Ch4. Shielding

2021 Quiz 4.

4. The Aluminium powder is coated on a ceramic substrate with a uniform coating thickness of 200 μm. Assume that the coated surface has no holes and cracks. Ignore the effect of the ceramic substrate. Electrical properties of Aluminium: $\sigma = 3.69 \times 10^7$ S/m and $\mu = 4\pi \times 10^{-7}$ H/m.

(a) Calculate the shielding effectiveness of the Aluminium coating for a 100 kHz radiating loop antenna source at 10 m away.

(15 Marks)

(b) Repeat part (a) if the frequency of the same loop antenna source has increased to 10 MHz.

(10 Marks)

(a) At 100 kHz, the wavelength λ is $\lambda = \dfrac{3\times10^8}{100\times10^3} = 3000$ (m)

$r = 10m < \dfrac{\lambda}{2\pi} = 477.46m$, so the shield is in the near-field region of the loop antenna.

the loop antenna is magnetic field dominant source.

$|Z_w| = 2\pi f \mu_0 r (\Omega) = 2\pi \times 10^5 \times 4\pi\times10^{-7} \times 10 = 7.896\,\Omega$

$|Z_s| = \sqrt{\dfrac{w\mu}{\sigma}} = \sqrt{\dfrac{2\pi\times10^5\times4\pi\times10^{-7}}{3.69\times10^7}} = 0.146\,m\Omega$

The skin depth is $\delta = \sqrt{\dfrac{1}{\pi f \mu\sigma}} = \sqrt{\dfrac{1}{\pi\times10^5\times3.69\times4\pi}} = 2.62\times10^{-4}\,m > 2\times10^{-4}\,m\ (t)$

Therefore the multiple Reflections can't be neglected.

Absorption loss $A = 8.686(\frac{t}{\delta})\ dB = 1.63\ dB$

Reflection loss $R = 20\log\dfrac{|Z_w|}{4|Z_s|} = 20\log\dfrac{7.896}{4\times0.146\times10^{-3}} = 82.62\ dB$

Multiple Reflection $B = 20\log(1-e^{-2t/\delta}) = 20\lg(1-e^{-2\frac{2\times10^{-4}}{2.62\times10^{-4}}}) = -2.13\,dB$

Hence, the $SE = A+R+B = 87.12\ dB$

(b) At 10 MHz, $\lambda = \dfrac{3\times10^8}{10^7} = 30$ (m), $\dfrac{\lambda}{2\pi} = 4.77$ (m)

$r = 10\,m > \frac{\lambda}{2\pi}\,(4.77\,m)$, therefore, the shield is in the far-field Region of the loop antenna.

$|Z_w| = 120\pi = 377\,\Omega$

$|Z_s| = \sqrt{\dfrac{2\pi f\mu}{\sigma}} = \sqrt{\dfrac{2\pi\times10^7\times4\pi\times10^{-7}}{3.69\times10^7}} = 1.46\,m\Omega$

$\delta = \dfrac{1}{\sqrt{\pi f\mu\sigma}} = \dfrac{1}{\sqrt{4\pi^2\times10^7\times3.69}} = 2.62\times10^{-5}$ (m)

At far-field region, the multiple reflection correction can be neglected.

$A = 8.686\ (\frac{t}{\delta})\ dB = 8.686\times\dfrac{2\times10^{-4}}{2.62\times10^{-5}} = 66.31\,dB$

$R = 20\log\dfrac{|Z_w|}{4|Z_s|} = 20\log\dfrac{377}{4\times1.46\times10^{-3}} = 96.20\ dB$

$SE = A+R = 162.51\,dB$

2018-2019 . 1.(b)

(b) Figure 2 shows a rectangular metal enclosure for shielding a noisy printed circuit board (PCB) mounted within the enclosure. Assume that all the edges of the enclosure are properly joined and there will be no leakage fields through these edges.

(i) For the given dimensions of the enclosure and the slot, what are the frequencies below 1 GHz where the shielding effectiveness is expected to deteriorate?

(7 Marks)

(ii) If the 20 cm by 0.2 cm slot is replaced by a row of four 5 cm by 0.2 cm slots, what are the frequencies below 1 GHz where the shielding effectiveness is expected to deteriorate?

