Transfer Impedance as a Measure of the Shielding Quality of Shielded Cables and Connectors

1. Surface Transfer Impedance
2. Transfer Impedance vs. Shielding Effectiveness
3. Other Transfer Functions

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Definition of Surface Transfer Impedance

- In the 1930's Shelkunoff showed that Surface Transfer Impedance was the Intrinsic Electromagnetic Shielding Property of Cables Connectors and Backshells

$$Z_t = (1 / I_o)\, dV/dz$$

I_o = Current flowing on Shield

dV/dz = Voltage per unit length on inside of shield

- In practice, $Z_t = V / (\ell * I_o)$ where ℓ is cable length

- For Connectors, V is a point source

$$Z_t = V_{oc} / I_o$$

where V_{oc} is the open circuit voltage on inside of shield

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Surface Transfer Impedance

- Similar to Common Impedance Coupling
- Current on one side of Barrier Produces Voltage on other side of Barrier due to Impedance of Barrier
- Surface Magnetic Field on one side of Barrier produces Tangential Surface Electric Field on other side of Barrier due to Impedance of Barrier
- At Low Frequencies, Impedance is Resistance due to Current Diffusion and Contact Resistance
- At High Frequencies, Impedance is Mutual Inductance due to Apertures, Porpoising, Etc.

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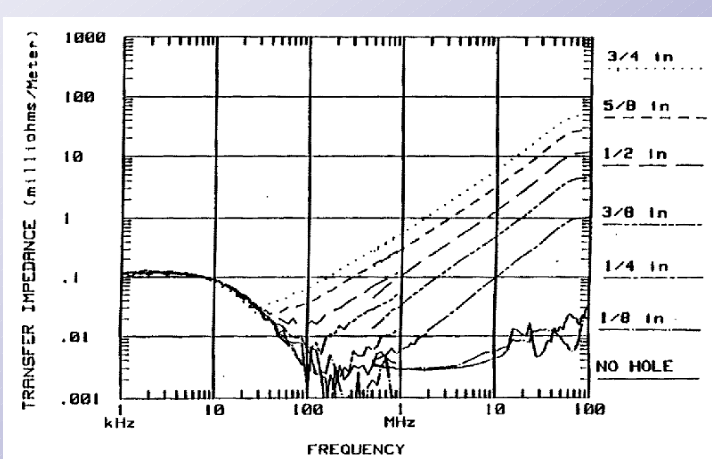
Measured Surface Transfer Impedance of 1-1/4" Diameter Cu Pipe with a Single Hole



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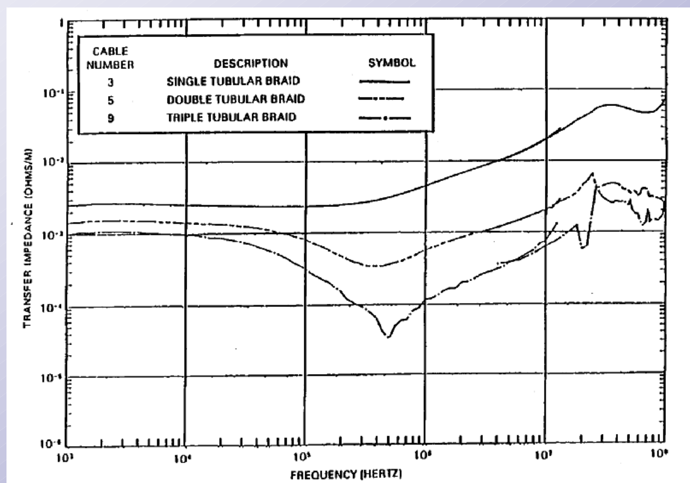
Surface Transfer Impedance of Braided Cable



