Fall 2001 **ECE 420** **Exam 1**

1. (35 points) A dielectric field rectangular waveguide has the following characteristics:

$$b = 1.5 \text{ cm},\ a = 3.0 \text{ cm},\ m_R = 1 \text{ and } e_R = 2.25.$$

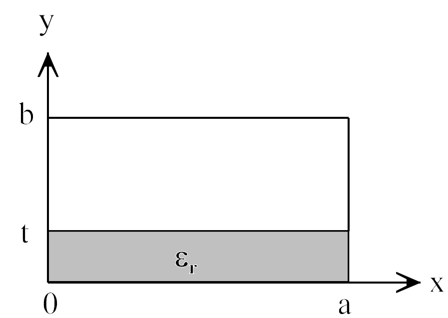
Calculate the lowest cut-off frequency for the guide. Also determine l_g, the guide wavelength at 4.0 GHz.

2. (30 points) An air filled rectangular waveguide has a = 5 cm and b = 2 cm. Determine if TM_{21} mode is evanescent at 8 GHz. If the mode is evanescent, find the attenuation constant; if not, find the phase constant and phase velocity for this mode.

3. (35 points) A plane wave at 2 GHz, in free space, is normally incident on a half space of copper. The conductivity of copper is 5.7×10^7 S/m. Compute the reflection and transmission coefficients. Also determine the depth at which the fields in copper would be attenuated by 30 dB.

1. (35 points) A microstrip line operating at 2.5 GHz has a dielectric substrate of $\varepsilon_r = 2.20$. The effective dielectric constant, ε_e for the microstrip geometry is measured as 1.87. Also, an approximate electrostatic solution is used to determine that the capacitance should be 91.2 pF/m. Determine the numerical values for the propagation constant, β and the characteristic impedance, Z_0 for this microstrip.

2. (30 points) Use the transverse resonance technique to derive a transcendental equation(s) for the propagation constant of the TE_{0n} modes of a rectangular waveguide that is dielectric filled from $0 < y < t$ and air filled from $t < y < b$. Do not solve the equation(s).



3. (35 points) Consider a circular waveguide with a = 0.75 cm, air filled for z < 0 and dielectric filled ($\varepsilon_r = 2.25$) for z > 0. If the operating frequency is 13.0 GHz, use an equivalent transmission line model to compute the reflection coefficient, Γ of a TE_{11} wave that is incident on the interface from z < 0.

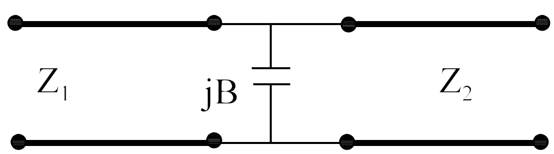
Fall 2001	ECE 420	Final Exam

1. (25 points) Determine the maximum power handling capacity of a WR-137 rectangular waveguide of dimension 3.485 x 1.580 cm and operating at 7.5 GHz in a TE_{10} mode. The electrical breakdown for air is 3 MV/m. Assume the waveguide is matched (VSWR = 1.0).

2. (30 points) Design a two-section Chebyshev quarter-wave impedance transformer to match a 40 Ω line to a 100 Ω load. The maximum permissible VSWR over the pass band is 1.2. What is the resulting bandwidth?

3. (20 points) Consider an air filled circular waveguide with a = 2.0 cm. What is the cut-off frequency of the guide for TM_{11} mode? This waveguide is used to form a cavity to resonate in TM_{111} mode at 10.5 GHz. Find the dimensions of the cavity.

4. (25 points) An equivalent circuit for a change in the height of a rectangular waveguide is shown below. Find the scattering matrix for the two-port network shown.



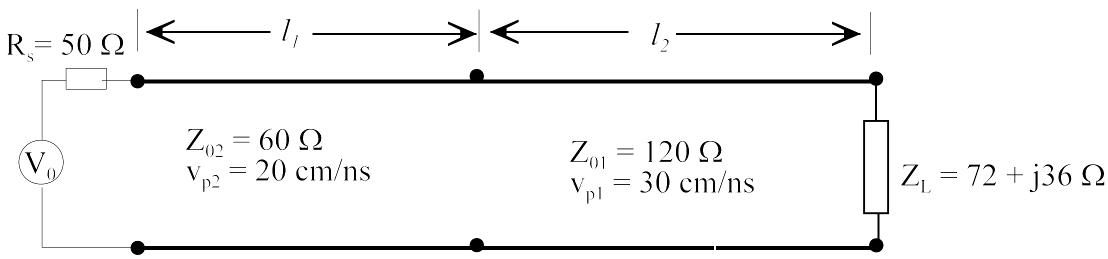
$Z_1 = 100\ \Omega$, $Z_2 = 200\ \Omega$ and B = 0.05 S.