(3 Marks)

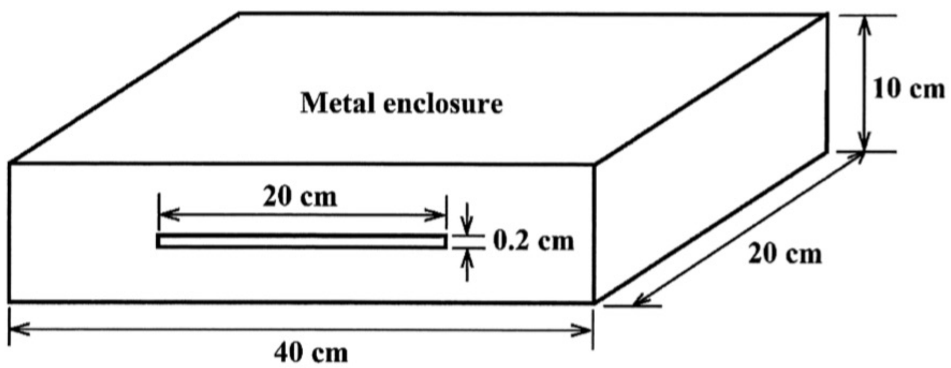

Figure 2

(a) The slot Resonance :

$$d = \frac{\lambda}{2} \Rightarrow \lambda = 2 \times d = 0.4m$$

$$\Rightarrow f_{slot} = \frac{3 \times 10^8}{0.4\,m} = 750\,MHz$$

$$f_{mnl} = 150\sqrt{(\frac{m}{L})^2 + (\frac{n}{W})^2 + (\frac{l}{H})^2}\ MHz$$

$m=0,\ n=1,\ l=1 \Rightarrow f = 1.68\,GHz > 1GHz$

$m=1,\ n=0,\ l=1,\ \Rightarrow f = 1.55\,GHz > 1GHz$

$m=1,\ n=1,\ l=0 \Rightarrow f = 838.53\,MHz$

$m=2,\ n=1,\ l=0 \Rightarrow f = 1.06\,GHz > 1GHz$

$m=1,\ n=2,\ l=0 \Rightarrow f = 1.55\,GHz > 1GHz$

Therefore, at frequency 750 MHz and 838.53 MHz the shielding effectness is expected to deteriorate.

(b) $d = 5\,cm.\ \lambda = 2d = 0.1m \Rightarrow f_{slot} = 3\,GHz$

only at 838.53MHz, the shielding effectness is expected to deteriorate.

2017-2018 1.(b)

(b) Figure 2 shows a car passing through an electronic road pricing (ERP) gantry. The windscreen of the car is coated with solar film for ultra violet (UV) radiation protection. The solar film has a thickness of 50 μm and its conductivity and permeability are found to be 3.5×10^4 S/m and $4\pi \times 10^{-7}$ H/m, respectively. The ERP system uses a microwave frequency of 2.45 GHz for wireless communication with the in-vehicle unit (IU) in the car. For the given frequency, the distance between the car and the transmit antenna mounted on the ERP gantry is expected to be in the far-field region.

(i) Determine the shielding effectiveness of the solar film.

(7 Marks)

(ii) If the signal from the transmit antenna is being attenuated by more than 20 dB, the IU in the car may not function property. Do you think the solar film will affect the operation of the IU?

(3 Marks)

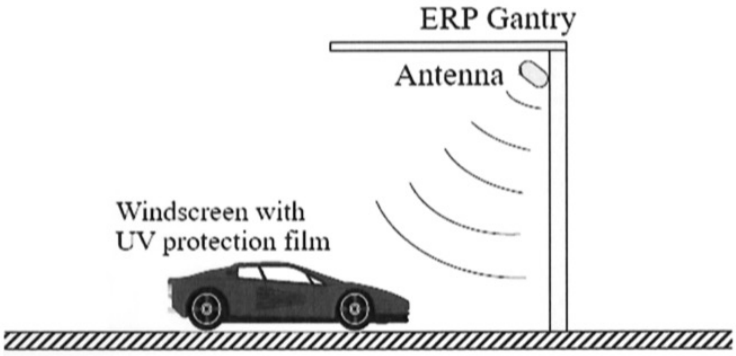

Figure 2

(i) At 2.45 GHz, the skin depth is $\delta = \dfrac{1}{\sqrt{\pi f \sigma \mu}} = \dfrac{1}{\sqrt{\pi \times 2.45\times10^9 \times 3.5\times10^4 \times 4\pi\times10^{-7}}} = 5.44\times10^{-5}$ (m)

The absorption loss $A = 8.686\left(\frac{t}{\delta}\right) = 8.686 \times \dfrac{50\times10^{-6}}{5.44\times10^{-5}} = 7.98$ dB

In the far-field region, $|Z_w| = 377\ \Omega$.

