EE3140 Hour Exam 2, Spring 2002

Note that the problems have different point values. All units are mks. Show your work for full credit. Useful constants:

$$\varepsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$$
$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

1. A wave propagates between two parallel plates of infinite extent which are $a = 10 \text{ cm}$ apart. The electric field of the wave is: (10 points)

$$E_z = E_o \sin(30\pi x) \cos(\beta y - \omega t)$$

What mode is propagating?

$$30\pi = \frac{m\pi}{a} \implies m = 30a \implies m = 3$$

$E_z$ is transverse to direction of propagation, $\beta$.

(mode $= \underline{\text{TE}_3}$)

2. An short-circuited 50-Ω transmission line of length $l$ presents an impedance of $j25 \Omega$ to the generator. Find the length of the line, $l$.

(see attached Smith chart)

$$l = 0.074\lambda$$
3. Given a load impedance of $Z_L = 60 + j40\,\Omega$ and a line impedance of 100 $\Omega$, find the distance (in terms of $\lambda$), $l$ for which a short-circuited 100$\Omega$ section of line of length $l_2$ (also in terms of $\lambda$) will present a VSWR =1 to the generator.

\[ Z_L = 60 + j40 \, \Omega \]

From Smith chart, $Y_L = 1.154 - j0.769$

\[ l_1 = 0.168 - 0.1525 \]
\[ = 0.0155\,\lambda \]

\[ l_2 = 0.25\,\lambda + 0.101\,\lambda = 0.351\,\lambda \]

\[ l_1 = 0.0155\,\lambda \quad (0.3205\,\lambda) \]

\[ l_2 = 0.351\,\lambda \quad (0.149\,\lambda) \]

4. Slotted line data show voltage minima at $z=16$cm and $z=24$cm for an short-circuited line at $z=0$cm. An unknown load is then connected, a VSWR of 2 is measured, and a minimum is measured at $z=11$cm and 19cm. Find the unknown (normalized) load impedance.

\[ \lambda = 16\,\text{cm} \]

\[ Z_{ln} = 1.35 - j0.72 \]
5. A lossless air-filled waveguide for an S-band radar has inside dimensions \( a = 7.214 \) cm and \( b = 3.404 \) cm. For the \( TM_{11} \) mode propagating at an operating frequency which is 1.1 times the cutoff frequency of this mode, calculate:

(a) cutoff frequency

\[
\frac{k_c^2}{k_x^2 + k_y^2} = \left(\frac{k_x}{k_c}\right)^2 + \left(\frac{k_y}{k_c}\right)^2 = \frac{c_x}{c_c^2}
\]

so

\[
\nu_c = \frac{c}{\nu_c} \sqrt{\left(\frac{k_x}{k_c}\right)^2 + \left(\frac{k_y}{k_c}\right)^2} = 3 \times 10^8 \text{ cm/s}
\]

(b) guide wavelength

\[
\lambda_\circ = \frac{c}{(1.1 \nu_c)} \frac{1}{\left(1 - \left(\frac{\nu_c}{\nu_c}\right)^2\right)^3} = 13.61 \text{ cm}
\]

6. A dipole in the \( z=0 \) plane is aligned with the \( z \)-axis and transmits a signal to an observer with a dipole also aligned with the \( z \)-axis and in the \( z=0 \) plane, 100m away from the transmitting dipole, and measures a signal strength of 1 \( \mu V/m \). The receiving dipole is then elevated to a new position 20 meters above its original position. What is the maximum signal, in \( \mu V/m \), that the receiving dipole will measure in this new position?

\[
E_1 = \frac{C_\circ \sin \theta}{r} = 1 \mu V/m \Rightarrow C_\circ = \frac{E_1 r}{\sin \theta}
\]

\[
E_2 = \frac{C_\circ \sin(90 - \tan^{-1}(\frac{120}{100}))}{\sqrt{100^2 + 20^2}}
\]

\[
= \frac{1 \mu V \cdot 100 \cdot \sin(78.9^\circ)}{\sqrt{100^2 + 20^2}}
\]

\[
= \frac{0.9615 \mu V}{m}
\]

maximum signal = \( 0.9615 \mu V/m \)
The Complete Smith Chart
Black Magic Design

[Image of the Smith Chart]