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:**

$$Z_T = V / J_S$$

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)

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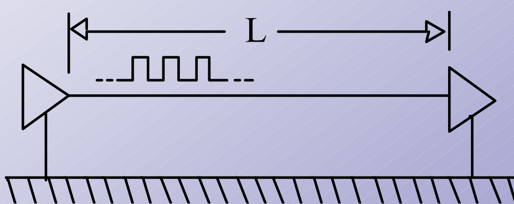
Figure 1: PC Card Trace

- **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.



  - 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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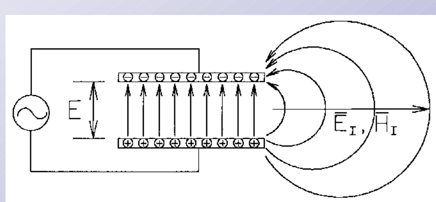
Figure 2: Generation of EM Wave

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



  - 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/m^2
  - The displacement current (in Amps/m) creates an Electromagnetic Wave which consists of an E and H field parallel to the displacement current.

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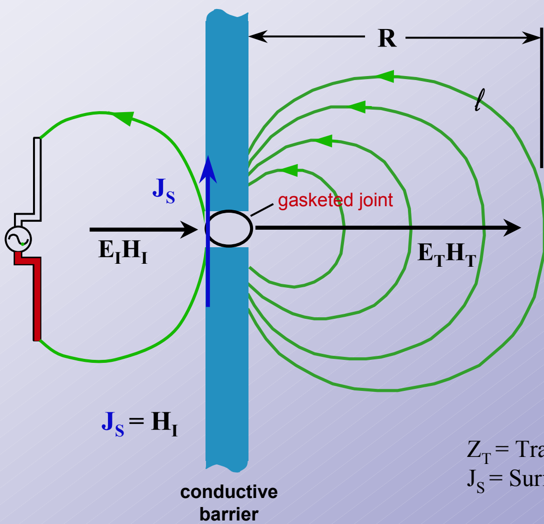
Figure 3: Wave Impinged on Gasketed Joint



$E_T \approx Z_T J_S / \ell$ (V/m)

$\ell = \Pi R$ (meters)

$H_T \approx E_T \lambda / 377 * 2\Pi R$ (A/m)

$R < \lambda / 2\Pi$

$H_T = E_T / 377$ (A/m)

$R \geq \lambda / 2\Pi$

Z_T = Transfer Impedance of Joint (Ωm)
J_S = Surface Current Density (A/m)

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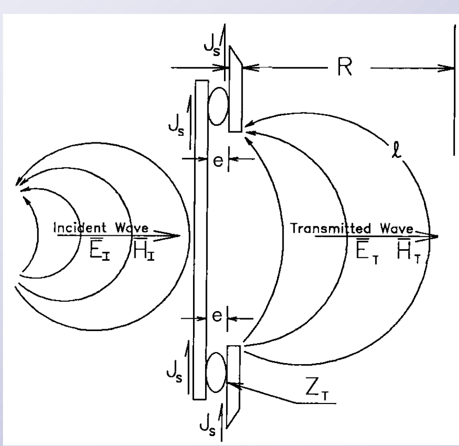
Figure 4: EMI Gasketed Maintenance Cover



J_S = Current due to Wave Impinged on Barrier
e = Voltage across Gasket
$= J_S Z_T$
Z_T = Transfer Impedance of Seam or Gasketed Joint (Ωm)

$E_T \approx 2e / \ell$ V/m)

$\ell \approx \Pi R$ (meters)

$H_T \approx E_T \lambda / (377 * 2\Pi R)$ (A/m)

$R < \lambda / 2\Pi$

$H_T = E_T / 377$ (A/m)

$R \geq \lambda / 2\Pi$

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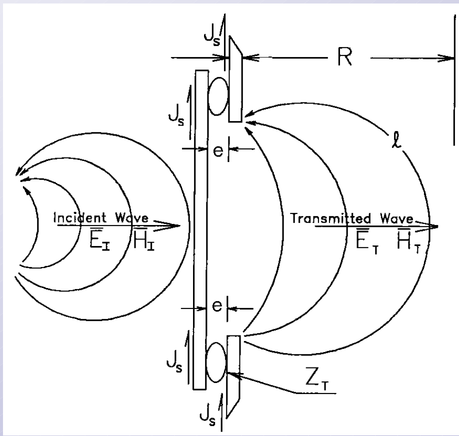
Figure 4: Example

