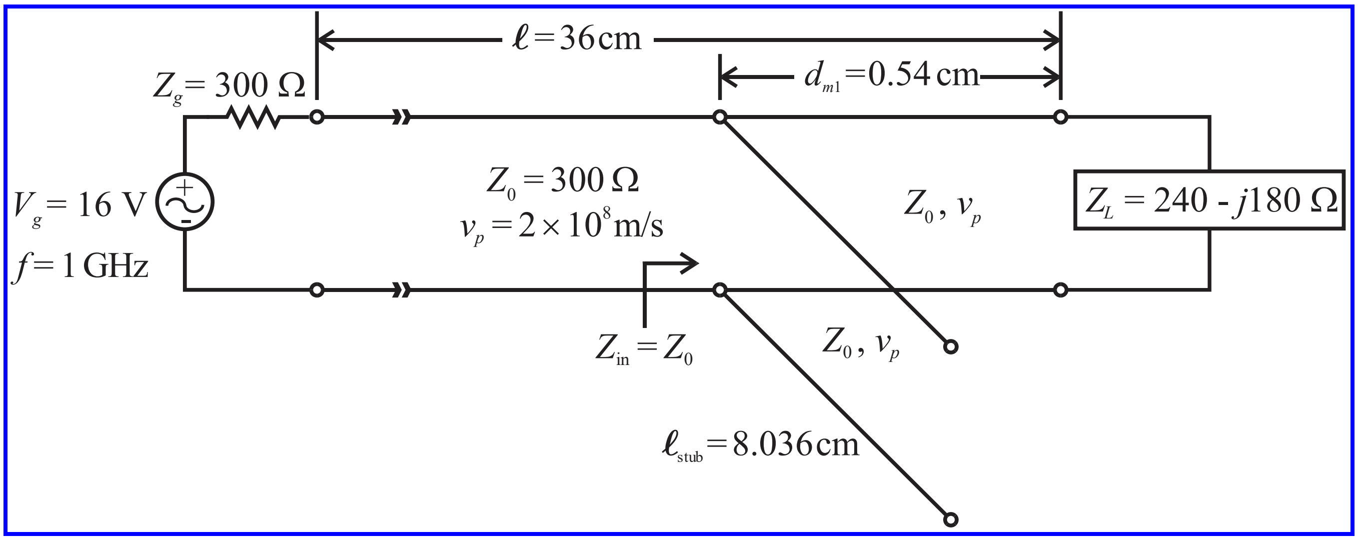
A lossless transmission line (300 Ω, 2×10^8 m/s) of length 36 cm connects a load of $240 - j180$ Ω to a matched 16 V generator operating at 1 GHz. Using a Smith chart, find the unmatched input impedance and load power. Then, design and sketch a shunt single-stub tuning network with an open circuit termination. Place the stub as close as possible to the load and make the stub as short as possible. Find the matched input impedance and load power.

