

EE 382 Applied EM (Spring 2018) Examination #2

Name Key B

Instructions: Place answers in indicated spaces, use notation as given in class for coordinates & vectors, and **show & label all work** for credit. Express impedances & propagation constants in rectangular format and reflection coefficients & phasor currents/voltages in polar format (angle in degrees). Attach equation sheet and hand-in with exam. Assume $c = 2.998 \times 10^8$ m/s.

- 1) A kimoyo bead technology load is connected to a lossless, 300Ω transmission line. Using an oscilloscope, the maximum and minimum peak-to-peak voltages on the transmission line are measured to be $9.1 V_{pp}$ and $1.3 V_{pp}$ respectively. Adjacent voltage minima occur at 30 cm intervals. There is 21 cm between the nearest voltage minima and load. Calculate the VSWR, wavelength, and operating frequency. Using a fully-labeled Smith chart, find the normalized impedance z_L and reflection coefficient of the load. Calculate the load impedance Z_L . Assume $u = c = 2.998 \times 10^8$ m/s.

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{9.1}{1.3} = \underline{7}$$

$$\lambda = 2(30 \text{ cm}) = \underline{60 \text{ cm}} \leftarrow \text{adj. minima separated by } \frac{\lambda}{2}$$

$$f = \frac{u}{\lambda} = \frac{2.998 \times 10^8}{0.6} = \underline{499.66 \text{ MHz}}$$

→ Use VSWR scale to set compass. Draw circle of radius $VSWR = 7$ ($r = 0.75$) centered on Smith chart

→ V_{min} occur @ $r_{min} = \frac{1}{VSWR} = 0.14286$ point on circle

→ Move $\frac{21 \text{ cm}}{60 \text{ cm}} = 0.35$ "WAVELENGTHS TOWARD LOAD" from r_{min} location to z_L / Γ_L point on circle

→ Read $z_L = 0.4 + j1.3 \Omega$ + $\Gamma_L = 0.75 \angle 72^\circ$

→ $Z_L = z_L Z_0 = (0.4 + j1.3) 300 = \underline{120 + j390 \Omega}$

VSWR = 7 $\lambda =$ 60 cm $f =$ 499.66 MHz

$\Gamma_L =$ $0.75 \angle 72^\circ$ $z_L =$ $0.4 + j1.3 \Omega$ $Z_L =$ $120 + j390 \Omega$