Useful Formulas:

$$\cosh^{-1} x = \ln\left(x + \sqrt{x^2 - 1}\right)$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

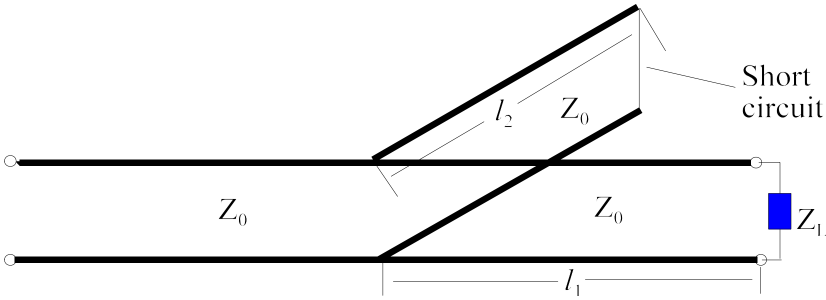
1. (20 points) For the transmission line system shown below, assuming both lines are lossless and assuming a source voltage $V_0 = 100\ e^{j0}$ V @ 100 MHz, find the input impedance of the line and the time average power delivered to the load. Note that l_1 = 3.75 m and l_2 = 1.75 m.



2. (20 points) A transmission line model of an IC interconnect at 5 Ghz is found to have following parameters: R = 143.5 Ω/cm, L = 10.1 nH/cm, C = 1.1 pF/cm and G = 0.014 S/cm. Determine the propagation constant β, attenuation α in dB/cm, characteristic impedance Z_0, velocity of propagation v_P, and wavelength λ_g in cm.

3. (20 points) A 50 Ω transmission line is terminated with an antenna (load) having a feed point impedance of 150 Ω. Calculate V_{max}, V_{min}, I_{max}, I_{min}, Z_{max}, Z_{min} along the line. Assume V^+ = 5 V and λ = 15 cm.

1. (20 points) Design a single stub tuner that will match a 100 Ω lossless, coaxial cable to an antenna with an input impedance of Z_L = 300 - j 100 Ω. Choose the design that locates the stub closest to the antenna.



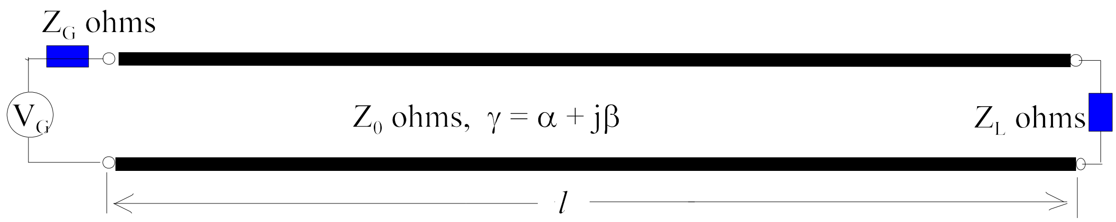
2. (10 points) The S-parameters for a certain two-port network are

$$s_{11} = 0.26 - j0.16,\ s_{12} = s_{21} = 0.42,\ s_{22} = 0.36 - j0.57.$$

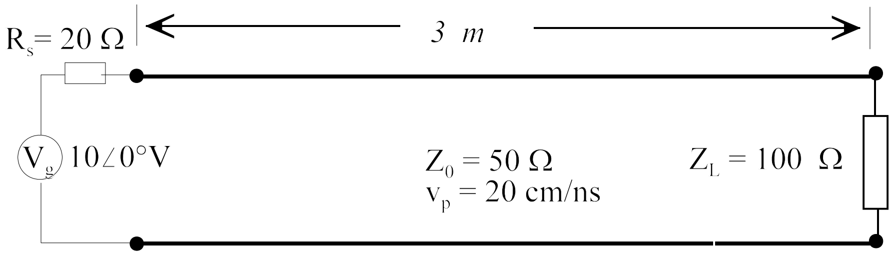
Determine the input reflection coefficient of the two-port when $Z_L = 3Z_0$.

3. (15 points) Design a <u>two section</u> quarter wave transformer to match a load of Z_L = 300 Ω to a line with Z_0 = 50 Ω line and to operate at 250 MHz. Assume the lines have velocity of propagation to be 250 Mm/s. Your design must specify the characteristic impedances and the line lengths in cm.

4. (15 points) Determine the power delivered by the source to the load. Note that α = 1.0 dB/km, β = 0.0182 rad/meter, and Z_0 = 50 Ω, Z_G = Z_L= 50 Ω. The line is 1 km long and the source voltage is 110 V rms.



5. (20 points) A sinusoidal voltage source of 10 V (rms) and R_s = 20 Ω is connected to a load impedance Z_L = 100 Ω through a 3-m long, lossless coaxial transmission line filled with polyethylene (v_p = 20 cm/ns at 25 MHz) and with Z_0 = 50 Ω as shown. Find the voltage and current at the load with reference to the source voltage.



6. (20 points) A Time Domain Reflectometer (TDR) is used to test the transmission line system shown below. The TDR scope display of $v_s(t)$ is also shown. Determine the values of Z_{01}, l_1 and R_1. Assume the propagation velocity to be $2\text{x}10^8$ m/s.