Transfer Impedance as a Measure of the Shielding of Seams & EMI Gasketed Joints

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Transfer Impedance Theory

♦ “Electromagnetic Leakage via Seams (and Gasketed Joints)” in Shielded Enclosures occurs primarily as a result of currents which cross the seam.
  - Such crossing cause a voltage to appear on the far side of the seam.
  - Electromagnetic Leakage via the seam is directly proportional to this (transfer) voltage.

♦ In shielding Theory the seam is characterized in terms of its Transfer Impedance as follows:

\[ Z_T = \frac{V}{J_S} \]

- \( Z_T \) = Transfer Impedance of Seam (Ohm-meters)
- \( V \) = Transfer Voltage (Voltage across Seam)
- \( J_S \) = Density of Current which crosses the Seam (A/m)
A radiated electromagnetic (EM) force field is generated by the action of driving a current through a wire.

- The figure below represents a sending/receiver circuit on a PC card above a ground plane.

![PC Card Trace Diagram](image)

- The EM Wave generated by the signal on the PC card trace is similar to a wave generated by an “electric dipole antenna.” i.e., the impedance of the wave (E/H) is the same.

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The EM Wave generated by an Electric Dipole Antenna is best illustrated using parallel plates as shown below.

![Generation of EM Wave Diagram](image)

- The electrons in the top plate are transferred to the bottom plate by a voltage source.
- The field between the plates is called “displacement current” in Amps/m².
- The displacement current (in Amps/m) creates an Electromagnetic Wave which consists of an E and H field parallel to the displacement current.
Transfer Impedance as a Measure of the Shielding Quality of Seams and Gasketed Joints

Figure 3: Wave Impinged on Gasketed Joint

$$Z_T = \text{Transfer Impedance of Joint (}\Omega\text{m})$$
$$J_S = \text{Surface Current Density (A/m)}$$

$$E_T \approx Z_T J_S / l (V/m)$$
$$l = \pi R \text{ (meters)}$$
$$H_T \approx E_T \lambda / (377 \times 2 \pi R) (A/m)$$
$$R < \lambda / 2 \pi$$

$$H_T = E_T / 377 (A/m)$$
$$R \geq \lambda / 2 \pi$$

Figure 4: EMI Gasketed Maintenance Cover

$$J_S = \text{Current due to Wave Impinged on Barrier}$$
$$e = \text{Voltage across Gasket}$$
$$= J_S Z_T$$
$$Z_T = \text{Transfer Impedance of Seam or Gasketed Joint (}\Omega\text{m})$$

$$E_T \approx 2e / l (V/m)$$
$$l \approx \pi R \text{ (meters)}$$
$$H_T \approx E_T \lambda / (377 \times 2 \pi R) (A/m)$$
$$R < \lambda / 2 \pi$$

$$H_T = E_T / 377 (A/m)$$
$$R \geq \lambda / 2 \pi$$
Figure 4: Example

Value of using Transfer Impedance of a Seam or Gasketed Joint

Let \( E_I = 1000 \, \text{V/m} @ 2 \, \text{Ghz} \)

\( H_I = 2.65 \, \text{A/m} \)

\( J_S = 2.65 \, \text{A/m} \)

\( Z_T = 1 \, \text{m} \, \Omega \)-meters

\( e = 2.65 \times 10^{-3} \)

\( 2e = 5.3 \times 10^{-3} \)

\( R = 1 \, \text{meter} \)

\( E_T \approx 5.3 \times 10^{-3} / \pi = 0.0017 \, \text{V/m} \)

\( H_T \approx 0.0017 / 377 = 4.48 \times 10^{-6} \, \text{A/m} \)

Figure 4: Example Continued

Shielding Effectiveness vs. Shielding Quality

\[
\text{Shielding Effectiveness} = \frac{E_I}{E_T} = \frac{1000}{0.0017} = 5.88 \times 10^5
\]

\[
\text{SE} = 20 \log (5.88 \times 10^5) = 115 \, \text{dB}
\]

\[
\text{Shielding Quality} = \frac{Z_T}{Z_W}
\]

\[
= 10^{-3}/377 = 2.65 \times 10^{-6} = 111 \, \text{dB}
\]
Figure 4: Example Continued