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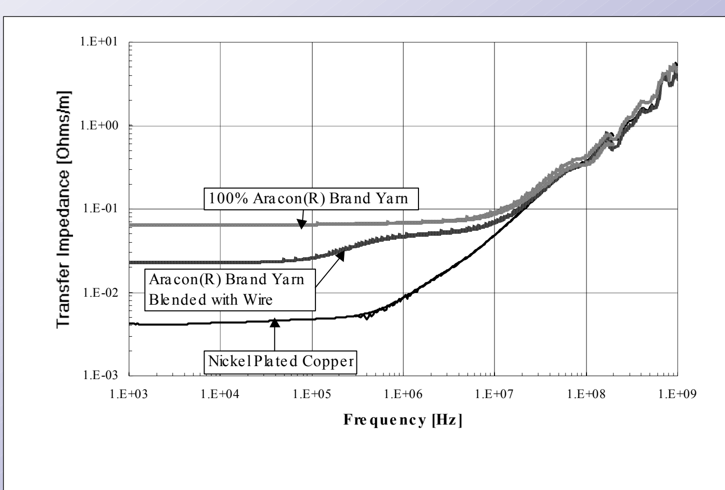
Surface Transfer Impedance of Metal Clad Aramid Fiber Cable Shields



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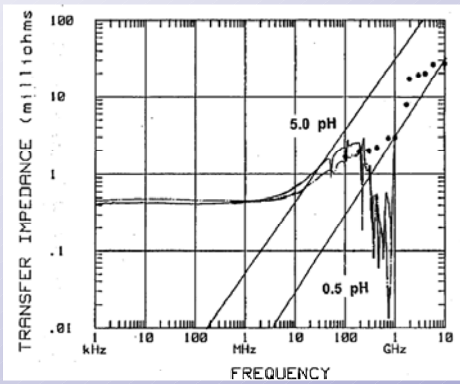
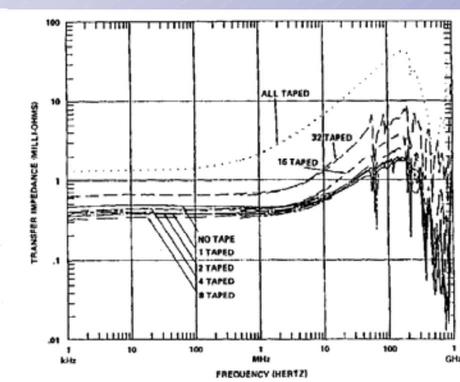
MIL-C-38999 Series IV Circular Connector with Backshell and Braid Termination

Mil-C-38999 Requirements Converted Into Transfer Impedance



Effect of Spring Fingers on Transfer Impedance



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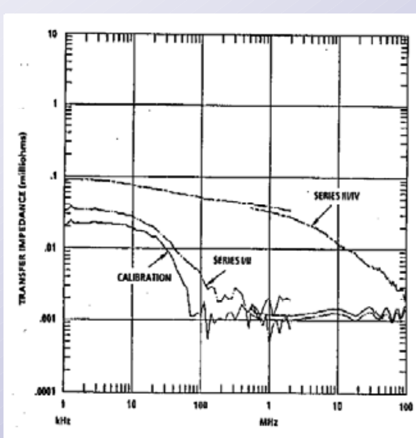
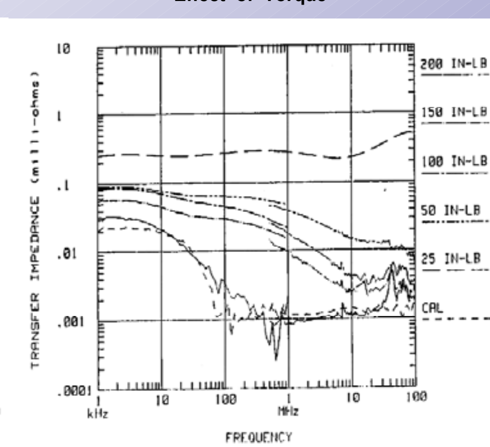
Transfer Impedance of Samples Using the MIL-C-38999 Connector/Backshell Interface

