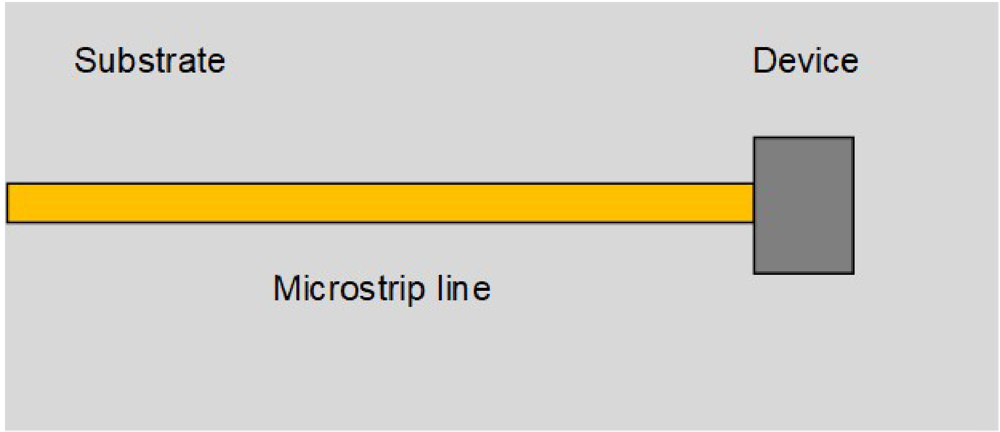
Blast From the Past!

Exam 1

Spring 2013

Problem 3 (40 pts.)

A transmission line is connected to a certain device on a printed circuit board, operating at 10.0 GHz (a top view is shown below). The device is located at $z = 0$. The microstrip line has a characteristic impedance of 50 [Ω]. The effective relative permittivity of the microstrip line is 1.5.



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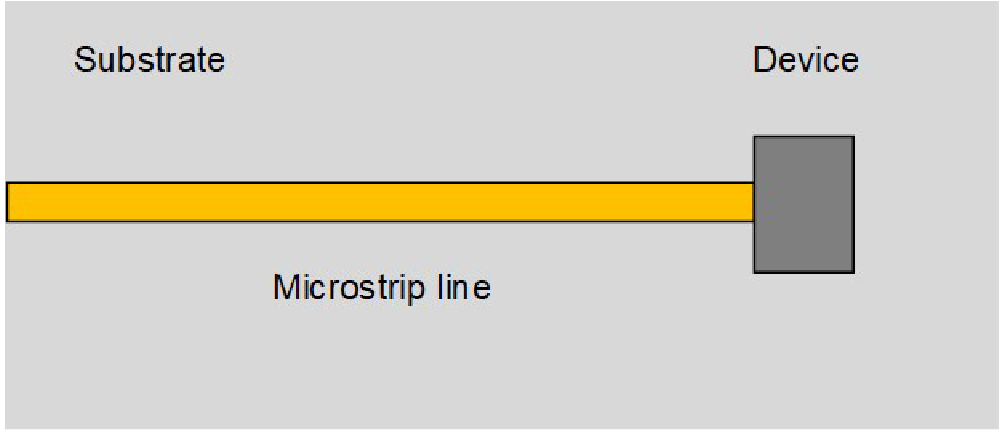
(a) By probing the line, it is found that the voltage on the line has a maximum magnitude of 1.5 volts and a minimum magnitude of 0.5 volts. A voltage minimum occurs at a distance of 0.75 [cm] from the device. Determine the input impedance of the device. Do the calculation exactly (do not use the Smith chart).



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Part (a) At 10.0 GHz we have: $\lambda_0 = 2.9979 \;\; [\mathrm{cm}]$ $\lambda_g = \dfrac{\lambda_0}{\sqrt{\varepsilon_r^{\mathrm{eff}}}} = 2.4478 \;\; [\mathrm{cm}]$

$$Z_{\mathrm{in}} = Z_0 \left(\frac{1+\Gamma_L}{1-\Gamma_L} \right)$$

$$\Gamma_L = \left|\Gamma_L\right| e^{j\phi}$$

$$\mathrm{SWR} = \frac{1+\left|\Gamma_L\right|}{1-\left|\Gamma_L\right|} \;\Rightarrow\; \left|\Gamma_L\right| = \frac{\mathrm{SWR}-1}{\mathrm{SWR}+1}$$

