



Another EMC resource  
from EMC Standards

Shield current induced noise is negligible

*Helping you solve your EMC problems*

AES Amsterdam CCC

## Audio-frequency shield current induced noise is negligible

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



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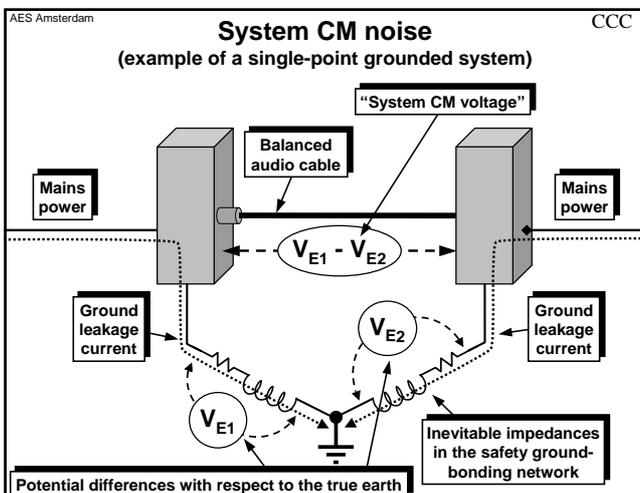
## Audio benefits from EMC installation techniques

- 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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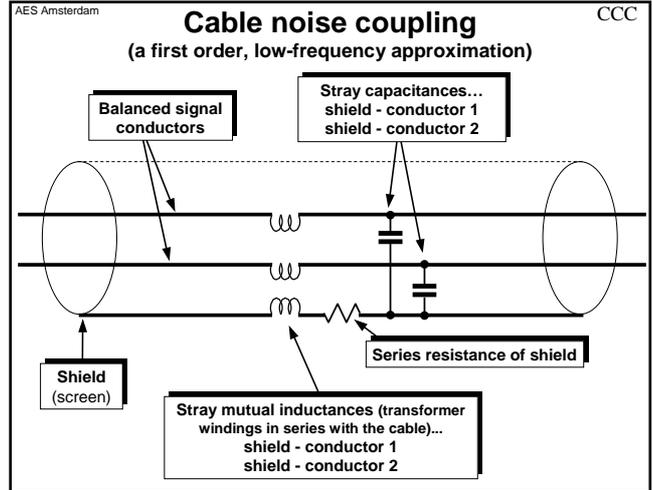
## How should we connect the shield of the balanced cable?

- 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...

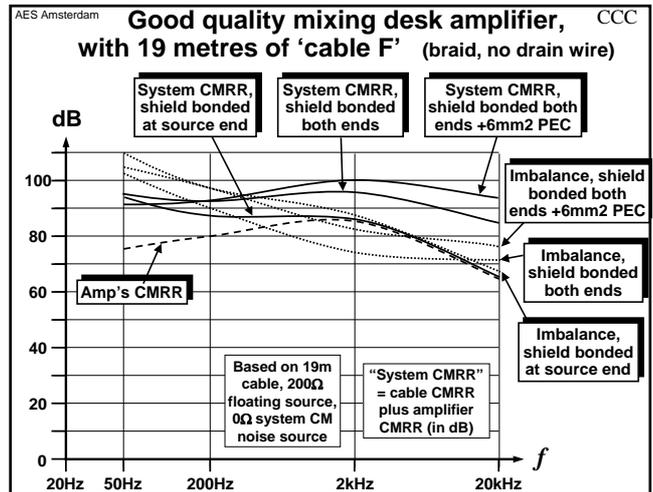
- Stray capacitance, which causes a common-mode (CM) noise voltage
  - and the *imbalance* between the stray capacitances causes differential-mode (DM) noise voltage
- Stray mutual inductance
  - ♦ i.e. a 1:1:1 transformer (above some frequency)
  - causes a CM noise voltage (180° to capacitance noise)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



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### Implications for signal/noise (S/N) ratios

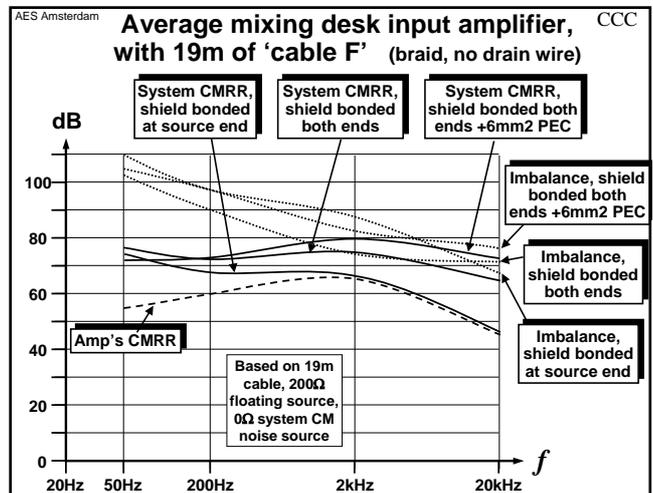
- The CM voltage on both of the signal conductors
  - is processed by the amplifier’s CMRR and its gain, resulting in a DM noise
- The imbalance (DM) voltage between the signal conductors
  - is processed by amplifier gain as if it is wanted signal
- Here are some examples for a cable type “F”
  - showing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



