EE5801 EMC

Tutorial 5 - Shielding

1. Design a copper shielded box of dimensions 1.0 x 0.5 x 0.5 m^3 with (plane-wave) shielding effectiveness (SE) of at least 100 dB in the frequency range from 10 kHz to 1 GHz. All doors, joints and seams are properly done. The conductivity of copper is 5.8 x 10^7 S/m.

   (**Note:** This is just an exercise since the source at frequencies below 80MHz will likely be near-field source instead of far-field source, i.e., no plane wave.)

   i) State the formula of calculating SE under good conductor condition.

   ii) Fig. 1 shows the SE of two copper sheets with thicknesses of 0.25 mm and 0.025 mm. Which thickness is recommended? [**Hint**: some margin is needed.]

   iii) Prove that the lowest SE provided by 0.025 mm and 0.25 mm copper sheets happen at ~7 MHz and ~70 kHz, respectively. [**Hint**: take the 1st derivative with respect to frequency of the formula in i) and find the zero-slope point which correspond to the minimum.]

   iv) If a rectangular hole of dimensions 10 x 5 cm^2 is to be opened on the front door to accommodate a meter of 10 x 5 x 5 cm^3, and a front plastic viewing panel of dimensions 10 x 5 x 0.5 cm^3. The plastic has a dielectric constant of 2.5. Can the shielded box still meet the design requirement? If not, state the degradation clearly.

   v) What of the following mitigation methos is the best to recover the SE performance back? State the reasons. [**Hint**: cost-effectiveness and the least modification to the meter/shielded box.]

      a) Open a smaller hole for the meter and add metal rim around the meter;

      b) Change the front plastic viewing panel with a lower dielectric constant material;

      c) Use a conductive front plastic panel that is able to provide an SE of 100 dB;

      d) Add a 0.25 mm thick copper box that can tightly accommodate the meter to cover the interior of the meter; the joining (soldering) between the second copper box and the main box and cabling are properly done.

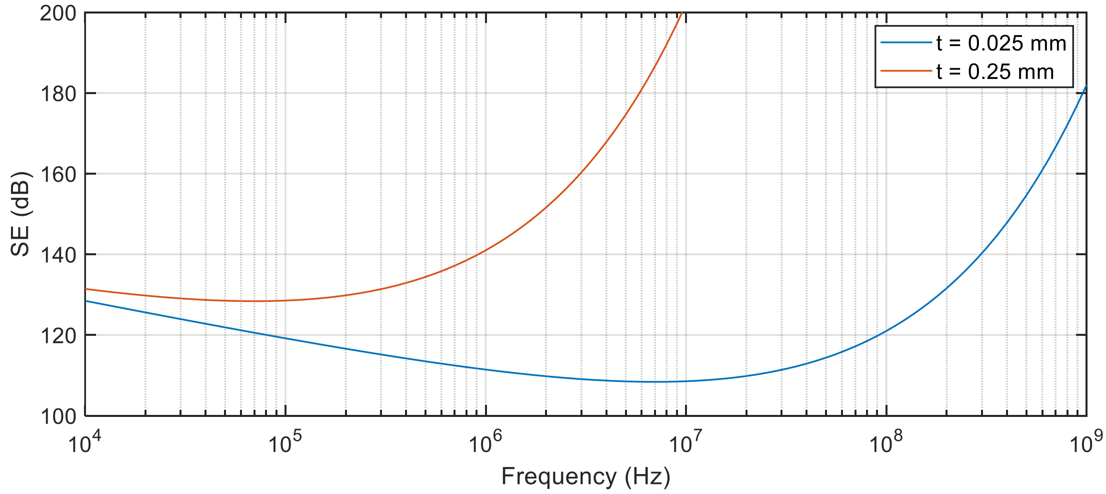

Figure 1. Shielding effectiveness versus frequency for two copper sheets of thickness t = 0.25 mm and t = 0.025 mm.

2. The shielding effectiveness (SE) of a solid shielding material arranged as in Fig. 2 is given as: $|T_1 T_2|^{-1} e^{\alpha t} \left|1 - \Gamma_2^2 e^{-2\gamma t}\right|$, where T_1 is the transmission coefficient at the first interface (between material 1 and material 2), T_2 is the transmission coefficient at the second interface (between material 2 and material 3), Γ_2 is the reflection coefficient at the second interface, t is the thickness of material 2, and $\gamma = \alpha + \mathrm{j}\beta$ is the complex propagation constant of material 2. Material 1 is air.

   The source is a 10 kHz low-impedance source located 0.01 m away from the interface. The wave impedance of a low-impedance source is $240\pi^2 r/\lambda_0 e^{-\mathrm{j}\pi/2}$ Ω, where r is the distance between the source and the interface, λ_0 is the free space wavelength of the source. Material 2 is a conductive material with $\epsilon = \epsilon_0$, $\sigma = 5.8 \times 10^7$ S/m. Material 3 is air.

   i) Find the required thickness t of Material 2 in order to achieve a 60 dB SE.

   ii) Discuss and comment on the results if the source is 50 Hz.

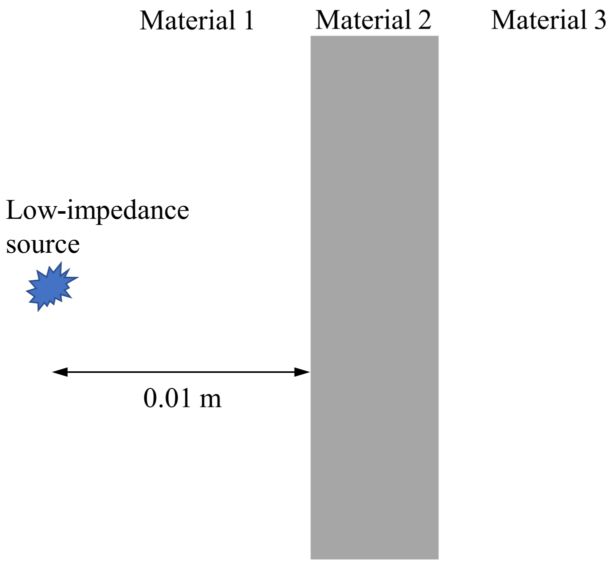

Figure 2. Arrangement of the low-impedance source and the conductive shield.