- Value of using Transfer Impedance of a Seam or Gasketed Joint



Let $E_I = 1000$ V/m @ 2 Ghz
$H_I = 2.65$ A/m
$J_S = 2.65$ A/m
$Z_T = 1 m\Omega$-meters
$e = 2.65 \times 10^{-3}$
$2e = 5.3 \times 10^{-3}$
R = 1 meter

$E_T \approx 5.3 \times 10^{-3} / \Pi = .0017$ V/m
$H_T \approx .0017/377 = 4.48 \times 10^{-6}$ A/m

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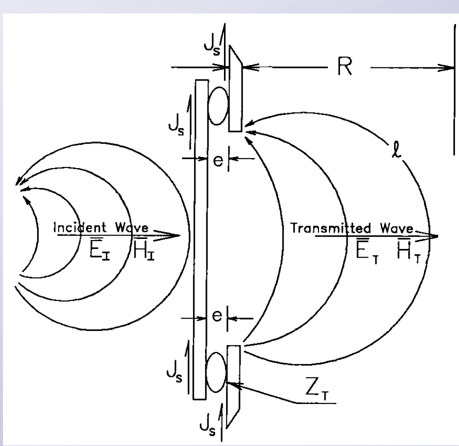
Figure 4: Example Continued

- Shielding Effectiveness vs. Shielding Quality



Shielding Effectiveness
$SE = E_I/E_T = 1000/.0017$
$= 5.88 \times 10^5$

$SE = 20 \log (5.88 \times 10^5)$
$= 115$ dB

Shielding Quality
$SQ = Z_T / Z_W$
$= 10^{-3}/377 = 2.65 \times 10^{-6}$
$= 111$ dB

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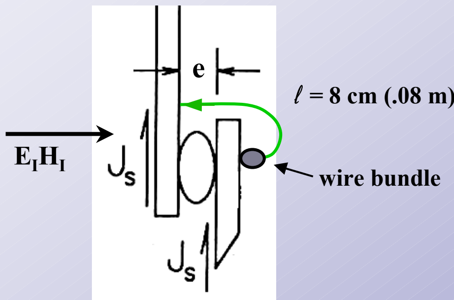
Figure 4: Example Continued

- Induced Fields into Inside Maintenance Cover Compartments



Let $E_I = 1000$ V/m @ 2 Ghz
$H_I = 2.65$ A/m
$J_S = 2.65$ A/m
$Z_T = 1$mΩ-meters
$e = 2.65 \times 10^{-3}$

$\lambda = c/f = 3\times 10^8/2\times 10^9 = .15$ m
c = speed of light

$\therefore\ E_B \approx e/\ell = 2.65\times10^{-3}/.08 = .0331$ V/m
$H_B \approx E_B\,\lambda/377\,\ell$
$H_B = .0331(.15)/30.16 \approx 1.64\times10^{-4}$ A/m

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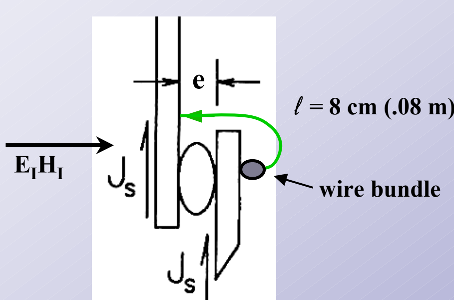
Figure 4: Example Continued

- Induced Fields into Wire Bundle due to Lightning Strike



Let $J_S = 10{,}000$ A (Lighting Strike)
$e = 10{,}000 \times 10^{-3} = 10$ Volts

$E_B = 10/.08 = 125$ V/m
Assuming rise time = 10μs

$H_B \approx 125\,\lambda/377(.08)$
$\lambda \approx 32 \times 10^3$ meters
$H_B \approx 131 \times 10^3$ A/m

