Interferences

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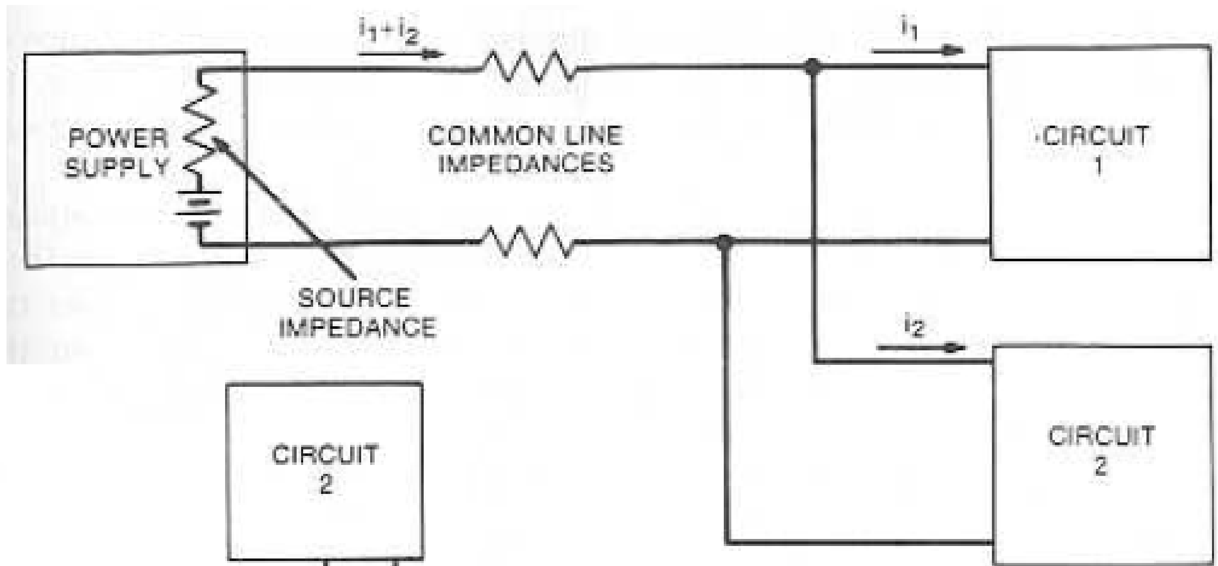
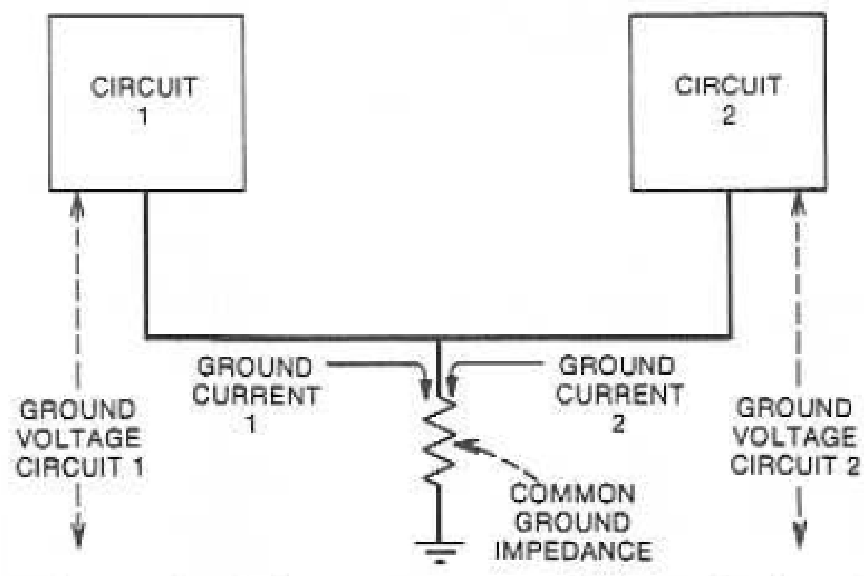
Slides are supplementary material and are NOT a replacement for textbooks and/or lecture notes

Interference and noise

- Interferences are due to other systems which are connected (either electrically or electro-magnetically) to the system under exam
- Noise is due to fundamental properties of matter (thermal agitation, charge quantization,…)
- Both can degrade the signal and must be curbed in a good design/test