Initial Measurements



Effect of Torque



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Surface Transfer Impedance vs. Shielding Effectiveness

- Conceptually, Surface Transfer Impedance can be used until the Circumference becomes Electrically Large
- Practically, Surface Transfer Impedance becomes Difficult to Measure above a GHz
- Shielding Effectiveness is another kind of Transfer Function
  - Originally Based on Insertion Loss Concept
  - Often Ratio of a Parameter at Two Places
  - Not an Intrinsic Property
  - Depends on Interior and Exterior Impedances
  - No Standard Shield
- When Sample is Electrically Large, Stirred Mode Shielding Effectiveness may be Appropriate

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Stirred Mode Shielding Effectiveness

- Definition:
  - Shielding Effectiveness = Exterior Power Density/Power Flowing Out of Cable into Load
- Apertures are Principle Coupling Mechanism
- Shielding Effectiveness depends not only on Apertures, but also on Load and Characteristic Impedances.
- Theory is available for converting Transfer Impedance to Stirred Mode SE and vice versa

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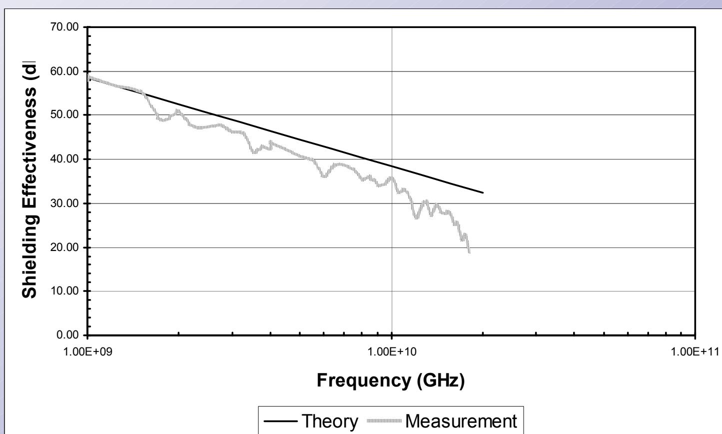
Stirred Mode Shielding Effectiveness of Shield Artifact

Type N Barrel with two 6.35 mm Holes



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Other Transfer Functions

- Normally, Surface Transfer Impedance assumes that the Current Flow and the resulting Electric Field are both Longitudinal.
- Broyde defines and demonstrates Transfer Impedances where Current Flow and Electric Field are Transverse and in some cases Orthogonal.

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Surface Transfer Admittance vs. Charge Transfer Elastance

- **Surface Transfer Impedance defines the Longitudinal Electric Field on one side of a Cable Shield resulting from a Surface Magnetic Field on the other side.**
- **If the Cable is in a Region of High Electric Field, its Effect must be evaluated:**
  - Surface Electric Field is Normal to Surface.
  - Surface Transfer Impedance does not describe the situation.
  - Surface Transfer Admittance, the compliment of Surface Transfer Impedance, is not appropriate because it is not an Intrinsic Characteristic of the Shield
- **Surface Charge Transfer Elastance, or Through Elastance, is the appropriate Characteristic**

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Surface Charge Transfer Elastance

- **Definition: Surface Charge Transfer Elastance or S_s Parameter, is the ratio of the Transfer Capacitance to the Internal and External Capacitances.**
  - An Electrical Elastance is the inverse of a Capacitance.
  - Internal and External Capacitances are normalized out.
  - Should be Frequency Independent
  - No resistive component, only capacitive
  - Measured at Low Frequencies, before Capacitively Coupled Currents generate Voltages/Currents via Transfer Impedance Coupling

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Summary

1. **Surface Transfer Impedance is the Intrinsic Electromagnetic Property for Characterizing Shields**
2. **Shielding Effectiveness is not an Intrinsic Property of a Shield, but is useful at frequencies where the Sample is Electrically Large**
3. **Charge Transfer Elastance may be useful is Regions of high Electric Field**

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Selected References

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