1) continued

Simple Smith Chart

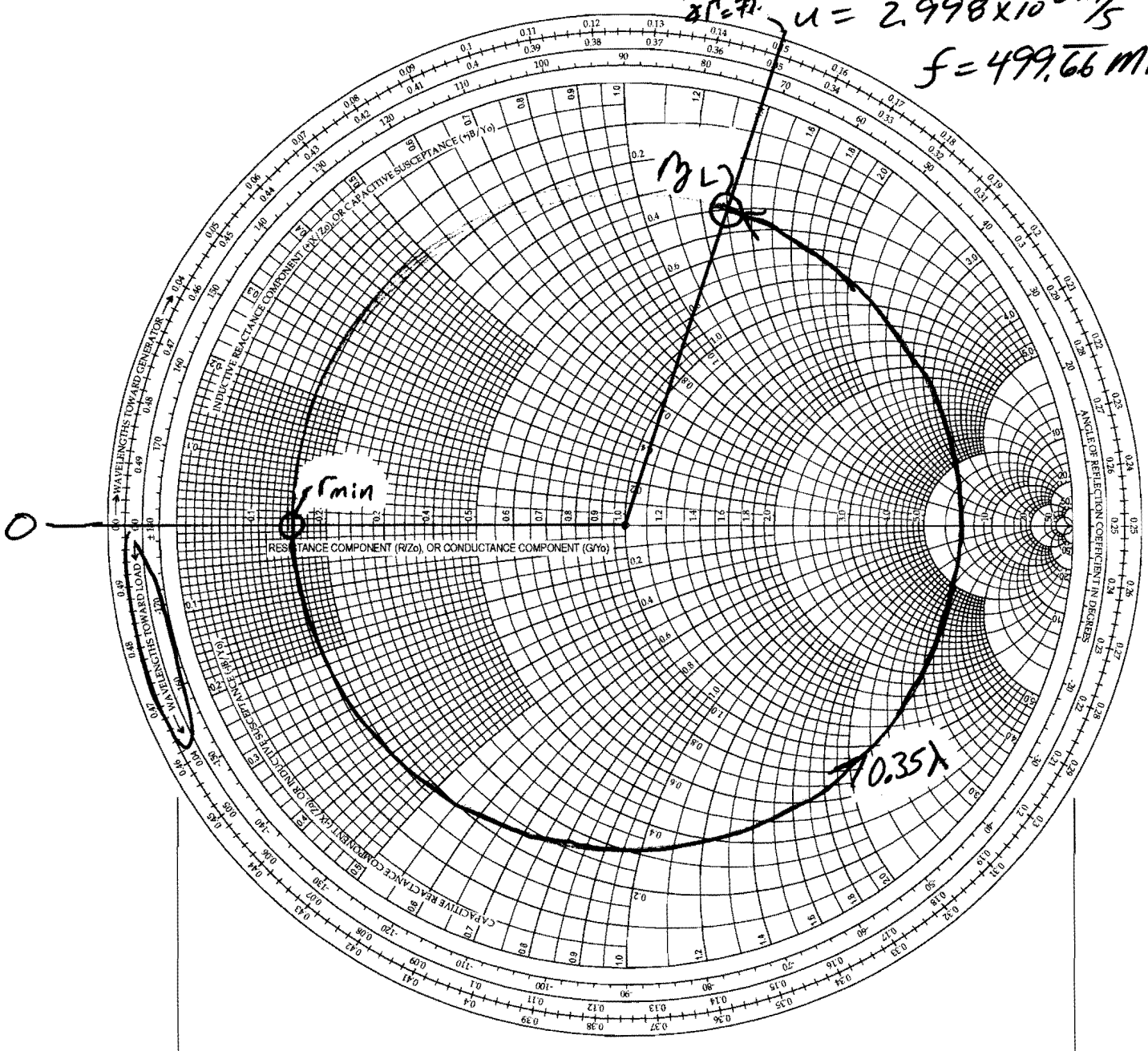
$Z_0 = 300 \Omega$

$\lambda = 60 \text{ cm}$

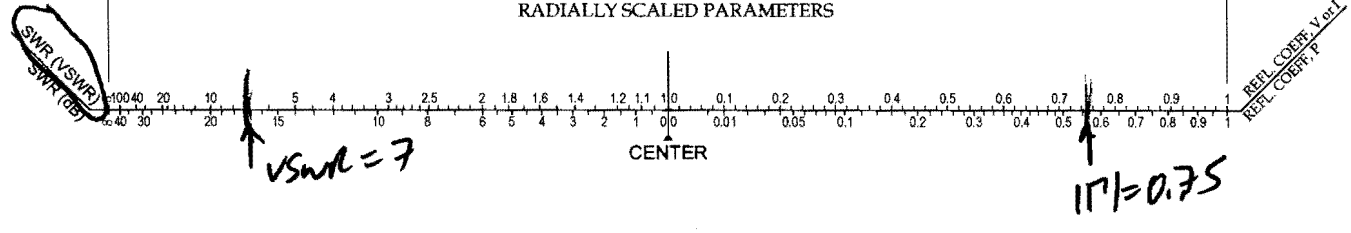
$0.35 \lambda + \lambda/4 = 7\lambda/8$

$u = 2.998 \times 10^8 \text{ m/s}$

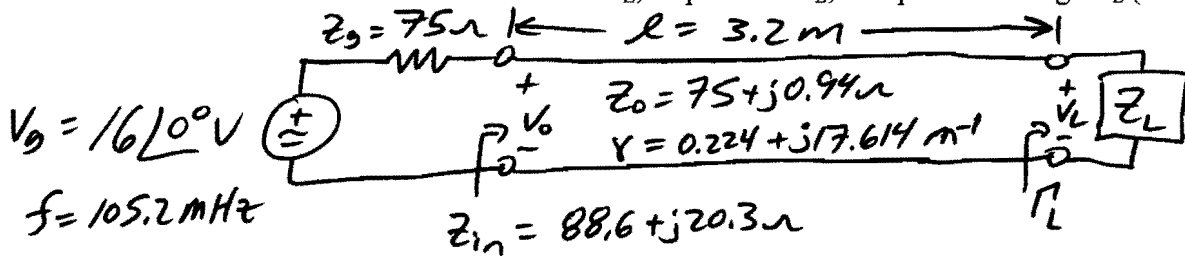
$f = 499.66 \text{ MHz}$



RADIALLY SCALED PARAMETERS



- 2) A 3.2 m long vibranium transmission line has $Z_0 = 75 + j0.94 \Omega$ and $\gamma = 0.224 + j17.614 \text{ m}^{-1}$. It is driven by a generator, operating at 105.2 MHz, with $V_g = 16 \angle 0^\circ \text{ V}$ and $Z_g = 75 \Omega$. Using a vector network analyzer, the input impedance is measured to be $Z_{in}(0) = 88.6 + j20.3 \Omega$. Find the input reflection coefficient $\Gamma_{in}(0)$, phasor input voltage V_0 , and forward traveling voltage wave V_0^+ . Determine the load reflection coefficient Γ_L , impedance Z_L , and phasor voltage V_L (extra credit).



