^{-7}}{2\times 5.96\times 10^7}} = 0.018 \qquad R_{s_{tot}} = \tfrac{1}{2}\times 0.018 = 0.009$$

$$\alpha L = \frac{0.009}{50\times 1.569}\times 8.97 = 0.001 \rightarrow |S_{21}| = 20\log e^{-0.001} = -0.008\,dB$$

@ f = 15

$$R_{s_{tot}} = 0.015 \qquad \alpha L = \frac{0.015}{50\times 1.569}\times 8.97 = 0.0018$$

$$|S_{21}| = 20\log e^{-0.0018} = -0.015\,dB$$

Ideal transmission line component in ADS

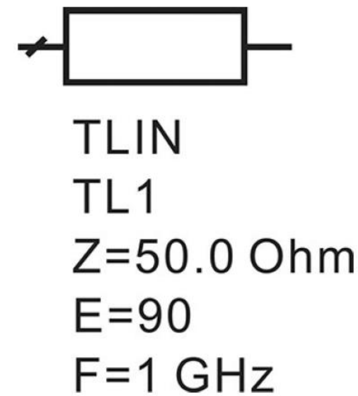


Figure An ideal transmission line component in ADS

Example

Figure shows an ideal transmission line in the ADS schematic window. The **E** in the figure represents the electrical length

(1) If the wavelength at 1 GHz is denoted as λ_o, what is the length of the transmission line?

(2) What is the electrical length **E** at a frequency of 3 GHz?

Solutions

(1) Since

$$\theta = \beta l = \frac{2\pi l}{\lambda_o} = \frac{\pi}{2}$$

then the length is found to be $l = 0.25\,\lambda_o$. physical length if fabricated=7.5 cm

(2) The electrical length is

$$\theta = \beta l = \frac{\omega l}{v_p} = \frac{2\pi l}{\lambda}$$

Now, keeping the phase velocity and length fixed, the electrical length is proportional to the frequency. Thus, at 3 GHz, **E** = 270°.