ECEG 390 Theory and Applications of Electromagnetics Spring 2024

Homework Assignment #8 – due via Moodle at 11:59 pm on Friday, Apr. 12, 2024

***Instructions, notes, and hints*:**

Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Some problems might require engineering approximations or assumptions to be applied to arrive at a solution, especially if critical information is missing. In those cases, your answer might differ significantly from the posted answer. If you justify any approximations that you make, you will be given full credit for such answers. Unless otherwise indicated, you may use Matlab, Mathematica, or Mathcad to make difficult or time-consuming calculations. If you do, include a print-out of the file or screen display that shows your work.

The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems.

***Graded Problems*:**

1. The receiver of a garage door opener (the part inside the garage) uses a circular loop antenna with a diameter of 2.0 cm. The opener operates at a frequency of 915 MHz. At the input terminals of the loop, a voltage with a peak value of at least 100 μV must be developed if the door is to open. Assuming that the loop is oriented for maximum response (i.e., maximum voltage across the terminals), find the peak magnitude of the magnetic field **H** in the vicinity of the loop antenna.

2. Suppose that the loop in the previous problem is now tilted 60° away from the position of maximum response and that the magnetic field has the peak magnitude found in the previous problem. Find the voltage that would be developed across the gap with the new orientation.

3. An engineering student builds a sensitive heart rate detector circuit on a piece of single-sided printed circuit board. (That is, there are copper traces on one side and no copper anywhere on the other side.) The copper circuit board traces from the sensor leading to the first stage of amplification are parallel, 4.0 cm long, and spaced 1.0 cm apart. The sensor, the copper traces, and the input terminals of the amplifier form a circuit loop. A diagram of the sensor system appears on the next page. A nearby FM radio station operating at 100 MHz generates an electric field **E** that has a peak magnitude of 40 mV/m in the vicinity of the detector. Find the peak voltage at 100 MHz that is developed across the input of the amplifier by the FM signal when the PC board is oriented for maximum response to the signal. Assume that the sensor has an equivalent impedance of nearly zero at 100 MHz. Recall that the electric field and magnetic field magnitudes of the transverse electromagnetic (TEM) fields radiated by all antennas have the relationship $|\mathbf{E}|/|\mathbf{H}| = \eta$, where η is the intrinsic impedance of the medium in which the wave propagates. For air and free space, $\eta = 120\pi\,\Omega = 377\,\Omega$.

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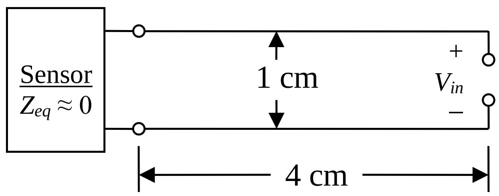

Diagram of sensor system for Graded Prob. 3.

4. The engineering student in the previous problem realizes that the FM radio station is being picked up by the heart rate detector's input circuitry and is interfering with its proper operation. The student redesigns the PC board by reducing the separation between the traces coming from the sensor from 1.0 cm to 1.0 mm. Find the largest possible peak voltage at 100 MHz that will be developed across the input of the amplifier with the new design. Assume that the width of the circuit board traces is negligible compared to the spacing between the traces.

***Ungraded Problem*:**

The following problems will not be graded, but you should attempt to solve them on your own and then check the solutions. Do not give up too quickly if you struggle with one or more of them. Move on to a different problem and then come back to the difficult one after a few hours.

1. The interference from the FM station considered in the last two graded problems can be reduced even further by using a twisted pair of wires from the sensor to the amplifier's input terminals. A comparison of the two feed arrangements is shown below. In the upper diagram, the leads from the sensor to the amplifier are straight and parallel. In the lower diagram, the leads are twisted. (You may assume that the wires in the twisted pair form either flat loops or helices; the answer is the same either way.) Provide a brief qualitative explanation based on Faraday's law for why a twisted pair usually has better signal rejection than two parallel wires.

H-field vector points into/out of page.