$$\Rightarrow\; \left|\Gamma_L\right| = \frac{3-1}{3+1} = \frac{1}{2}$$

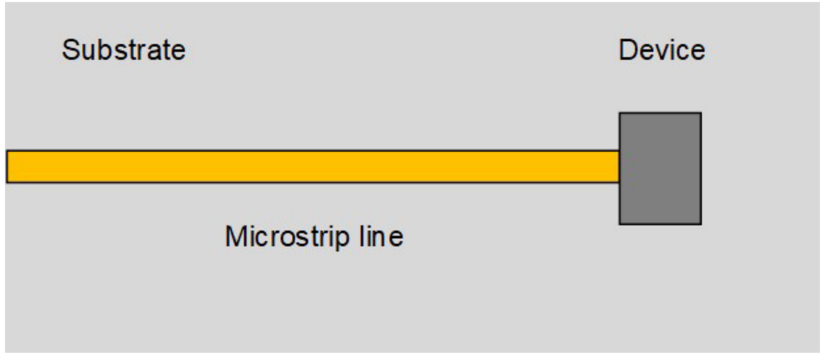
$$\phi + 2\left(2\pi \frac{z_{\min}}{\lambda_g}\right) = \pi + 2\pi n \qquad \left(z_{\min} = -0.75 \; [\mathrm{cm}]\right)$$

$$\Rightarrow\; \phi = 0.70875 \;\; [\mathrm{rad}]$$ (any multiple of 2π can be added on)

Therefore: $\Gamma_L = 0.5\, e^{j(0.70875)}$

$$Z_{\mathrm{in}} = 50 \left(\frac{1+0.5\, e^{j(0.70875)}}{1-0.5\, e^{j(0.70875)}} \right)$$

$$Z_{\mathrm{in}} = 76.402 + j(66.305) \;\; [\Omega]$$



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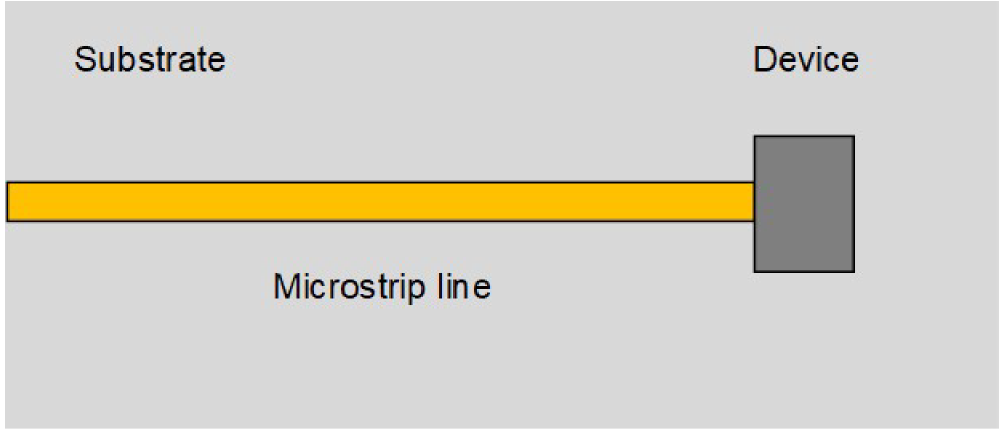
(b) Assume now that a new device is connected to the end of the line, which has an input impedance of $Z_{in} = 100+j100$ [Ω]. An open-circuited stub line having characteristic impedance of 50 [Ω] and an effective permittivity of 1.5 is added at a distance d from the load. Find the distance d and the length of the open-circuited stub line (in cm) to obtain a perfect match seen by an incoming wave that arrives from a generator on the left (not shown). Use the shortest distance d possible. Use the Smith chart to do all calculations. (A Smith chart is included at the end of this problem.)



