UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, APRIL 22 1996

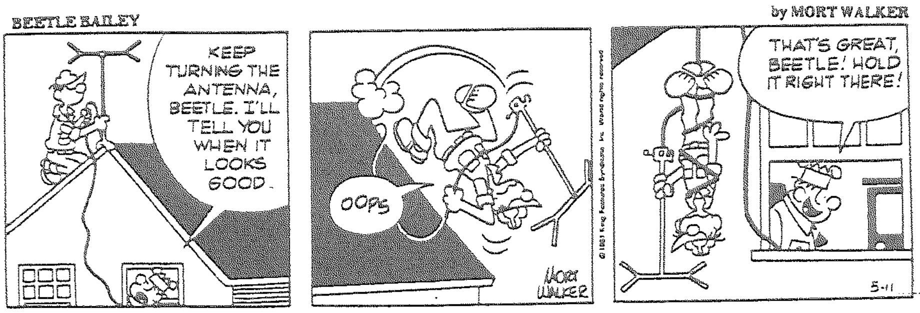
Third Year

ECE357S - ELECTROMAGNETIC FIELDS

Professor E. van Deventer

AIDS PERMITTED:

Double-sided aid sheet and non-programmable calculator



Electromagnetic Waves

Problem 1 (15 points)

A uniform plane wave having the electric field

$$E_i = \left(\frac{\sqrt{3}}{2}\hat{x} - \frac{1}{2}\hat{z}\right) E_o \cos\left(6\pi 10^9 t - 10\pi\left(x + z\sqrt{3}\right)\right) + aE_o\hat{y}\sin\left(6\pi 10^9 t - 10\pi\left(x + z\sqrt{3}\right)\right)$$

is incident on the interface between free-space and a dielectric medium of $\varepsilon = 6\,\varepsilon_0$ and $\mu = \mu_0$
Find the value of a for the reflected wave to be right circularly polarized.

Problem 2 (15 points)

Consider a distributed current source flowing on an infinite sheet lying in the x-y plane

$$J_s\Big|_{z=0} = -J_s(t)\,\hat{x}$$

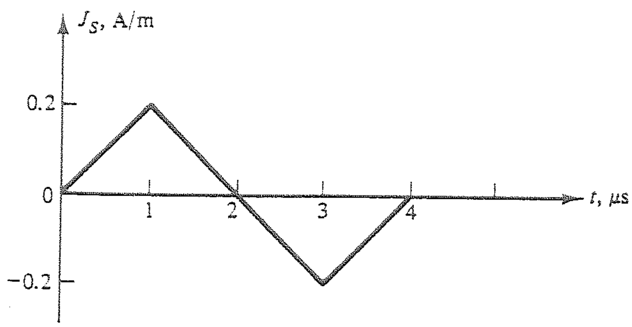
This current source produces uniform plane waves traveling in the regions $z > 0$ and $z < 0$, where

$$E(z,t) = F\left(t \mp \frac{z}{v_p}\right)\hat{x} \quad , z \gtrless 0$$

$$H(z,t) = \pm\frac{1}{\eta_o} F\left(t \mp \frac{z}{v_p}\right)\hat{y} \quad , z \gtrless 0$$

(i) Using the appropriate boundary conditions at the surface $z = 0$, show that $F(t) = \eta_0/2\, J_s(t)$.

(ii) The medium on either side of the current sheet is now a perfect dielectric of $\varepsilon = 9\varepsilon_0$ and $\mu = \mu_0$.
The amplitude of the surface current density J_s (A/m) is shown below. Find and sketch
(a) E_x versus t for $z = 100$ m,
(b) H_y versus z for $t = 5$ μs

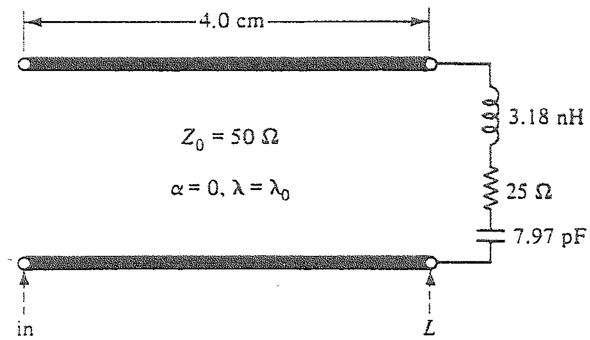


Transmission Lines

Problem 3 (15 points)