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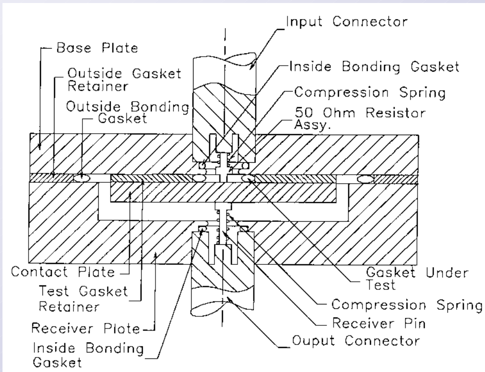
Figure 5: Transfer Impedance Test Fixture



- 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.

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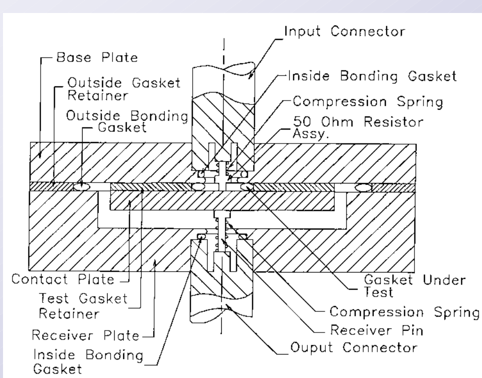
Figure 5: Transfer Impedance Calculations



$$Z_T = (V_O/I_I)L_G$$
$$Z_T = V_O - I_I + L_G \text{ (dB)}$$
$$I_I = V_I/50$$
$$I_I = V_I - 20\log 50 \text{ (dB)}$$
$$I_I = V_I - 34 \text{ (dB)}$$

$$\therefore Z_T = V_O - [V_I - 34] + 20\log G_L \text{ (dB)}$$
$$\& \; V_I = 0 \text{ (dBm)}$$

$$\therefore Z_T = V_O + 34 + 20\log G_L \text{ (dB)}$$

I_I = Input Current (Amps)
L_G = Length of Gasket (m)
V_I = Input Voltage (dBm)
V_O = Output Voltage (dBm)

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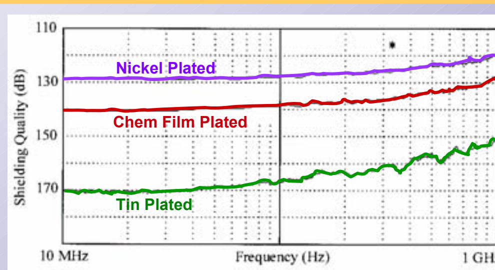
Figure 6: Shielding Quality Test Data

Tin Plated EMI Gaskets against Plated Aluminum Joint Surfaces



Stainless Steel EMI Gaskets against Plated Aluminum Joint Surfaces

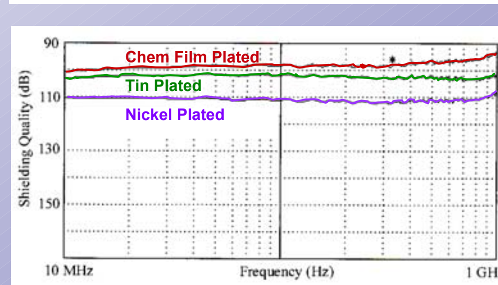


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Figure 6: Shielding Quality Test Data

Stainless Steel EMI Gaskets against Plated Aluminum Joint Surfaces

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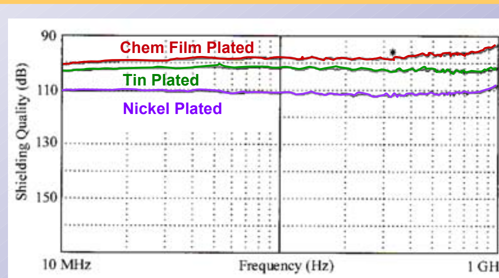