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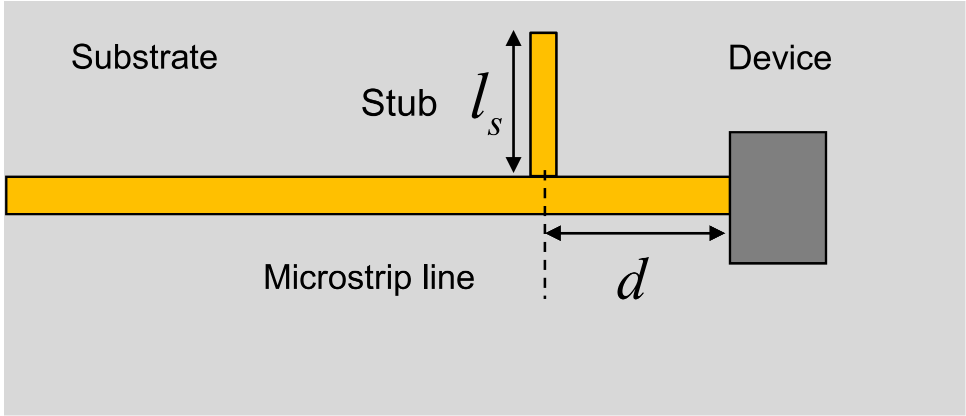
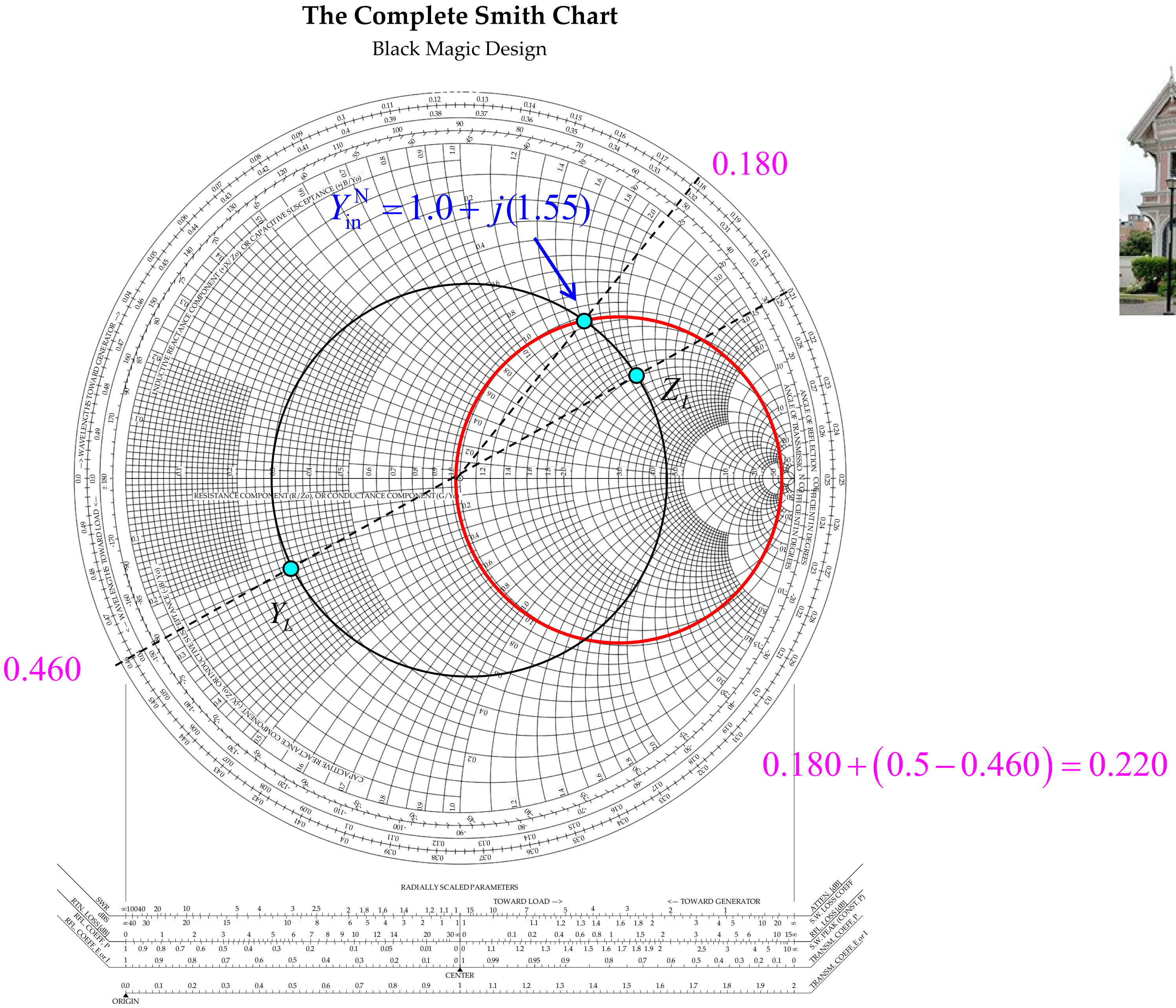
Part (b) At 10.0 GHz we have: $\lambda_0 = 2.9979 \;\; [\text{cm}]$ $\qquad \lambda_g = \dfrac{\lambda_0}{\sqrt{\varepsilon_r^{\text{eff}}}} = 2.4478 \;\; [\text{cm}]$