$|Z_s| = \sqrt{\dfrac{\omega\mu}{\sigma}} = \sqrt{\dfrac{2\pi\times2.45\times10^9\times4\pi\times10^{-7}}{3.5\times10^4}} = 0.743\ \Omega$

The reflection loss $R = 20\log\dfrac{|Z_w|}{4|Z_s|} = 20\log\dfrac{377}{4\times0.743} = 42.07$ dB

Since it's in the far-field region of the source antenna, the multiple reflection correction can be neglected

Hence, the shielding effectiveness of the solar film is:

$SE = A + R = 50.05$ dB

(ii) Since the SE is 50.05 dB > 20 dB, the solar film will affect the operation of the IU.

2016-2017 1. (b)

(b) Figure 2 shows a rectangular metal enclosure made of 0.5 mm thick stainless steel with conductivity and permeability of 1.16×10^{6} S/m and 6.28×10^{-4} H/m, respectively. A printed circuit board (PCB) is mounted within the enclosure. The PCB can be modelled as a radiating loop antenna and its nearest distance from the surface of the metal enclosure is 5 cm.

(i) Ignoring the effects of cavity resonances and slot, determine the expected shielding effectiveness of the metal enclosure at 10 MHz.

(5 Marks)

(ii) Taking into consideration the given dimensions of the enclosure and the slot, what are the frequencies below 1 GHz where the shielding effectiveness is expected to deteriorate?

(5 Marks)

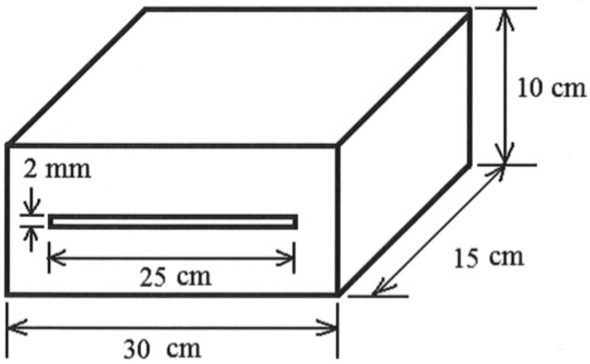

Figure 2

(i) At 10 MHz, the wavelength λ is $\lambda = \frac{3\times10^{8}}{10^{7}} = 30\ (m)$

The $r\ (0.05 m) < \frac{\lambda}{2\pi}\ (4.77 m)$. So it is in the near-field of the source.

The skin depth is $\delta = \frac{1}{\sqrt{\pi f \sigma \mu}} = \frac{1}{\sqrt{\pi \times 10^{7} \times 1.16\times10^{6} \times 6.28\times10^{-4}}} = 6.61\times10^{-6}\ (m)$

Since $t = 0.5\times10^{-3}\ (m) > \delta = (6.61\times10^{-6}\ m)$, the multiple reflection correction can be neglected.

$|Z_w| = 2\pi f \mu_0 r\ (\Omega) = 2\pi \times 10^{7} \times 6.28\times10^{-4} \times 0.05 = 1.97\ k\Omega$

$|Z_s| = \sqrt{\frac{\omega\mu}{\sigma}} = \sqrt{\frac{2\pi\times10^{7}\times6.28\times10^{-4}}{1.16\times10^{6}}} = 0.184\ \Omega$

The absorption loss is $A = 8.686 \times (\frac{t}{\delta}) = 8.686 \times \frac{0.5\times10^{-3}}{6.61\times10^{-6}} = 657.03\ dB$

The reflection loss is $R = 20\log\frac{|Z_w|}{4|Z_s|} = 20\log\frac{1.97\times10^{3}}{4\times0.184} = 68.55\ dB$

The shielding effectiveness is : $SE = A + R = 725.58\ dB$

(ii) Since $d = \frac{\lambda}{2}$, $\Rightarrow \lambda = 2d = 0.5\ m$

$f_{slot} = \frac{3\times10^{8}\ m/s}{0.5\ m} = 600\ MHz$

$f_{mnl} = 150\sqrt{(\frac{m}{0.3})^2 + (\frac{n}{0.15})^2 + (\frac{l}{0.1})^2}\ MHz$

$m=0,\ n=1,\ l=1 \Rightarrow f_{011} = 1.80\ GHz > 1 GHz$.

