EE5801 EMC

Tutorial 5 - Shielding

1.

i) For good conductors, we can use the approximated equation for SE:

$$SE_{\mathrm{dB}} = 20\log_{10}\left|\frac{\eta_0}{4\eta}\right| + 20\log_{10} e^{t/\delta} \tag{1}$$

or

$$SE_{\mathrm{dB}} = R_{\mathrm{dB}} + A_{\mathrm{dB}} \tag{2}$$

$$R_{\mathrm{dB}} = 168 + 10\log_{10}\left(\frac{\sigma_{\mathrm{r}}}{\mu_{\mathrm{r}} f}\right) \tag{3}$$

$$A_{\mathrm{dB}} = 131.4t\sqrt{f\mu_{\mathrm{r}}\sigma_{\mathrm{r}}} \quad (t \text{ in m}) \tag{4}$$

ii) From Fig. 1, the least SE from 10 kHz to 1 GHz for 0.025 mm thick copper sheet is around 108 dB. It is too close to the required SE of 100 dB. Hence, the 0.25 mm thick copper sheet is recommended for it is able provided an SE of 128 dB.

iii) To find the minimum, we can resort to the 1st derivative of SE. Expressing (1) in linear form:

$$SE = \left|\frac{\eta_0}{4\eta}\right| e^{t/\delta} \tag{5}$$

Substitute $\eta_0 = 120\pi$, $|\eta| = \sqrt{\omega\mu/\sigma}$, and $\delta = \sqrt{2/\omega\mu\sigma}$ into (5),

$$SE = \frac{30\pi}{\sqrt{2\pi f\mu/\sigma}} e^{t\sqrt{\pi f\mu\sigma}} \tag{6}$$

Take the derivative of (6) with respect to frequency, we have

$$\begin{aligned}\frac{d}{df}SE &= -\frac{15\pi}{\sqrt{\frac{2\pi\mu}{\sigma}}} f^{-\frac{3}{2}} \cdot e^{t\sqrt{\pi f\mu\sigma}} + \frac{30\pi}{\sqrt{\frac{2\pi\mu}{\sigma}}} f^{-\frac{1}{2}} \cdot \frac{t\sqrt{\pi\mu\sigma}}{2} f^{-\frac{1}{2}} \cdot e^{t\sqrt{\pi f\mu\sigma}} \\ &= e^{t\sqrt{\pi f\mu\sigma}}\left(\frac{15\pi t\sigma}{\sqrt{2}} f^{-1} - \frac{15\pi}{\sqrt{\frac{2\pi\mu}{\sigma}}} f^{-\frac{3}{2}}\right) \\ &= e^{t\sqrt{\pi f\mu\sigma}} \frac{15\pi}{\sqrt{2}} f^{-1}\left(t\sigma - \sqrt{\frac{\sigma}{\pi\mu}} f^{-\frac{1}{2}}\right)\end{aligned} \tag{7}$$

Hence, the zero slope can only happens at $t\sigma - \sqrt{\frac{\sigma}{\pi\mu}} f^{-\frac{1}{2}} = 0$, which is simplified to

$$f = \frac{1}{\sigma \pi \mu t^2} \tag{8}$$

When t = 0.025 mm, f is 6.9877 MHz; when t = 0.25 mm, f is 69.877 kHz.

iv) First, calculate the cutoff frequency of TE_{10} mode based on the aperture size and filling material (a front viewing panel of a dielectric constant of 2.5) using the below formula:

$$f_c = \frac{c_0}{2a\sqrt{\epsilon_\mathrm{r}}} \tag{9}$$

Since the largest linear dimension is a = 0.1 m, f_c = 0.949 GHz which is below the upper frequency bound of interest (1 GHz). Hence the shield is completely compromised. Any extension of the aperture will not be effective because SE due to waveguide depth only happens below cutoff frequencies.

v) Choice d) is the best method because

1) it does not need much modification to the meter and shielded box;
2) it is the easiest to implement.

2.

i) For good conductor and low-impedance magnetic sources, we may use the below approximated formulas for SE:

$$SE_\mathrm{dB} = R_\mathrm{dB} + A_\mathrm{dB} \tag{10}$$

where

$$R_\mathrm{dB} = 14.57 + 10\log_{10}\left(\frac{fr^2\sigma_\mathrm{r}}{\mu_\mathrm{r}}\right)$$
$$A_\mathrm{dB} = 131.4t\sqrt{f\mu_\mathrm{r}\sigma_\mathrm{r}}$$

Since the shield material (Material 2) is copper, $\sigma_\mathrm{r} = 1$ and $\mu_\mathrm{r} = 1$. R_dB is calculated to be 14.57 dB. To obtain 60 dB SE, the rest 45.43 dB must be provided by A_dB. Hence, the thickness is calculated to be 3.5 mm.

ii) If the source were radiating at 50 Hz, R_dB would be -8.44 dB. Hence, A_dB would need to be 68.44 dB and the thickness would need to be increased to 73.7 mm. This is because that for lower frequency, R_dB would be ineffective and more skin depths would be needed to attenuate the fields.