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### 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 6mm² PEC makes system CM noise worse by up to 4dB above 1kHz
  - achieving >75dB overall, over the frequency range



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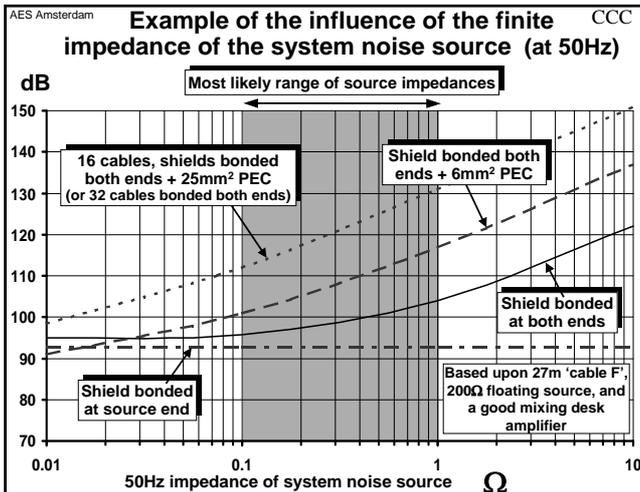
### 19m of 'cable F' with an *average* mixing desk amplifier

- **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<sup>2</sup> 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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### 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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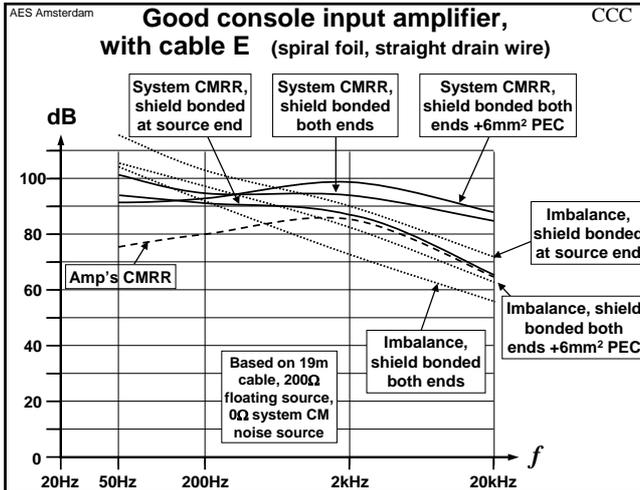
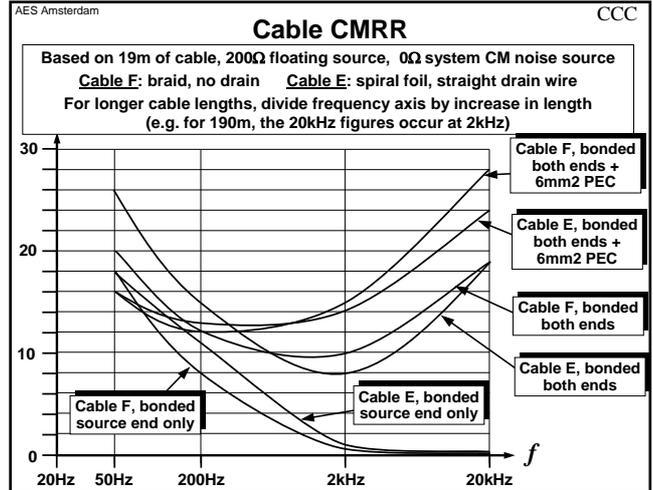
## Audio-frequency shield current induced noise is negligible

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

# the end



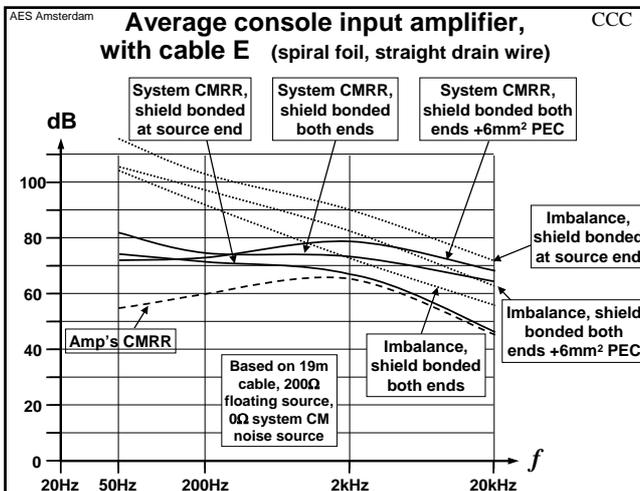
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### 19m of cable E with a good console amplifier

- 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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### 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