From the Smith chart:

$$d = 0.220\lambda_g = 0.530 \; [\text{cm}]$$

$$l_s = 0.342\lambda_g = 0.837 [\text{cm}]$$





Part (b)

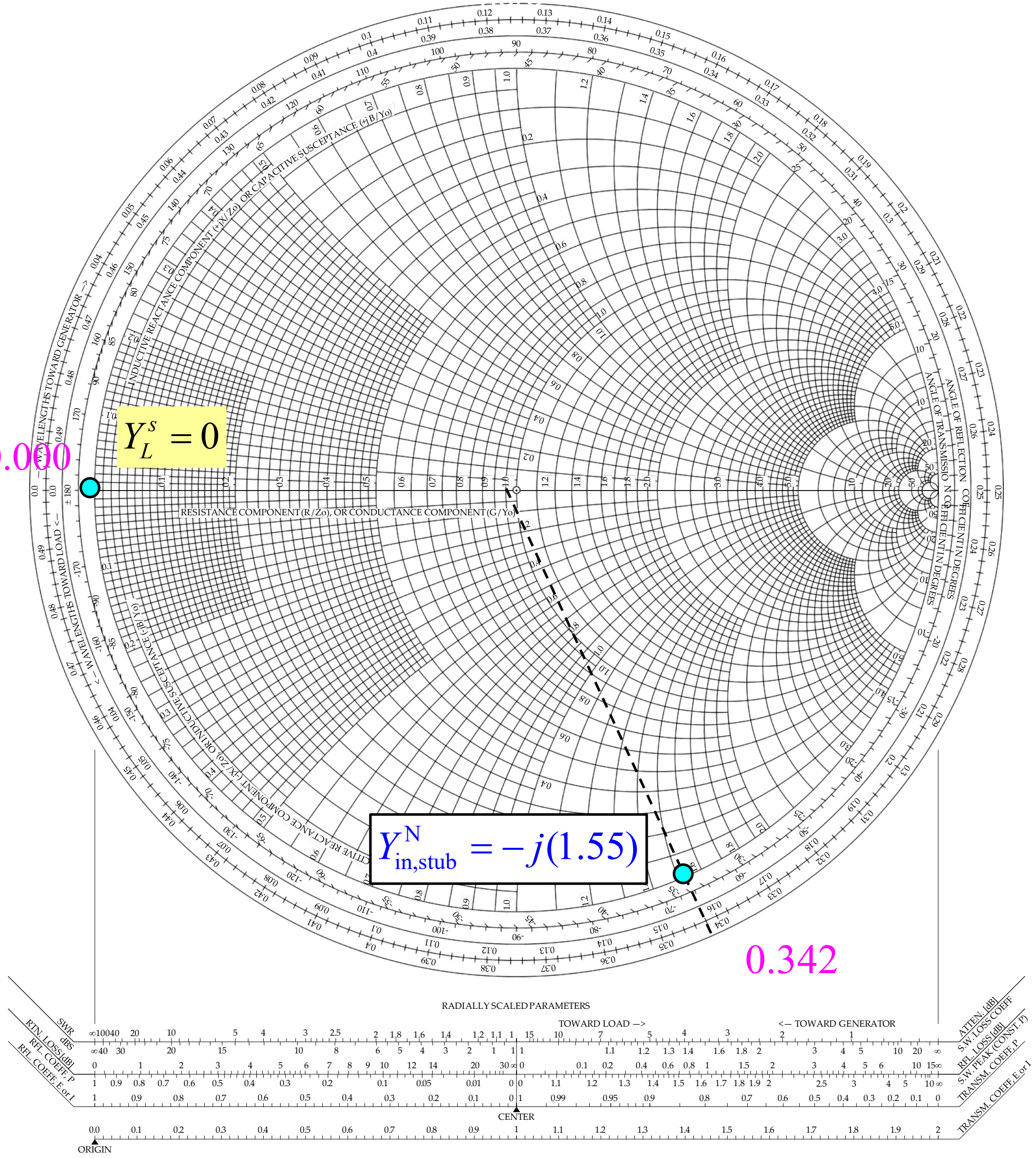
Calculation for d

The Complete Smith Chart

Black Magic Design

Part (b)

Calculation for l_s



Note:
We are using the Smith chart as an <u>admittance</u> calculator here.

