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Audio-frequency shield current induced noise is negligible

Helping you solve your EMC problems

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Audio-frequency shield current induced noise is negligible

(as long as it does not flow in the 0V system)

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Audio benefits from EMC installation techniques

- **To meet the EMC directive, a number of large pro-audio systems have followed IEC 61000-5-2**
  - **with cable shields connected to chassis at both ends**
    - **allowing ‘ground loop’ currents to flow in the shields**
- **These systems have been excellent for EMC**
  - **but have also been found to have improved audio performance over precious systems (S/N, bandwidth)**
- **This short presentation helps to explain why the audio performance is so good**

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The origin of common mode (CM) noise in a system

- **Systems have a number of items of equipment located in different places**
  - **so experiencing different ground (earth) potentials from each other**
  - **and interconnected by balanced shielded cables**
- **The balanced interconnect is intended to reject the “system CM noise”**
    - **the noise voltage that exists between the grounds of two items of interconnected equipment**
  - **but nothing is perfect**

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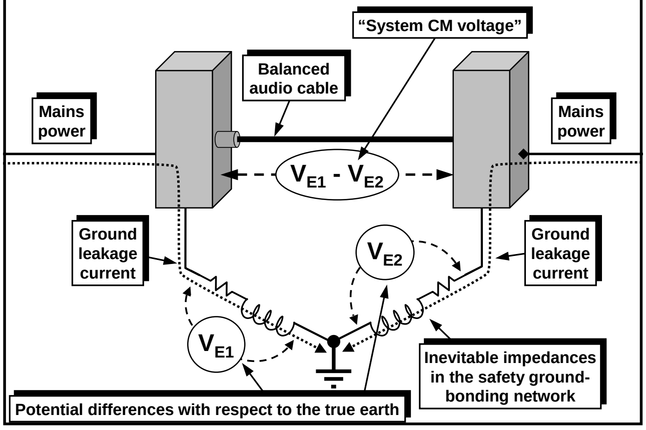
System CM noise

(example of a single-point grounded system)



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How should we connect the shield of the balanced cable?

- **We can choose to connect each cable’s shield to the equipment at one end only, or at both ends**
- **Experience shows that good EMC performance and low levels of RF demodulation**
    - **and compliance with the EMC Directive (EN 55103-1 / -2)**
  - **is most easily achieved at lowest cost by direct (DC) shield bonding at *both ends***
    - **as recommended by IEC 61000-5-2**
  - **but how does this affect the amount of system CM noise that gets into the signal?**

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The system noise voltage couples from the shield to the signal conductors by...

- **Stray capacitance, which causes a common-mode (CM) noise voltage**
  - **and the *imbalance* between the stray capacitances causes differential-mode (DM) noise voltage**
- **Stray mutual inductance**
  - **i.e. a 1:1:1 transformer (above some frequency)**
  - **causes a CM noise voltage (180˚ to capacitance noise)**
  - **and the *imbalance* between the stray mutual inductances causes a DM noise voltage**

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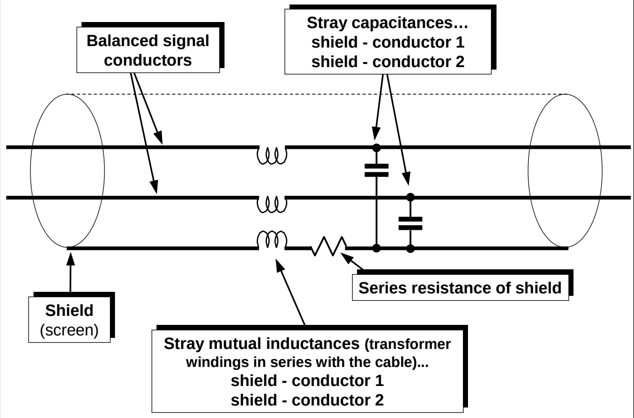
Cable noise coupling

(a first order, low-frequency approximation)



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Implications for signal/noise (S/N) ratios

- **The CM voltage on both of the signal conductors**
  - **is processed by the amplifier's CMRR and its gain, resulting in a DM noise**
- **The imbalance (DM) voltage between the signal conductors**
  - **is processed by amplifier gain as if it is wanted signal**
- **Here are some examples for a cable type "F"**
  - **showing the relative effects of each of the above noise contributions….**