Stainless Steel EMI Gaskets against Nickel Plated Joint Surfaces

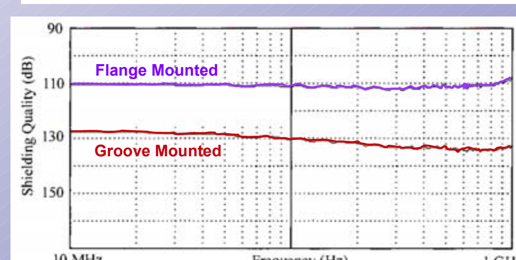

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Figure 7: Shielding Quality of Various EMI Gaskets

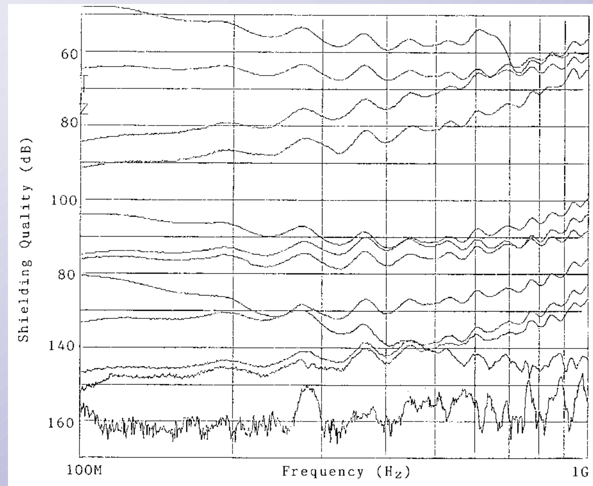

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Figure 8: Comparison of Shielding Quality

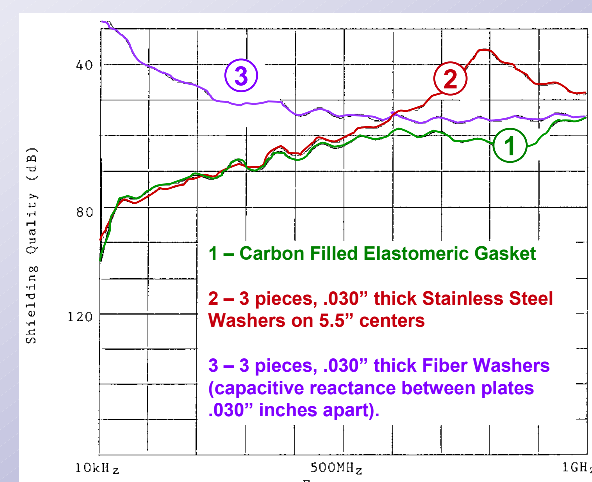

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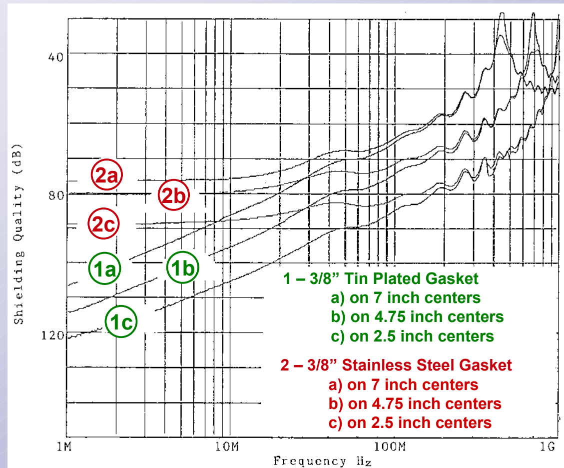
Figure 9: Shielding Quality of Gasketed Segments



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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.

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Selected References

1. George Kunkel, Joseph E. Butler, & Louis A. Messer, “Guest Editorials; Testing of EMI Gaskets”, EMC Technology, January, March, May 1989.
2. George Kunkel, “Lightning Induced Electromagnetic Fields into Aerospace Vehicles”, Evaluation Engineering, August 1990.
3. George Kunkel, “Testing the Shielding Quality of EMI Gaskets and Gasketed Joints - A Demonstration”, IEEE/EMC 1994 Symposium.
4. George Kunkel, “Electromagnetic Leakage Through Seams and Gasketed Joints – A Demonstration”, IEEE/EMC 1996 Symposium.

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