# ELT-47426 Transmission lines and waveguides

Exam, April 28th 2014. Answer to all questions.
No material. Own calculators (not programmable) allowed.
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1. Through a non-magnetic material ($\mu_r = 1$) is traveling a wave. Its electric field is given as

$$\mathbf{E}(x,t) = 4\sin(2\pi * 10^7 t - 0.8\beta x)\mathbf{u}_z \qquad [\mathrm{V/m}]$$

   (a) Could this expression hold for a plane wave?

   (b) Find the phase velocity, relative permittivity, and wave impedance of the material.

   (c) Find the accompanying magnetic field intensity $\mathbf{H}(x,t)$.

   In total 4.5 p.

2. Define in an appropiate way

   (a) Transmission line equations.

   (b) Inductance per unit length in transmission lines.

   (c) Telegrapher's equation.

   (d) Hybrid mode.

   In total 6 p.

3. (a) Explain briefly key properties of dielectric waveguides.

   (b) In the last page are two plots that are obtained after simulation of a rectangular waveguide. The plots are taken in the $xy$–plane. Based on them, explain which mode is propagating (with proper reasoning).

   (c) State how to form so called leap frog algorithm to simulate EM waves in ideal transmission lines.

   In total 7.5 p.

4. In the course, we considered first ideal transmission lines and assumed such structure to have as materials either ideal dielectric or perfect electric conductor (PEC). Let us consider a structure that has as materials either ideal dielectric or perfect magnetic conductor. Could the latter structure support TEM waves? If, so what kind of properties would EM fields need to fullfil? Support your answer with proper reasoning. (HINT: try to find logical steps that allow your reasoning. You will need the Maxwell laws, but try not to get too much into their details.) (7.5 p.)

5. (a) Define briefly quality factor of a cavity resonator. Which factors affect on its value (when considering cavities in practice)?

   (b) Consider a rectangular cavity resonator whose dimensions are $a \times b \times c = 5 \times 4 \times 3\ \mathrm{cm}^3$

      i. What is the lowest *resonance mode* and *resonance frequency* of such a cavity when it is filled with air?

      ii. It is known that the lowest *resonance frequency* of such a cavity is 3437MHz when it is filled with snow. Determine the *relative permittivity* of (this kind of) snow.

   In total (4.5 p.)

TURN OVER

*Miscellaneous information about rectangular waveguides etc.*

- The propagation constant can be expressed as

$$\gamma = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2\mu\epsilon},$$

where $\mu_0 = 4\pi * 10^{-7}$H/m and $\epsilon_0 = 8.854 * 10^{-12}$F/m.

- For good conductors skin depth is

$$\delta = \frac{1}{\alpha} = \frac{1}{\sqrt{\pi f \mu\sigma}}$$

- Conductivities:

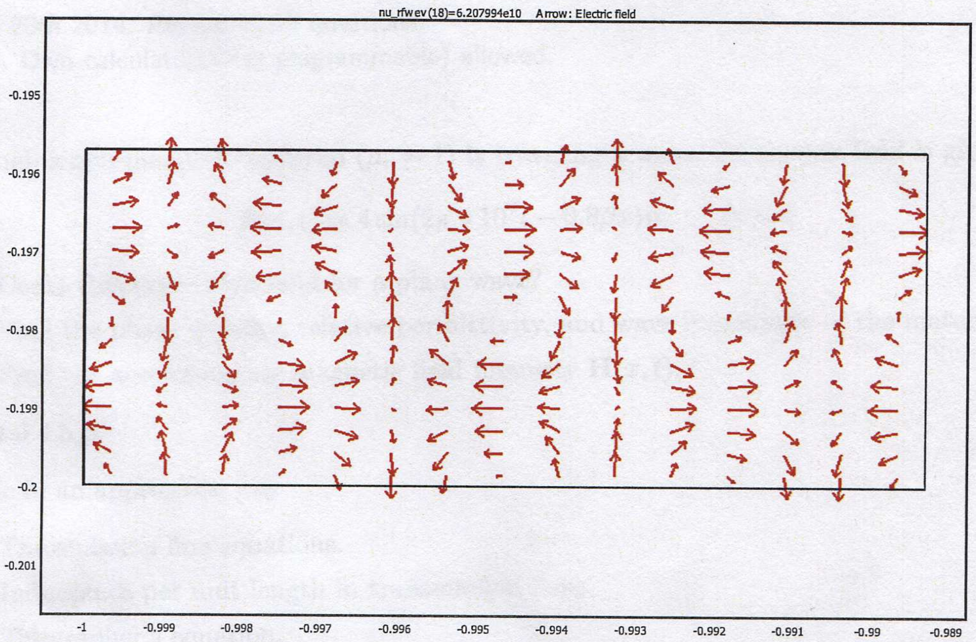
Silver $6.17 * 10^7$ [S/m]

Copper $5.80 * 10^7 \approx 4 * \sqrt{2} * 10^7$ [S/m]

Brass $1.57 * 10^7$ [S/m]

Iron $10^7$ [S/m]

- speed of light in vacuum $c = 2.99792458 * 10^8\text{m/s} \approx 3 * 10^8\text{m/s}$
- intrinsic impedance $\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 120\pi\ \Omega$
- $e^x \approx 1 + x$ if $|x|$ small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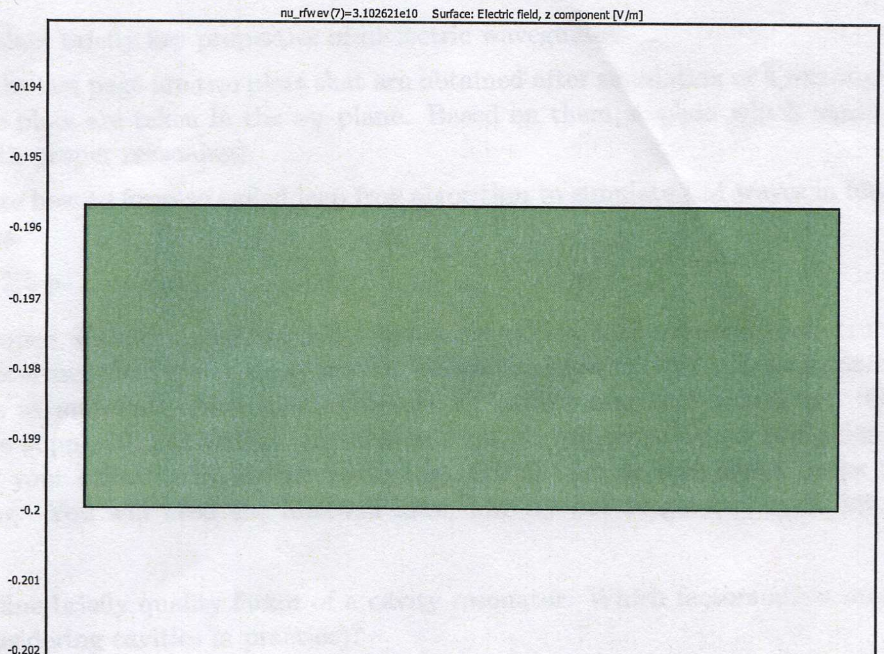
-0.196
-0.197
-0.198
-0.199
-0.2
-0.201
-1
-0.999
-0.998
-0.997
-0.996
-0.995
-0.994
-0.993
-0.992
-0.991
-0.99
-0.989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-0.195
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-0.197
-0.198
-0.199
-0.2
-0.201
-0.202
-0.8
-0.799
-0.798
-0.797
-0.796
-0.795
-0.794
-0.793
-0.792
-0.791
-0.79
-0.789