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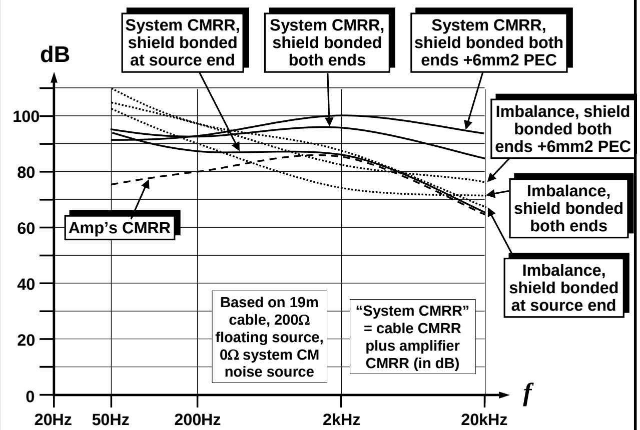
Good quality mixing desk amplifier, with 19 metres of 'cable F' (braid, no drain wire)



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19m of 'cable F' with a *good* mixing desk amplifier

- **Single-ended shield bonding at source**
  - **gives better system CM noise than would be expected from the amp's CMRR spec, below 2kHz**
- **Bonding shield at both ends makes system CM noise worse by up to 15dB above 300Hz**
  - **achieving >70dB overall, over the frequency range**
- **Both-ends-bonded plus 6mm^2 PEC makes system CM noise worse by up to 4dB above 1kHz**
  - **achieving >75dB overall, over the frequency range**

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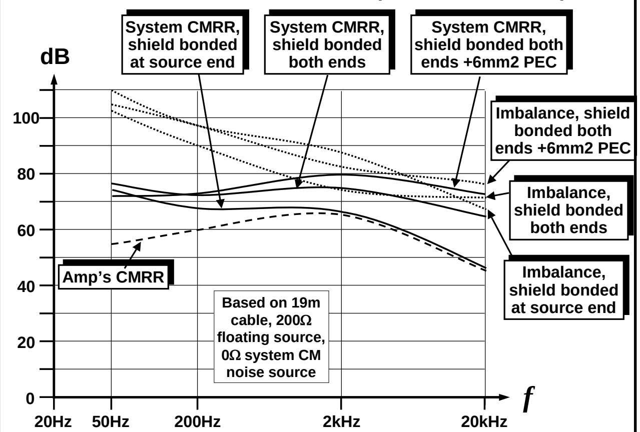
Average mixing desk input amplifier, with 19m of 'cable F' (braid, no drain wire)



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19m of ‘cable F’ with an *average* mixing desk amplifier

- Single-ended shield bonding at source
  - gives better system CM noise than would be expected from the amp’s CMRR spec, below 2kHz
- Bonding shield at both ends makes system CM noise better by up to 19dB, above 50Hz
  - achieving >65dB overall, over the frequency range
- Both-ends-bonded + 6mm^2 PEC makes system CM noise better by up to 28dB above 100Hz
  - achieving >70dB overall, over the frequency range

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But the system’s voltage noise source does *not* have a 0Ω impedance

(as the previous graphs assumed)

- So bonding shields at both ends will *reduce the source noise voltage*
  - as will using using PECs
- Reducing both capacitive and inductive coupled cable noise (CM and DM)
- In a large system there can be >100 cables
  - and bonding all their shields at both ends has a *very* beneficial effect indeed on system CM noise rejection

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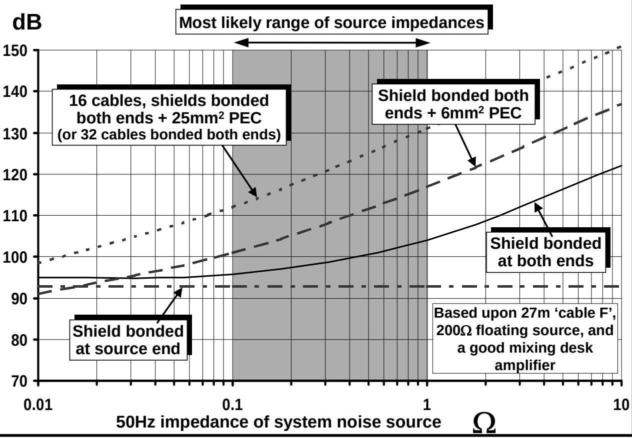
Example of the influence of the finite impedance of the system noise source (at 50Hz)



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Always connect the shield to the chassis, frame or enclosure shield

- It used to be common to connect shields to circuit 0V
  - now well-known to be very bad practice
  - because of ‘common-impedance coupling’
- If the circuit’s 0V reference is pure clean water…
  - then the shields are sewers
  - and their currents should never flow in the 0V

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Why we don’t let shield currents flow in the 0V any more

- Example: a 0.1” wide 0V trace just 1” long (in a 1oz copper printed circuit board)
  - has an impedance of 4.8mΩ at 50Hz
- Just 25mV of ‘system CM noise’ at 50Hz creates a shield current of 100mA (in 19 metres of ‘cable F’)
- If this 100mA shield noise current was allowed to flow in the 1” long 0V trace…
  - it would create 480µV of ‘common impedance noise’ in the circuit’s 0V reference system