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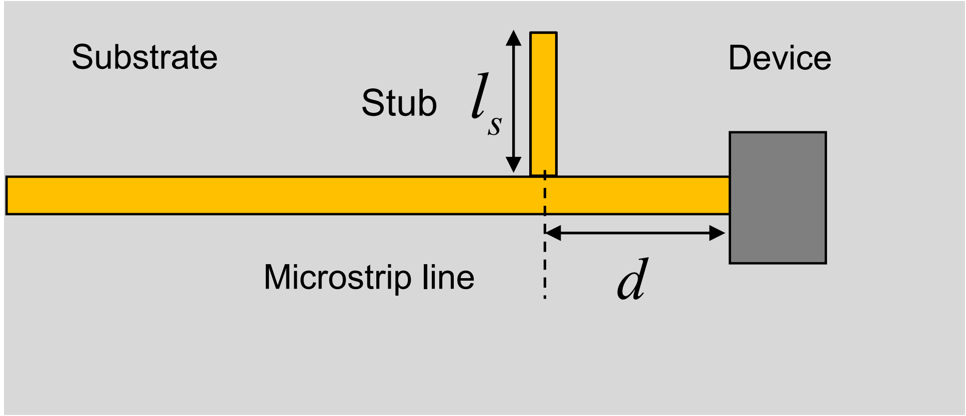
(c) As a continuation of part (b), what is the SWR on the main line between the device and the open-circuited stub? What is the SWR on the open-circuited stub line? What is the SWR on the main line to the left of the open-circuited stub? Do the calculations exactly (do not use the Smith chart).



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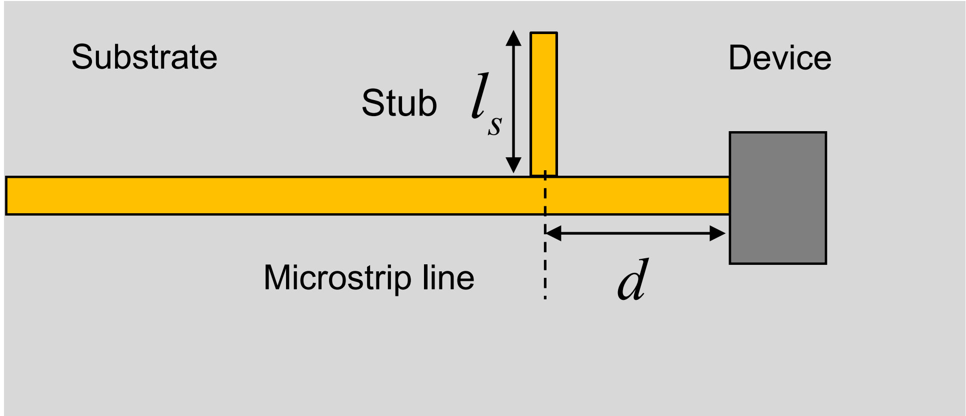
Part (c)

SWR between device and stub: $$\Gamma_L = \frac{Z_{\text{in}} - Z_0}{Z_{\text{in}} + Z_0} = 0.538 + j(0.308)$$

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

$$\text{SWR} = 4.26$$



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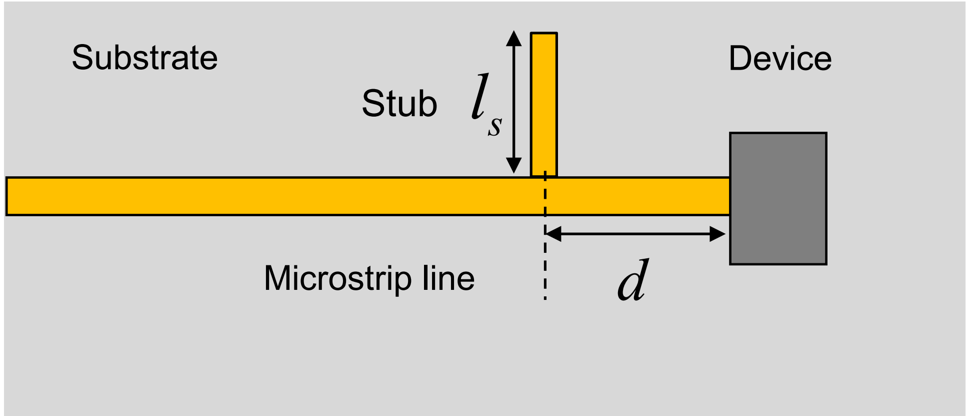
Part (c)

SWR on stub: $\mathrm{SWR} = \infty$



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Part (c)

SWR on feed line: $\mathrm{SWR} = 1$