Common point

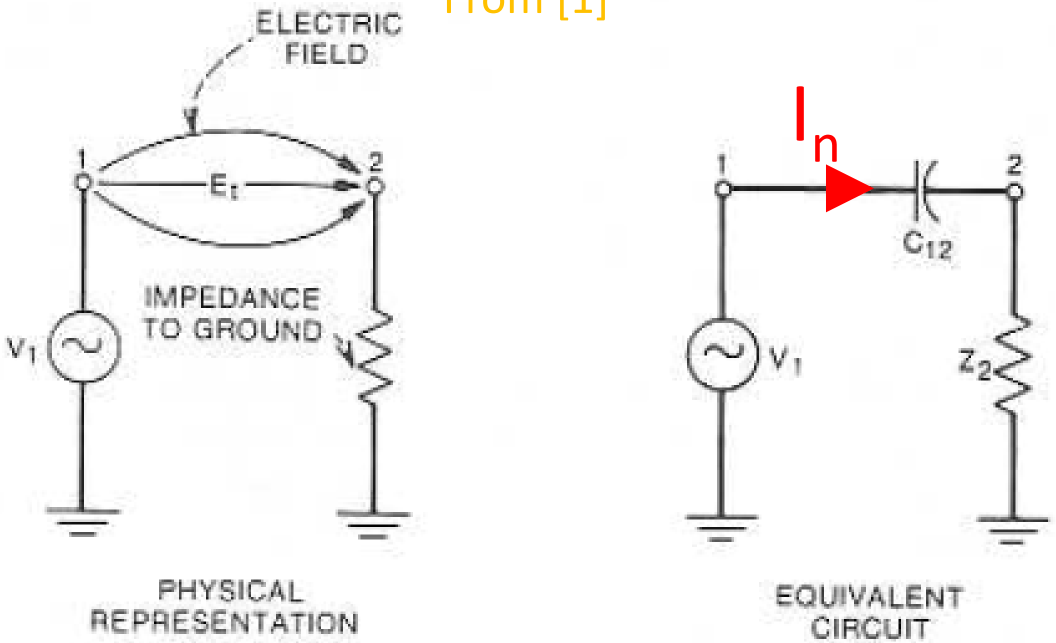




From [1]

Capacitive coupling

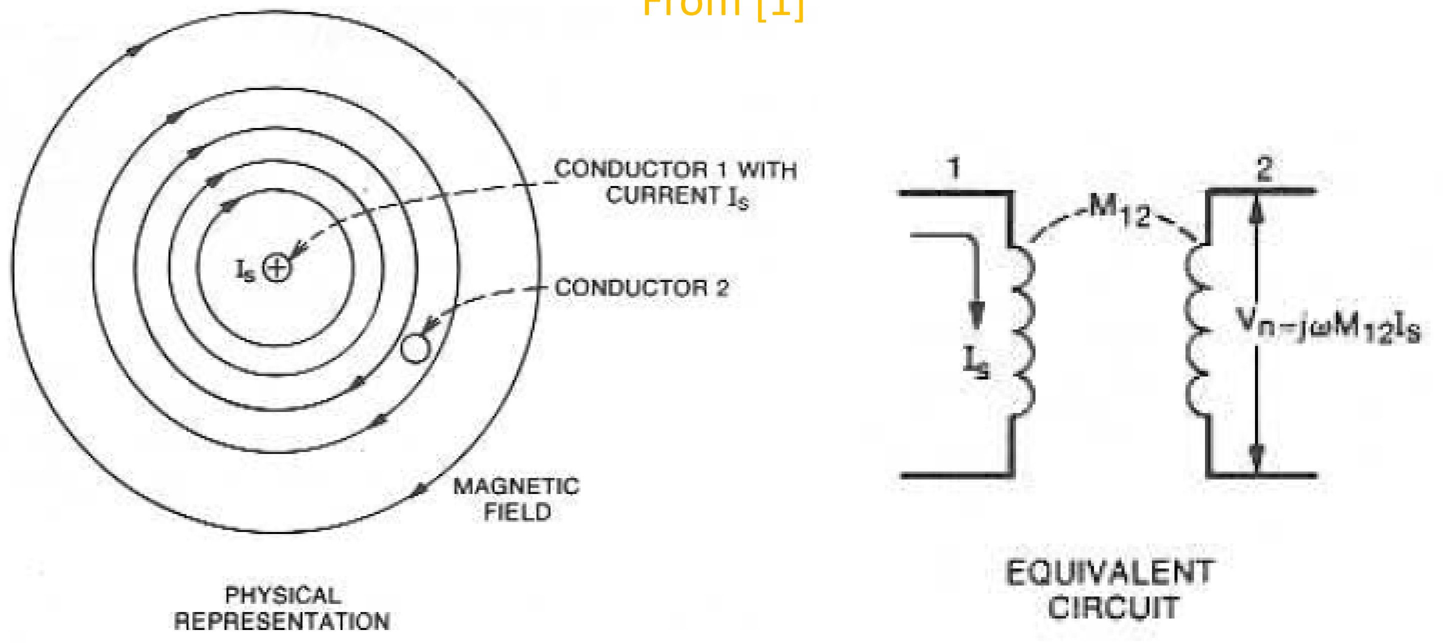
From [1]