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For a singer or violinist using a typical 200Ω dynamic microphone…

- 480µV of noise in the 0V could result in a S/N ratio of 20dB
  - worse, where a number of signals share the noisy 0V
- Whereas S/N due to shield-coupled noise alone
  - would be 56dB for an average mixing desk amplifier, and 76dB for a good one (single cable, 0Ω noise source)
  - both much lower than the acoustic background noise for a microphone signal
    - for 16 cable shields in parallel: >66dB and >86dB likely

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(as long as it does not flow in the 0V system)

the end

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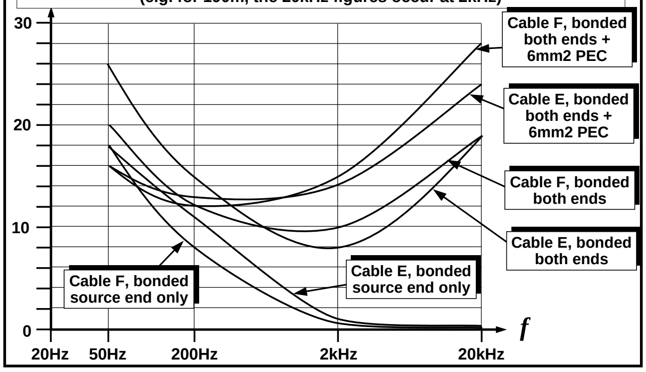
Cable CMRR

Based on 19m of cable, 200Ω floating source, 0Ω system CM noise source
Cable F: braid, no drain Cable E: spiral foil, straight drain wire
For longer cable lengths, divide frequency axis by increase in length
(e.g. for 190m, the 20kHz figures occur at 2kHz)



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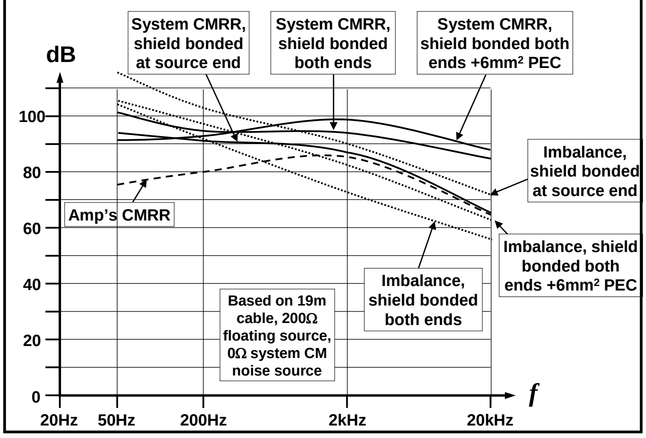
Good console input amplifier, with cable E (spiral foil, straight drain wire)



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19m of cable E with a *good* console amplifier

- **Single-ended shield bonding at source**
  - **gives better system CM noise than would be expected from the amp's CMRR spec, below 2kHz**
- **Bonding shield at both ends makes system CM noise worse by up to 15dB above 200Hz**
  - **giving >70dB overall, over the frequency range**
- **Both-ends-bonded plus 6mm² PEC makes system CM noise worse by up to 5dB above 1kHz**
  - **giving >75dB overall, over the frequency range**

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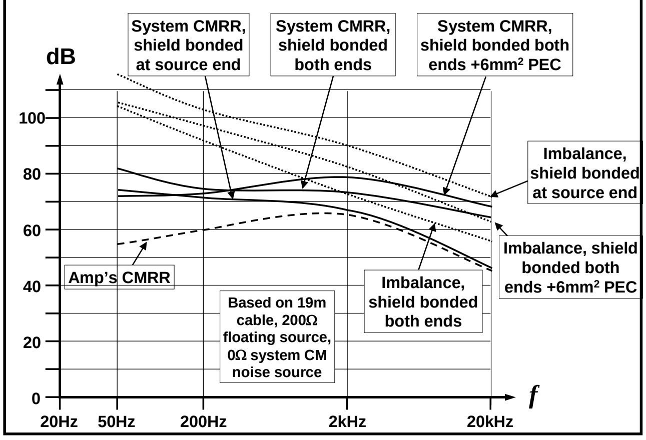
Average console input amplifier, with cable E (spiral foil, straight drain wire)



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19m of cable E with an average console amplifier

- **Single-ended shield bonding at source**
  - **gives better system CM noise than would be expected from the amp's CMRR spec, below 2kHz**
- **Bonding shield at both ends makes system CM noise better by up to 10dB, above 200Hz**
  - **giving >55dB overall, over the frequency range**
- **Both-ends-bonded + 6mm² PEC makes system CM noise better by up to 18dB above 50Hz**
  - **giving >62dB overall, over the frequency range**