$$\Gamma_{in}(0) = \frac{Z_{in}(0) - Z_0}{Z_{in}(0) + Z_0} = \frac{(88.6 + j20.3) - (75 + j0.94)}{(88.6 + j20.3) + (75 + j0.94)} = \underline{0.1434 \angle 47.5155^\circ}$$

$$V_0 = V_g \frac{Z_{in}(0)}{Z_g + Z_{in}(0)} = 16 \angle 0^\circ \frac{88.6 + j20.3}{75 + (88.6 + j20.3)} = \underline{8.8219 \angle 5.8316^\circ \text{ V}}$$

Note: $V_0 = V_0^+ e^{-\gamma l} (1 + \Gamma_{in}(0))$

$$\hookrightarrow V_0^+ = \frac{V_0}{1 + \Gamma_{in}(0)} = \frac{8.8219 \angle 5.8316^\circ}{1 + 0.1434 \angle 47.5155^\circ} = \underline{8.0057 \angle 0.324^\circ \text{ V}}$$

$$\Gamma_L = \Gamma_{in}(0) e^{2\gamma l} = (0.1434 \angle 47.5155^\circ) e^{2(0.224 + j17.614)3.2}$$

$$\Gamma_L = \underline{0.60145 \angle 26.44579^\circ}$$

$$Z_L = Z_0 \frac{1 + \Gamma_L}{1 - \Gamma_L} = (75 + j0.94) \frac{1 + 0.60145 \angle 26.446^\circ}{1 - 0.60145 \angle 26.446^\circ}$$

$$\underline{Z_L = 166.36 + j143.22 \Omega}$$

Extra Credit

$$V_L = V_0^+ e^{-\gamma l} (1 + \Gamma_L) = (8.006 \angle 0.324^\circ) e^{-(0.224 + j17.614)3.2} = \underline{6.105 \angle 20.735^\circ \text{ V}}$$

$$\Gamma_{in}(0) = \underline{0.1434 \angle 47.52^\circ} \quad V_0 = \underline{8.822 \angle 5.832^\circ \text{ V}} \quad V_0^+ = \underline{8.006 \angle 0.324^\circ \text{ V}}$$

$$\Gamma_L = \underline{0.60145 \angle 26.446^\circ} \quad Z_L = \underline{166.36 + j143.22 \Omega} \quad \left. \begin{array}{l} V_L = \underline{6.105 \angle 20.735^\circ \text{ V}} \\ \text{(Extra)} \end{array} \right\}$$

- 3) A load $Z_L = 90 - j210 \Omega$ is connected to a 300Ω , $14\angle 0^\circ \text{ V}$, 900 MHz generator by a 80 cm long, lossless transmission line ($u = 2.5 \times 10^8 \text{ m/s}$, $Z_0 = 300 \Omega$) in a Dragon flyer communications module. Using a Smith chart, determine the input impedance $Z_{in,NM}$ and $VSWR_{NM}$ with no matching. Next, using a Smith chart, match the load to the generator using the shortest possible **open circuit** stub, made of the same transmission line, connected in parallel as close to the load as possible. What are the normalized admittances of the closest match point y_{M1} and the corresponding stub y_{stub} ? How long is the stub d_{stub} (in λ & cm) and how far is the stub from the load l_{stub} (in λ & cm)? Sketch the resulting circuit with all relevant lengths (cm) and values labeled. **Clearly label all points and relevant dimensions/parameters on Smith chart.**

No Match

→ Normalize load impedance $y_L = \frac{Z_L}{Z_0} = \frac{90 - j210}{300} = \underline{0.3 - j0.7} \frac{\Omega}{\Omega}$

→ Plot y_L on Smith Chart

→ Draw circle, centered on Smith chart, through y_L

→ Move $\frac{l}{\lambda} = \frac{0.8}{\left(\frac{2.5 \times 10^8}{900 \times 10^6}\right)} = \frac{0.8}{0.277} = 2.88 \rightarrow 0.38$

"WAVELENGTHS TOWARD GENERATOR" from

y_L to $\underline{y_{in,NM} = 2.9 - j2.4} \frac{\Omega}{\Omega}$

→ $Z_{in,NM} = y_{in,NM} Z_0 = (2.9 - j2.4)300 = \underline{870 - j720 \Omega}$

→ Use compass + VSWR scale to get $\underline{VSWR_{NM} = 5.05}$
(Exact 5.07)

Matching

→ Move 180° (or $\lambda/4$) around circle from y_L to

$\underline{y_L = 0.517 + j1.207} \frac{S}{S}$ point

→ From y_L , need to move $(0.183 - 0.148)\lambda = \underline{0.035 \lambda = l_{stub}}$
 $= 0.035(27.7) = \underline{0.972 \text{ cm}}$

"WAVELENGTHS TOWARD GENERATOR" to arrive @ y_{M1} .

3) continued

→ lead $\underline{y_{m1} = 1 + j1.8 \text{ S/S}}$

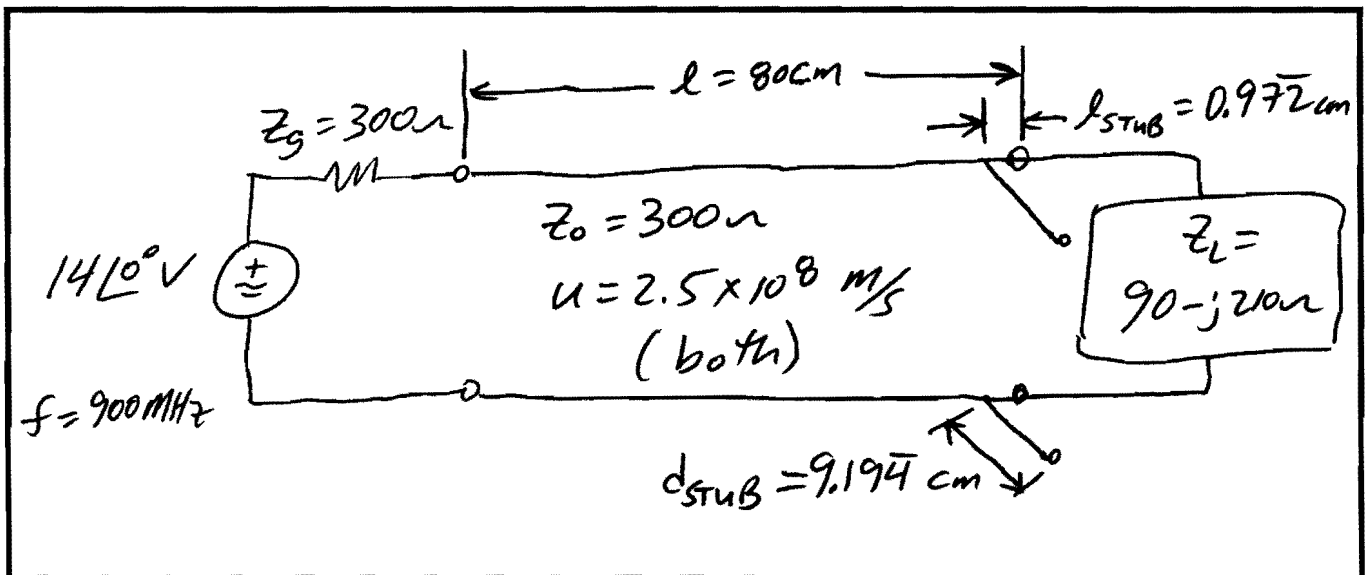
→ For parallel stub to match load to TL

$$y_{m1} + y_{\text{STUB}} = (1 + j1.8) + y_{\text{STUB}} = 1$$

↳ $\underline{y_{\text{STUB}} = -j1.8 \text{ S/S}}$

→ starting @ open ckt point ($y_{oc} = \frac{1}{j0} = 0$) on Smith Chart ($\Gamma_{oc} = 1 = 1 \angle 180^\circ$), move along perimeter ($|\Gamma| = 1$) of Smith chart toward generator to arrive @ $y_{\text{STUB}} = -j1.8 \text{ S/S}$. Reading scale $\underline{d_{\text{STUB}} = 0.331 \lambda = 0.331 (27.7 \text{ cm}) = 9.194 \text{ cm}}$

Fully-labeled sketch of **matched** transmission line circuit



VSWR_{NM} = 5.07

Z_{in,NM} = 870 - j720 Ω

y_{M1} = 1 + j1.8 S/S

y_{stub} = -j1.8 S/S

d_{stub} = 0.331 λ = 9.194 cm

l_{stub} = 0.035 λ = 0.972 cm

3) continued

Simple Smith Chart

$Z_0 = 300 \Omega$
 $u = 2.5 \times 10^8 \text{ m/s}$
 $f = 900 \text{ MHz}$

