ECE 3300 Lab 5

Numerical Integration and Biot-Savart's Law

Overview: In this lab, EM Fields will be calculated using Biot-Savart Law and trapezoidal integration.

Equipment: Matlab® software is required to complete this lab. If you have a laptop running Matlab, please bring it to the lab with you.

Objectives:

1. Understand Biot-Savart Law

2. Be able to set up the integral equation for any 1D distribution of currents, and be able to identify the variables and limits of integration.

3. Use numerical integration (Trapezoidal method) to find the magnetic field at any place in space from a distribution of currents.

4. Understand the dualism (similarity in equations and methods) between Biot-Savart and Coulomb's laws.

Problem:

Given a thin wire antenna oriented along the z-axis from z_s = - L to L. The current distribution on the rod is given. Find the magnetic field at any point (x_p,y_p,z_p).

Prelab:

- Read the reference material on the lab website.
- Write the integral equation for the magnetic field.
  1. Define an origin and sketch the 3-D system.
  2. Write and sketch the vector R_s from the origin to the source.
  3. Write and sketch the vector R_p from the origin to the field point.
  4. Find the vector R from the source to the field. Find the unit vector in the direction of R and the magnitude of R.
  5. Define the source, which is a differential element length *dl* times the current distribution I (where I is a vector) along the length.
  6. Apply Biot-Savart's law (do the X-product)

$$d\overline{H} = \frac{I}{4\pi}\frac{d\bar{l}\times\hat{R}}{|R|^2}$$

  7. Write the integral to find H. Define the limits of integration. CIRCLE the variables of integration. Divide into separate integrals for the x,y,z components.

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Procedure:

1 Write code to integrate a vector representing F(z) using Trapezoidal integration.
  a. Program the Matlab code.
  b. Test it by filling in the chart below.
  c. For F(z) = z, demonstrate that smaller values of Δz give smaller error.

$$A = \int_{z=1}^{5} F(z)\,dz \quad where \quad F(z) = z, z^2, z^3$$

F(z)	$\mathbf{A_{analytical}}$	$\mathbf{A_{numerical}}$	**Error = ($\mathbf{A_{analyt} - A_{num}}$)**
z			
$\mathbf{z^2}$			
$\mathbf{z^3}$			

2. Write a function to find the magnetic field at a point (x_p,y_p,z_p) from a given current distribution. Do the integration using trapezoidal integration.

3. Plot the magnetic field along the y-axis for a rod extending from z = - $\pi/2$ to $\pi/2$ meters having a current distribution of I(z) = cos (z) in the z-direction. (This is like a half-wave length dipole antenna.)

Hand in:

- Prelab derivations.
- Printout of program, well commented.
- Demonstration that H field along the y axis for y=.5 to 100 meters drops off linearly as it gets far away from the antenna. What does it do closer to the antenna?

References:

[1] F. Ulaby, *Fundamentals of Applied Electromagnetics*, 6th ed., 2010, ch. 5.

[2] Trapezoidal Integration Summary, see Lab webpage.

THERE IS NO FORMAL WRITTEN REPORT FOR THIS LAB

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