(1) For purely reactive networks, the slope of the reactance or susceptance versus frequency curve is always positive. This places a restriction on the possible shape of impedance and admittance versus frequency curves. When plotted on a Smith chart, do the Z and Y curves have a clockwise or counterclockwise trend with increasing frequency? Explain why.

(2) A frequency sensitive load impedance is shown below.

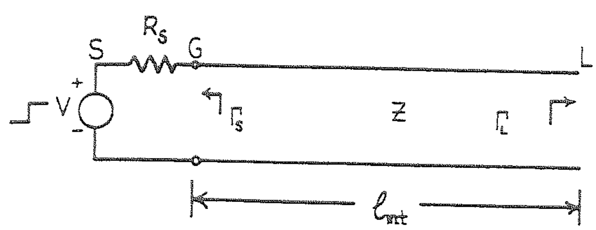


(i) For the given values of L and C, what is the series resonance frequency f_o?
(ii) Calculate and plot the values of Z_{in} and Z_L at f_o, and $f_o \pm f_o/4$ on the Smith chart.
(iii) Calculate the angular spread of Z_{in} and Z_L over the given frequency range. Explain the effect of the 4 cm length of lossless line on the shape of the impedance plot.

Problem 4 (15 points)

When sending high-speed digital signals down transmission lines, it is important to avoid ringing which causes the receiver to switch on and off a few times before the waveform settles. This ringing can be disastrous in a clock or asynchronous line because the glitches can be observed as a transition and can cause the circuit to transit to a wrong state.

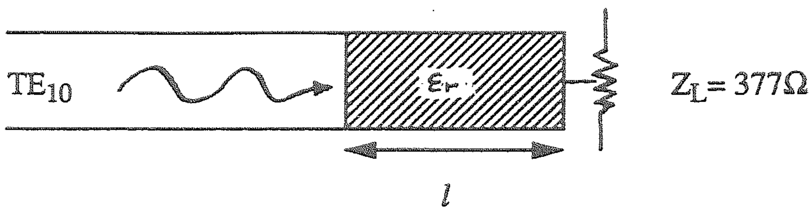
Consider an open-circuited line driven by a source resistance R_S. Plot V_S, V_G and V_L as a function of time for R_S= 10 Z, Z and 0.1 Z. Deduce what condition should be imposed on the source resistance with respect to the characteristic impedance of the line to avoid ringing.



Waveguides and Antennas

Problem 5 (15 points)

A waveguide load with an equivalent TE_{10} wave impedance of 377Ω must be matched to an air-filled X-band rectangular guide (a = 2.286 cm) at 10 GHz. A quarter-wave matching transformer is to be used, and is to consist of a section of guide filled with dielectric. Find the required dielectric constant ε_r and physical length l of the matching section.



Problem 6 (10 points)

The pattern multiplication technique can be used in reverse to synthesize an array for a specified radiation pattern. Find an arrangement of isotropic elements for the group pattern

$$\frac{\cos^2(6\pi\cos\phi)}{9\cos^2(2\pi\cos\phi)}$$

Problem 7 (15 points)

A uniform linear array consists of six short dipoles. The spacing between adjacent elements is λ/4, as shown below.

(i) What should the phase shift ξ be, in order to point the maximum radiation in the $\phi = 90^\circ$ (i.e. y) direction?

(ii) Suppose that the E field is due to the first element (the dipole at far left) is given as follows

$$E_{\theta e} = \frac{1000}{r} e^{-jkr} \sin\theta$$

Calculate $|E_\theta|$ of the entire array at point A (0, 1000, 0), point B (1000, 0, 0), point C (0, -1000, 0), and point D (-1000, 0, 0), separately. All positions are given in rectangular coordinates in meters. Use the phase shift found in (i).