- Calculate wavelength $\lambda = v_p / f = 2 \times 10^8 / 1 \times 10^9 \Rightarrow$ **$\lambda = 0.2$ m = 20 cm**.
- Calculate the normalized load impedance $z_L = Z_L / Z_0 = (240 - j180) / 300$ $\Rightarrow$ **$z_L = 0.8 - j0.6$ Ω/Ω**. Plot z_L on Smith chart.
- Use compass to draw a circle through z_L, centered on Smith chart. Use a straight edge to draw line through center of Smith chart & z_L to outer rings of Smith chart. Note $|\Gamma| = 0.5$ and SWR = 3.
- Calculate $\ell/\lambda = 36/20 = 1.8$. Remove extraneous 1.5λ to get $\ell/\lambda = 0.3$. Move 0.3λ in the "WAVELENGTHS TOWARD GENERATOR" direction along the circle of constant $|\Gamma|$ to **$z_{in,NM} = 1.24 + j0.75$ Ω/Ω.** The unmatched input impedance is then $Z_{in,NM} = z_{in,NM} Z_0 = 1.24 + j0.75(300) \Rightarrow$ **$Z_{in,NM} = 372 + j225$ Ω**.
- The unmatched input current is $I_{0,NM} = V_g / (Z_g + Z_{in,NM}) = 16\angle 0° / (300 + 372 + j225)$ $\Rightarrow$ **$I_{0,NM} = 0.02258\angle\text{-}18.512°$ A**. The unmatched input voltage is $V_{0,NM} = I_{0,NM} (Z_{in,NM}) = (0.02258\angle\text{-}18.512°)(372 + j225) \Rightarrow$ **$V_{0,NM} = 9.816\angle 12.656°$ V**.
- The unmatched input power is $P_{0,NM} = 0.5\ \text{Re}(V_{0,NM}\ I_{0,NM}^*) = 0.5\ \text{Re}\{(9.816\angle 12.656°)(0.02258\angle 18.512°)\} \Rightarrow$ **$P_{0,NM} = 0.094813$ W = 94.813 mW**.
- To match, begin by moving 180° around the circle of constant $|\Gamma|$ from z_L point to **$y_L = 0.8 + j0.6$ S/S**.
- Note the match points where the circle of constant $|\Gamma| = 0.33$ intersects the circle of $g = 1$ S/S at **$y_{m1} = 1 + j0.71$ S/S** and $y_{m2} = 1 - j0.71$ S/S. Choose **y_{m1}** as it is closest.
- Find distance in the "WAVELENGTHS TOWARD GENERATOR" direction from **y_L** to **y_{M1}** as $d_{m1} = 0.152\lambda - 0.125\lambda \Rightarrow$ **$d_{m1} = 0.027\lambda = 0.54$ cm**.

- To match, connect an open circuit stub with input admittance $\boldsymbol{y_{stub} = -j0.71}$ **S/S** at $\boldsymbol{y_{M1}}$ location.

