Use and abuse of screened cables

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Outline

• How does a screened cable work?
  – electric fields, magnetic fields, low versus high frequency

• Types of screen

• Transfer impedance
  – definition, examples, correlation with shielding effectiveness

• Termination:
  – full screening, pigtail, no connection at one end
The electric field screen (LF)

- Need only be connected at one end: screen coverage must be good, e.g. wrapped foil

Emissions: common-mode voltage on inner couples to screen, not to outside

Immunity: external E-field couples to screen, not to inner circuit

- No current flows in screen, if only one end connected

The magnetic field screen (LF)

- Must be connected at both ends: screen conductivity and coaxiality must be good

Emissions: common-mode currents cancel the external H-field

Immunity: mutual inductance between inner and screen reduces amplitude of inner currents above screen cut-off frequency

- Current flows in screen, both ends connected
Radiated field screen (RF)

- RF coupling involves both electric and magnetic fields, ratio determined by the wave impedance.
- Both good conductivity and good coverage are necessary, current must be allowed to flow at both ends.

Currents in cross-section: LF vs HF

- solid screen allows perfect separation.
- Braided screen compromises effect through weave and "porpoising".
Types of screen

• The selection of cable type always forms part of the total EMC design, i.e. the design of the circuits, the choice of reference system, the screening, etc.

Types of screen: foil and drain wire

• Not much good for anything except LF capacitive screen
• Cheap, light and flexible
Types of screen: single braid

• Standard, general purpose; e.g. RG58 coax, multi-conductor instrumentation
• Reasonably cheap, light and flexible, not especially good screening

Types of screen: double braid

• Noticeably better performance at HF than single braid; braids may be in contact or separated
• Expensive, can be heavy and stiff
Types of screen: foil & braid

• Good all-round performance, reasonable compromise between performance, weight, flexibility and cost

Types of screen: solid tube (semi-rigid)

• Excellent for RF, performance just gets better and better as frequency increases
• Can't be repeatedly flexed, good for permanent installation
Types of screen: superscreen

- Absolutely superb screening across the whole spectrum
- Very expensive, heavy, little flexibility

Transfer impedance: definition

- Induced screen current $I_S$...
  - ...creates internal voltage $V$

Transfer impedance $Z_T = \frac{(dV/dx)}{I_S} \ \Omega/m$

$$Z_T = R_S + j\omega(L_S - M) = R_S + j\omega L_S \ (1 - k)$$
Transfer impedance: examples

Transfer impedance vs. shielding effectiveness

• If shielding effectiveness is defined as:
  \[ \text{SE (dB)} = 10 \log_{10}\left(\frac{P_{\text{feed}}}{P_{\text{rad,max}}}\right) \]
  where \( P_{\text{feed}} \) = feed power into cable, \( P_{\text{rad,max}} \) = power radiated from outside of cable

• then you need to know the detail of the outer environment (dielectric and characteristic impedance) to know \( P_{\text{rad,max}} \) — not generally known

• \( Z_T \) is a function of the cable only, and so is useful for comparing different constructions, but doesn't directly relate to the SE of the cable

• A practical, simple but inexact expression for the conversion is
  \[ \text{SE (dB)} = 36 - 20\log_{10}(Z_T) - 20\log_{10}(L) \]
  where \( Z_T \) is in ohms per metre and \( L \) is cable length in metres; 36dB is a fudge factor for typical environments
Termination: best practice

- To avoid compromising the cable assembly's transfer impedance, screen continuity must be maintained around the whole of the inner conductors right through the mating shells.

Termination: the pigtail

- Pigtail screen connection taken through connector to ground point.
- Equivalent circuit diagram:
  - $V_{pigg} = L \frac{dlI}{dt}$
  - $I_s$ is the cable screen current.

Graph: Transfer impedance of pigtail connections

- dB re 1 ohm vs MHz for:
  - 1 pigtail, 50mm
  - 1 pigtail, 15mm
  - 2 pigtails, 15mm
Termination: one end open

- If one end of the screen is left open then there is no RF screening effect: only LF capacitive screening is provided.

Suggested reading

- Anatoly Tsaliovich, Cable Shielding for Electromagnetic Compatibility, Van Nostrand Reinhold 1995
- Pat Fowler, Superscreened cables, The Radio and Electronic Engineer Vol 49 No 1 pp 38-44 Jan 1979
- E.F. Vance, Coupling to Shielded Cables, Krieger, 1978
- IEC TS 62153-4-1:2014, Metallic communication cable test methods - Part 4-1: Electromagnetic compatibility (EMC) - Introduction to electromagnetic screening measurements
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THE END

Thanks for your attention!

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