**Induced Fields into Inside Maintenance Cover Compartments**

Let \( E_I = 1000 \text{ V/m} \) @ 2 Ghz

\[
H_I = 2.65 \text{ A/m}
\]

\[
J_S = 2.65 \text{ A/m}
\]

\[
Z_T = 1 \text{ m} \Omega \text{-meters}
\]

\[
e = 2.65 \times 10^{-3}
\]

\[
\lambda = c/f = 3 \times 10^8/2 \times 10^9 = .15 \text{ m}
\]

\[c = \text{speed of light}\]

\[
\therefore E_B \approx e/\lambda = 2.65 \times 10^{-3}/.08 = .0331 \text{ V/m}
\]

\[
H_B \approx E_B \lambda/377
\]

\[
H_B = .0331(.15)/30.16 \approx 1.64 \times 10^{-4} \text{ A/m}
\]

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**Induced Fields into Wire Bundle due to Lightning Strike**

Let \( J_S = 10,000 \text{ A} \) (Lightning Strike)

\[
e = 10,000 \times 10^{-3} = 10 \text{ Volts}
\]

\[
E_B = 10/.08 = 125 \text{ V/m}
\]

Assuming rise time = 10\(\mu\)s

\[
H_B \approx 125 \lambda/377(.08)
\]

\[
\lambda \approx 32 \times 10^3 \text{ meters}
\]

\[
H_B \approx 131 \times 10^3 \text{ A/m}
\]
- Input power (from 50 Ω source) comes into the Input connector and is terminated into a 50 Ω resistor that makes contact with the contact plate.
- The Input Current ($I_I$) associated with the power flows through the gasket under test and returns to the input source via the base plate.
- The voltage drop (Output Voltage $V_O$) is measured by a 50 Ω receiver attached to the output connector.

**Figure 5: Transfer Impedance Test Fixture**

![Transfer Impedance Test Fixture Diagram]

$Z_T = \frac{V_O}{I_I} L_G$

$Z_T = V_O - I_I + L_G$ (dB)

$I_I = \frac{V_I}{50}$

$I_I = V_I - 20\log50$ (dB)

$I_I = V_I - 34$ (dB)

$V_I = 0$ (dBm)

$Z_T = V_O - [V_I - 34] + 20\log G_L$ (dB)

$G_L = \frac{V_O}{V_I}$

$Z_T = V_O + 34 + 20\log G_L$ (dB)

$I_I = \text{Input Current (Amps)}$

$L_G = \text{Length of Gasket (m)}$

$V_I = \text{Input Voltage (dBm)}$

$V_O = \text{Output Voltage (dBm)}$
Figure 6: Shielding Quality Test Data

Tin Plated EMI Gaskets against Plated Aluminum Joint Surfaces

Stainless Steel EMI Gaskets against Plated Aluminum Joint Surfaces

Stainless Steel EMI Gaskets against Nickel Plated Joint Surfaces (repeated)
Figure 7: Shielding Quality of Various EMI Gaskets

Figure 8: Comparison of Shielding Quality

1 – Carbon Filled Elastomeric Gasket
2 – 3 pieces, .030” thick Stainless Steel Washers on 5.5” centers
3 – 3 pieces, .030” thick Fiber Washers (capacitive reactance between plates .030” inches apart).
Figure 9: Shielding Quality of Gasketed Segments

1 – 3/8" Tin Plated Gasket
   a) on 7 inch centers
   b) on 4.75 inch centers
   c) on 2.5 inch centers

2 – 3/8" Stainless Steel Gasket
   a) on 7 inch centers
   b) on 4.75 inch centers
   c) on 2.5 inch centers

Summary

- Transfer Impedance Test Data provides an accurate measure of the shielding obtainable from EMI gaskets as applied to various joint surfaces.

- Transfer Impedance Testing can also be used to assess the degradation of the shielding due to exposure to moisture and salt fog environments.
Selected References