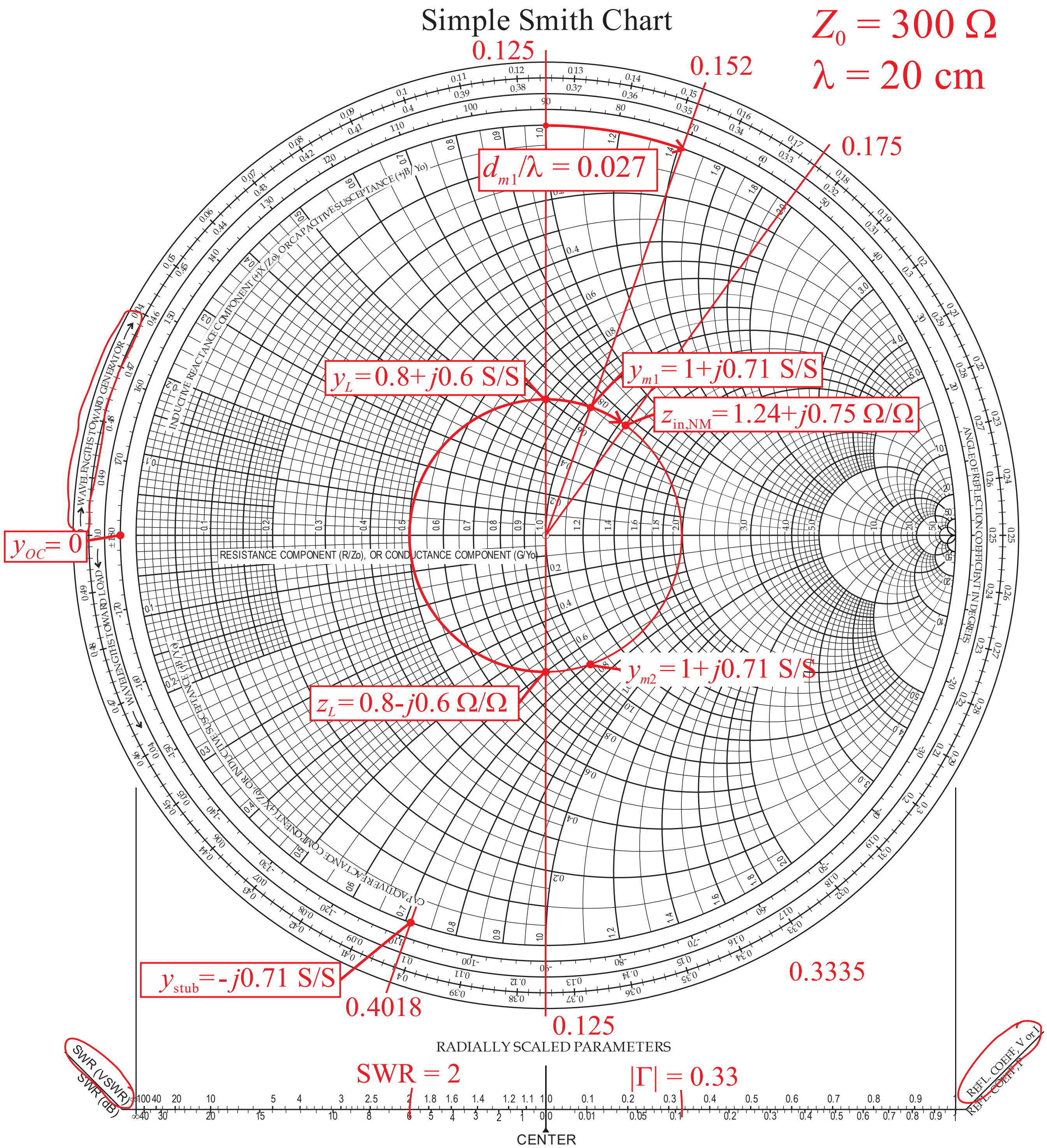
- To find the stub length, plot $y_{oc} \to \infty$ at 0 and go in the "WAVELENGTHS TOWARD GENERATOR" direction to the location of $\boldsymbol{y_{stub} = -j0.71}$ **S/S** at 0.4018λ $\Rightarrow$ $\boldsymbol{\ell_{stub} = 0.4018\lambda = 8.036}$ **cm**.



- The matched input impedance is $\boldsymbol{Z_{in,M} = Z_0 = 300\ \Omega}$.

- The matched input current is $I_{0,M} = V_g/(Z_g + Z_{in,M}) = 16\angle 0° /(300 + 300) \Rightarrow \boldsymbol{I_{0,M} = 0.02667\angle 0°}$ **A**. The matched input voltage is $V_{0,M} = I_{0,M}\ (Z_{in,M}) = (0.02667\angle 0°)(300) \Rightarrow \boldsymbol{V_{0,M} = 8\angle 0°}$ **V**.

- The matched input power is $P_{0,M} = 0.5\,\mathrm{Re}(V_{0,M}\, I_{0,M}^*) = 0.5\,\mathrm{Re}\{(8\angle 0°)(0.02667\angle 0°)$ $\Rightarrow$ $\boldsymbol{P_{0,M} = 0.10667}$ **W = 106.667 mW**, an increase of 11.85 mW over the unmatched case.


Simple Smith Chart
$Z_0 = 300\ \Omega$
$\lambda = 20$ cm
0.125
0.152
0.175
$d_{m1}/\lambda = 0.027$
$y_L = 0.8 + j0.6$ S/S
$y_{m1} = 1 + j0.71$ S/S
$z_{in,NM} = 1.24 + j0.75\ \Omega/\Omega$
$y_{OC} = 0$
$y_{m2} = 1 + j0.71$ S/S
$z_L = 0.8 - j0.6\ \Omega/\Omega$
$y_{stub} = -j0.71$ S/S
0.4018
0.125
0.3335
RADIALLY SCALED PARAMETERS
SWR = 2
$|\Gamma| = 0.33$
SWR (VSWR)
SWR (dB)
REFL. COEFF. V or I
CENTER
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES