KTH ROYAL INSTITUTE
OF TECHNOLOGY

Solution to EMC Problems

Exercises

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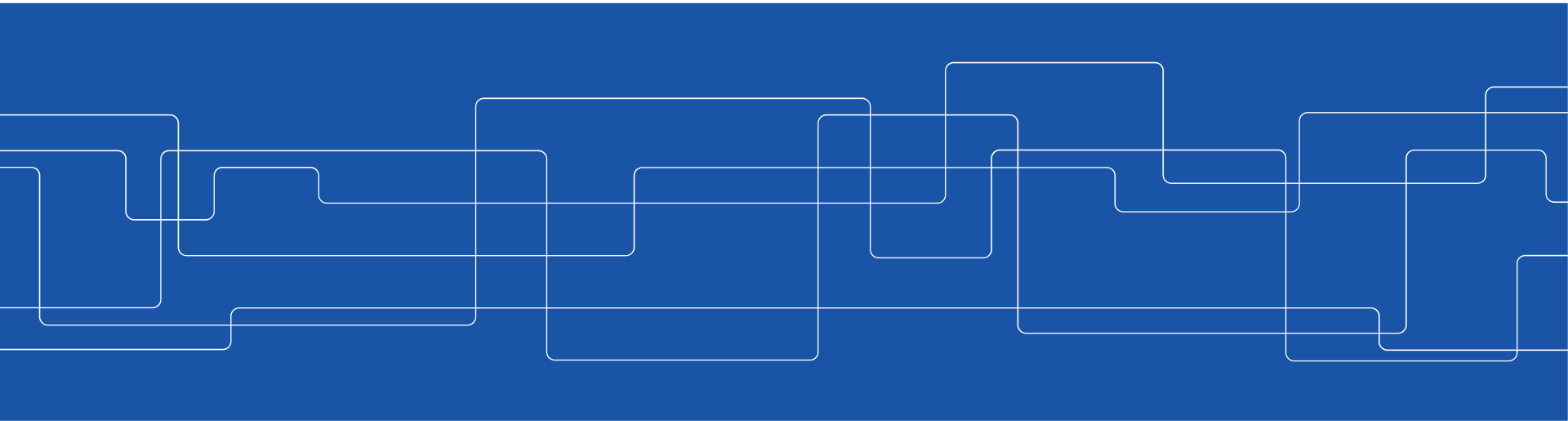
MODULE 5.7



Module 5.7

Numerical example on shielding effectiveness - 1

1) A shielded enclosure is made of 0.5 mm thick aluminium sheet with $\mu_r = 1$, $\sigma_r = 0.6$. Find the shielding effectiveness of the enclosure for the following situation, considering only attenuation due to absorption and reflection for a nominal frequency of 1 kHz. Use $\mu_0 = 4\pi \cdot 10^{-7}$ H/m, $\sigma_{Cu} = 5.8 \cdot 10^{7}$ S/m.

a) Assume a far-field source

b) Assume a near-field electric source at a distance of 10 cm

c) Assume a near-field magnetic source at a distance of 10 cm

Solution:

Skin depth $\delta = \frac{1}{\sqrt{\pi f \mu \sigma}} = 2.7\ mm$

Attenuation due to absorption $S_A = 20\log_{10} e^{d/\delta} \approx 8.7 \frac{d}{\delta}$ = 1.6 dB (d = 0.5 mm)

Attenuation due to absorption is the same for far-field as well as near-field sources

Numerical example on shielding effectiveness - 2

Attenuation due to reflection:

Intrinsic impedance of aluminium $S_R = \frac{(Z_w + Z_m)^2}{4 Z_w Z_m}$ $Z_m \approx \sqrt{\frac{\omega\mu}{\sigma}} = 151 \cdot 10^{-7}\ \Omega$

r = 0.01 m

Far field source

$Z_w = 377\ \Omega$

$S_R \approx \frac{377}{4 Z_m}$

$S_R(dB) = 20\log_{10}(\frac{377}{4 Z_m})$

= 136 dB

Near field E source

$Z_E = \frac{1}{2\pi f \varepsilon_0 r}$ = $1.8 \cdot 10^9\ \Omega$

$S_R \approx \frac{Z_E}{4 Z_m}$

$S_R(dB) = 20\log_{10}(\frac{Z_E}{4 Z_m})$

= 270 dB

Near field H source

$Z_M = 2\pi f \mu_0 r$ = $790 \cdot 10^{-7}\ \Omega$

$S_R = \frac{(Z_M + Z_m)^2}{4 Z_M Z_m}$

$S_R(dB) = 20\log_{10} \frac{(Z_M + Z_m)^2}{4 Z_M Z_m}$

= 5.4 dB

Numerical example on shielding effectiveness - 3

Attenuation due to multiple reflections

$$S_{MR} = 1 - \left| \frac{Z_w - Z_m}{Z_w + Z_m} \right|^2 e^{-2\frac{d}{\delta}} \qquad d/\delta = 0.185$$

Far field source

$Z_w = 377\ \Omega$

$$S_{MR} \cong 1 - e^{-2d/\delta}$$

$= 1 - 0.691 = 0.309$

$S_{MR}(dB) =$ **-10.2 dB**

S = 1.6 + 136 – 10.2

= 127 dB

Near field E source

$$Z_E = \frac{1}{2\pi f \varepsilon_0 r} = 1.8 \cdot 10^9\ \Omega$$

$$S_{MR} \cong 1 - e^{-2d/\delta}$$

$= 1 - 0.691 = 0.309$

$S_{MR}(dB) =$ **-10.2 dB**

S = 1.6 + 270 – 10.2

= 261 dB

Near field H source

$$Z_M = 2\pi f \mu_0 r = 790 \cdot 10^{-7}\ \Omega$$

S_{MR}= 1-0.679*0.691 = 0.531

$S_{MR}(dB) =$ **-5.5 dB**

S = 1.6 + 5.4 – 5.5

= 1.5 dB

2. A shielded enclosure is made of 0.5 mm thick iron sheet with $\mu_r = 1000$, $\sigma_r = 0.1$. Find the shielding effectiveness of the enclosure for the following situation, considering only attenuation due to absorption and reflection for a nominal frequency of 10 kHz. Assume a far-field source.

3. A radio communication tower 35 meter tall is struck by lightning. The antenna is placed at the top of the tower and the electronics at the base of the tower. A cable with solid copper shield connect the electronics with the antenna. It is estimated that about 60 % of the lightning current will be flowing through the cable shield. What would be the approximate peak overvoltage appearing at the output port of the electronic circuit (that is voltage between the inner conductor and the shield of the cable at the base of the tower) if the lightning current has a peak amplitude of 50 kA? The shield of the cable has a resistance of 4 mΩ/m and negligible leakage inductance.

4. The total shielding effectiveness provided by a metal plate can be considered to be due to absorption of the waves as it passes through the metal and also due to the reflection of the waves from the metal surfaces. In the following table write what happens to the absorption loss and reflection loss when the parameter in the first column is increased, keeping other parameters constant. There are three choices for each answer: **Increase, Decrease, or No change**. Assume that the shield is in the far-field region of the field source. Give the reason behind your choice

Parameter	Absorption loss	Reflection loss
Increase plate thickness	?	?
Increase the frequency	?	?
Increase the conductivity	?	?
Increase the permeability (μ)	?	?