$m=1,\ n=0,\ l=1 \Rightarrow f_{101} = 1.68\ GHz > 1 GHz$

$m=1,\ n=1,\ l=0 \Rightarrow f_{110} = 1.12\ GHz > 1 GHz$, Hence, only at 600 MHz, the SE is expected to deteriorate.

2015 - 2016 1.

1. In a hardware shop, Copper and Steel sheets of thickness 5 mm are available. Their electrical properties are given in Table 1. You need to choose one of them to shield against a 100 Hz radiating loop at a distance 10 m away.

(a) For the given radiating source and distance, compute the shielding effectiveness (SE) of Copper sheet.

(8 Marks)

(b) Repeat part (a) if Steel sheet is used as the shield.

(8 Marks)

(c) Based on the SE obtained from parts (a) and (b), should you buy the Copper sheet or Steel sheet from the hardware shop?

(4 Marks)

Table 1

Conductive Material	**Conductivity (σ)**	**Permeability (μ)**
Copper	5.82×10^{7} S/m	$4\pi \times 10^{-7}$ H/m
Steel	5.82×10^{6} S/m	$4\pi \times 10^{-4}$ H/m

(a) at 100 Hz, the wavelength $\lambda = \frac{3\times10^8}{100} = 3\times10^6 m$

$r\ (10m) < \frac{\lambda}{2\pi}\ (4.77\times10^5 m)$, the shield is in the near-field of the source.

the skin-depth $\delta = \frac{1}{\sqrt{\pi f \sigma \mu}} = 6.60\times10^{-3}\ (m)$

$|Z_w| = 2\pi f \mu r\ (\Omega) = 2\pi\times100\times4\pi\times10^{-7}\times10m = 7.90\ m\Omega$

$|Z_s| = \sqrt{\frac{\omega\mu}{\sigma}}\ (\Omega) = \sqrt{\frac{2\pi\times100\times4\pi\times10^{-7}}{5.82\times10^{7}}} = 3.68\times10^{-3}\ m\Omega$

The absorption loss $A = 8.686\cdot\frac{t}{\delta} = 8.686\times\frac{5}{6.60} = 6.58\ dB$

The reflection loss $R = 20\log\frac{|Z_w|}{4|Z_s|} = 20\log\frac{7.90}{4\times3.68\times10^{-3}} = 54.59\ dB$

Since $t < \delta$, the multiple reflection correction can't be neglected.

The multiple reflection is: $B = 20\log(1-e^{-2t/\delta}) = 20\log(1-e^{-2\times5/6.60}) = -2.16\ dB$

Hence, the shielding effectiveness of copper sheet is

$SE = A+R+B = 6.58+54.59-2.16 = 59.01\ dB$

(b) As for steel sheet,

$\delta = \frac{1}{\sqrt{\pi f\sigma\mu}} = \frac{1}{\sqrt{\pi\times100\times5.82\times10^{6}\times4\pi\times10^{-4}}} = 0.66\times10^{-3}\ (m)$

$|Z_w| = 2\pi f \mu_0 r\ (\Omega) = 2\pi\times100\times4\pi\times10^{-4}\times10 = 7.90\ \Omega$

$|Z_s| = \sqrt{\frac{2\pi f\mu}{\sigma}} = \sqrt{\frac{2\pi\times100\times4\pi\times10^{-4}}{5.82\times10^{6}}} = 0.368\ m\Omega$

The absorption loss is $A = 8.686 \frac{t}{\delta} = 8.686 \times \frac{5mm}{0.66mm} = 65.80$ dB.

The reflection loss is $R = 20 \log \frac{|Z_w|}{4|Z_s|} = 20 \log \frac{7.90}{4 \times 0.368 \times 10^{-3}} = 74.59$ dB

Since t (5mm) $> \delta$ (0.66 mm), the multiple reflection correction can be neglected.

Hence the SE for Steel sheet is

$SE = A + R = 65.80dB + 74.59dB = 140.39$ dB

(c) I would buy steel sheet, because it has better shielding effectiveness