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:
Rac@1Ghz = 0.375Ω
Note: FR4 PC board with 1oz copper (what we have in the EE shop) has copper 1.4 mil thick.

$$R_{ac} = \frac{2.61 \times 10^{-7} \sqrt{f \times \rho_r}}{2 \times (w + h)}$$

b. 10 mils wide and 2 mils thick
Rac@1Ghz = 0.343Ω
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
Rac@1Ghz = 0.196Ω
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. ln(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.

$$\text{Shielding Effectiveness (dB)} = 20\log_{10}\left(\frac{\lambda}{2 \cdot L}\right)$$

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).