jari. suikkola@student.tut.fi

ELT-47426 Transmission lines and waveguides

Small Exam I, January 27th 2014. Answer to all questions.
Jari Kangas

1. Consider following description in wikipedia under title *Transmission line*: 2 or more wires

   Uniformity of TL is important

   "In communications and electronic engineering, a transmission line is a specialized cable or other structure designed to carry alternating current of radio frequency, that is, currents with a frequency high enough that their wave nature must be taken into account."

   electric length

   Do you consider that this is an accurate definition? If not, highlight points to be clarified. Give also precise and concise reasoning on how you would correct them. (3 p.)

2. You find in the opposite side of the paper field plots of a simulation case on a transmission line (coaxial cable with non–circular inner conductor). The case has been further analyzed and data given in the table below is gathered. On the white board additional information about the curves and domains is provided.

   Your task is to use the given data to analyze the case, to derive relevant quantities and parameters in terms of transmission line analysis (the more, the better). Pay attention to details and support your analysis with reasoning (again, try to give precise and concise answers). (4.5 p.)

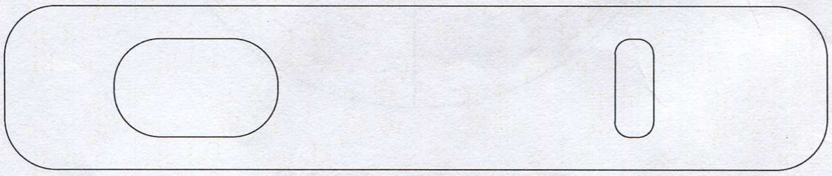
Domain	Function	Expression	Value	Unit	
Curve 1,2,3,4	Integral	$\mathbf{n}\cdot\mathbf{D}$	8.18692e-9	C/m	Charge
Curve 1,2,3,4	Integral	$\mathbf{u}_z\cdot\mathbf{J}_s$	-1.58429	A	Current
Curve 5	Integral	E_x	59.90137	V	Voltage
Domain D1, D2, D3, D4	Integral	$\frac{1}{2}\mathbf{E}\cdot\mathbf{D}$	2.4536e-07	J/m	Energy
Domain D1, D2, D3, D4	Integral	$\frac{1}{2}\mathbf{H}\cdot\mathbf{B}$	2.4536e-07	J/m	Energy
Curve 5	Integral	B_y	3.09543e-7	Wb/m	Magnetic flux
Curve 1,2,3,4	Integral	$\mathbf{t}\cdot\mathbf{H}$	-1.58429	A	Current
Curve 6	Integral	B_x	-3.09543e-7	Wb/m	Magnetic flux

3. (a) Let us consider the transmission line below that consists of three conductors and dielectric in between (lets assume ideal dielectric with relative permittivity ϵ_r and relative permeability μ_r). What could you say about possible TEM–wave solutions to the problem, how could you characterize them? (2.5 p.)

   $I_1+I_2+I_3=0$

   Think of three voltages between 3 conductors

   TEM wave, components of E- and H-fields



   (b) A phone line has $R = 30\Omega/\text{Km}$, $L = 0.1\text{H/km}$, $G = 0$ and $C = 20\mu\text{F/km}$. Assume that $f = 1\text{kHz}$, find

   i. The line characteristic impedance. ~70 Ω
   ii. The propagation constant.
   iii. The phase velocity. ~10^5 m/s
   iv. The attenuation in dB after 2 km. ~3-4 dB

   (In total 2 p.)

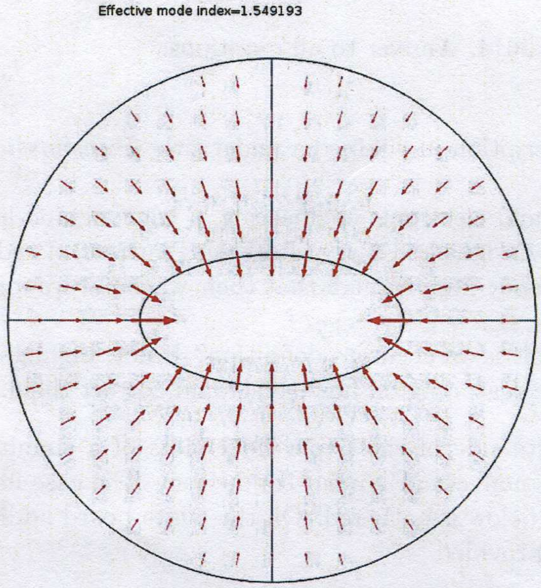
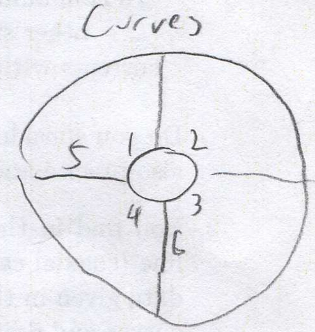


Figure 1: Plot of E-field



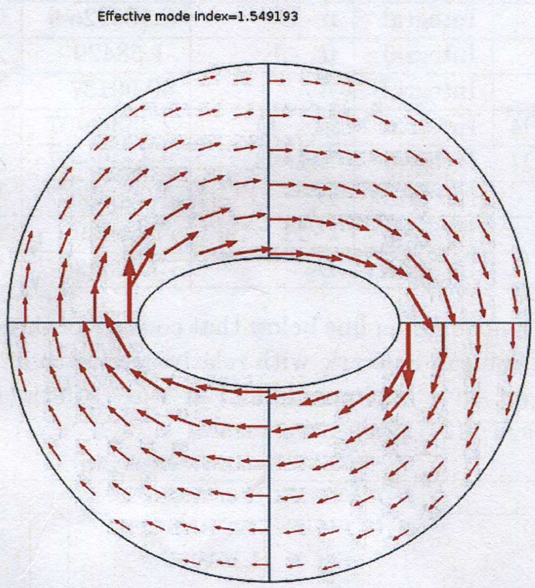
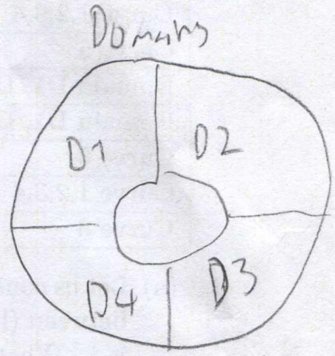


Figure 2: Plot of H-field



Constants in free space and some formulas:

- dielectric constant $\epsilon_0 \approx 8.854 * 10^{-12}\text{F/m}$
- permeability $\mu_0 \approx 4\pi * 10^{-7}\text{H/m}$
- speed of light $c \approx 2.997925 * 10^{8}\text{m/s}$
- intrinsic impedance $\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 120\pi\ \Omega$
- $e^x \approx 1 + x$ if $|x|$ small

Domain	Expression	Value	Unit
S1	$G \cdot \hat{n}$	x	

$$x = \int_{S1} G \cdot \hat{n}\, dn \text{ [Unit]}$$