Homework #11  EMI & Shielding

1. What is the skin depth in aluminum at 1Mhz and 1Ghz?
   The skin depth (in inches) for Al is given as $3.3 / \sqrt{f}$ so at 1Mhz it's 3.3 mils (i.e. 3.3 thousandths of an inch or 83.8um) and at 1Ghz it's 0.104 mils(2.65um).

2. What is the impedance at 1Ghz of a one inch long copper PC board trace with the following dimensions (use the Rac equation in the following link)?
   a. 10 mils wide and 1 mil thick
      The equation for AC resistance of a PC board trace is:
      \[
      R_{ac} = \frac{2.61 \times 10^{-2} \sqrt{f \times \rho_{t}}}{2 \times (w + h)}
      \]
      Note: FR4 PC board with 1oz copper (what we have in the EE shop) has copper 1.4 mil thick.

   b. 10 mils wide and 2 mils thick
      \[ R_{ac} = 0.343\Omega \]
      Note: The DC resistance is half what it was before but the AC impedance is only slightly lower because it depends on the surface area.

   c. 20 mils wide and 1 mil thick
      \[ R_{ac} = 0.196\Omega \]
      Note: The impedance is about half the original impedance because the surface area is almost twice as large as before.

3. You need to shield a sensitive circuit from a nearby radio station. The radio station broadcasts at 100Mhz and the signal strength at your location is 100mV/m. You need to reduce the strength down to 1mV/m inside your enclosure (i.e. inside the shield).
   a. How much attenuation do you need (give your answer in db)?
      The signal from the radio station needs to be attenuated by a factor of 100 or 40db.

   b. How thick should an aluminum enclosure be to guarantee the needed attenuation at 100Mhz?
      At high frequencies the loss is mainly due to absorption rather than reflection. The absorption loss in a shield one skin-depth thick is $1/e$ (8.7db). We need a factor of 100. In(100) = 4.6 so we would need 4.6 skin depths of aluminum to attenuate the signal by 100 (40db). The skin depth of aluminum at 100Mhz is 0.33 mils. Therefore the aluminum enclosure should be a minimum of 4.6* 0.33 mils = 1.52 mils thick (38.6um).

      Alternately, you know for every skin depth the signal is attenuated by 8.7db. You need 40db of attenuation. Therefore you need a shield with a minimum thickness of 40/8.7 = 4.6 skin depths.

   c. You need to have a hole in the enclosure for some power and I/O lines. What is the largest dimension the hole can have and still guarantee the needed attenuation at 100Mhz?
      The wavelength at 100Mhz = 3m.
      To attenuate the signal by 40db the longest dimension can't be larger than 3m/(2*100) = 1.5cm.

      For 1/20 of a wavelength you get an attenuation of 10 (20db). Therefore you need a hole smaller than 1/200th of the wavelength (i.e. <1.5cm).