A time-varying voltage leads to electric coupling, represented by a capacitor connecting the two circuits

Inductive coupling

From [1]



A time-varying current leads to magnetic coupling, represented by mutual inductance between the two circuits

Ground potential fluctuations

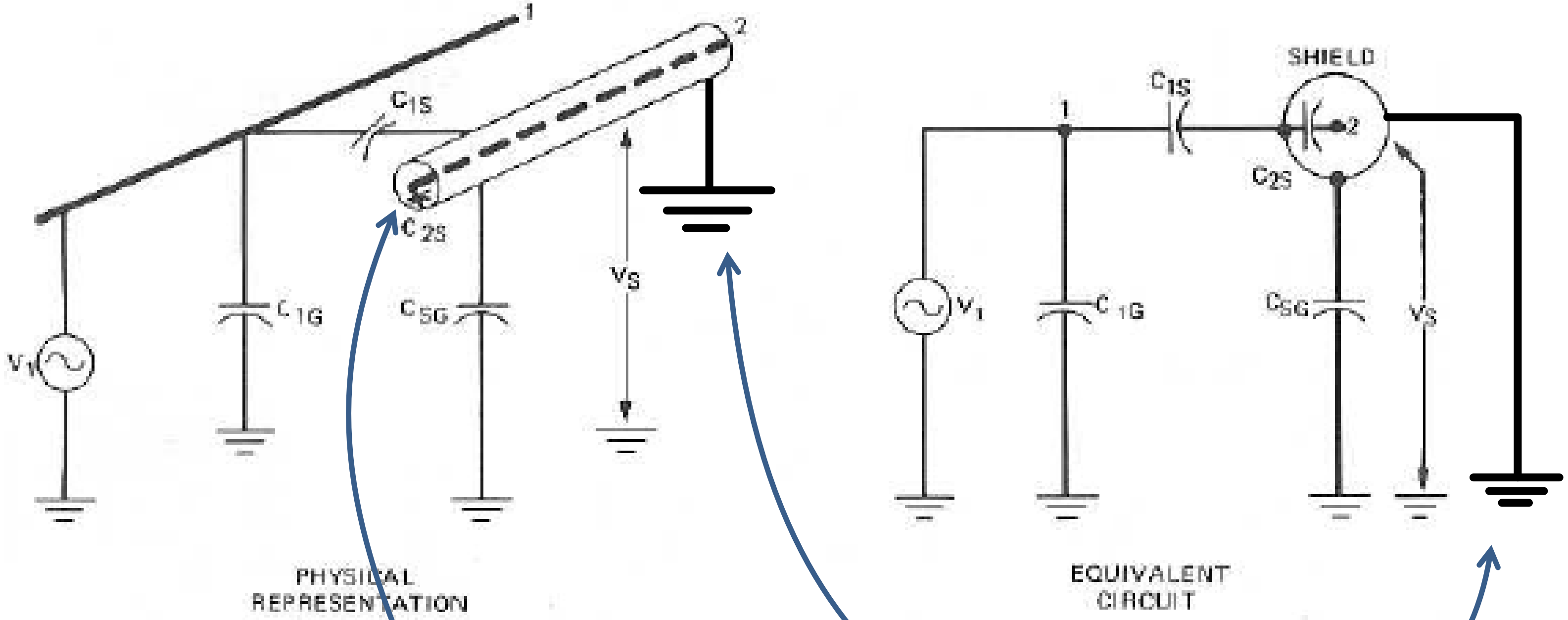
- IC is related to the circuit loop area
- If the circuit is grounded at two points, current flows beneath the surface and disturbs arise (loop area cannot be controlled)
- Earth contact resistance (typically 1-10 Ω) can also contribute to electrical interferences

General approach

- Electrical coupling
  - Use electrostatic shield (Faraday cage)
- Magnetic coupling
  - Reduce loop area, check orientation (magnetic shielding is not effective)
- Ground fluctuations
  - Use single ground point
- The requirements are often conflicting!

Cables (CC)

From [1]

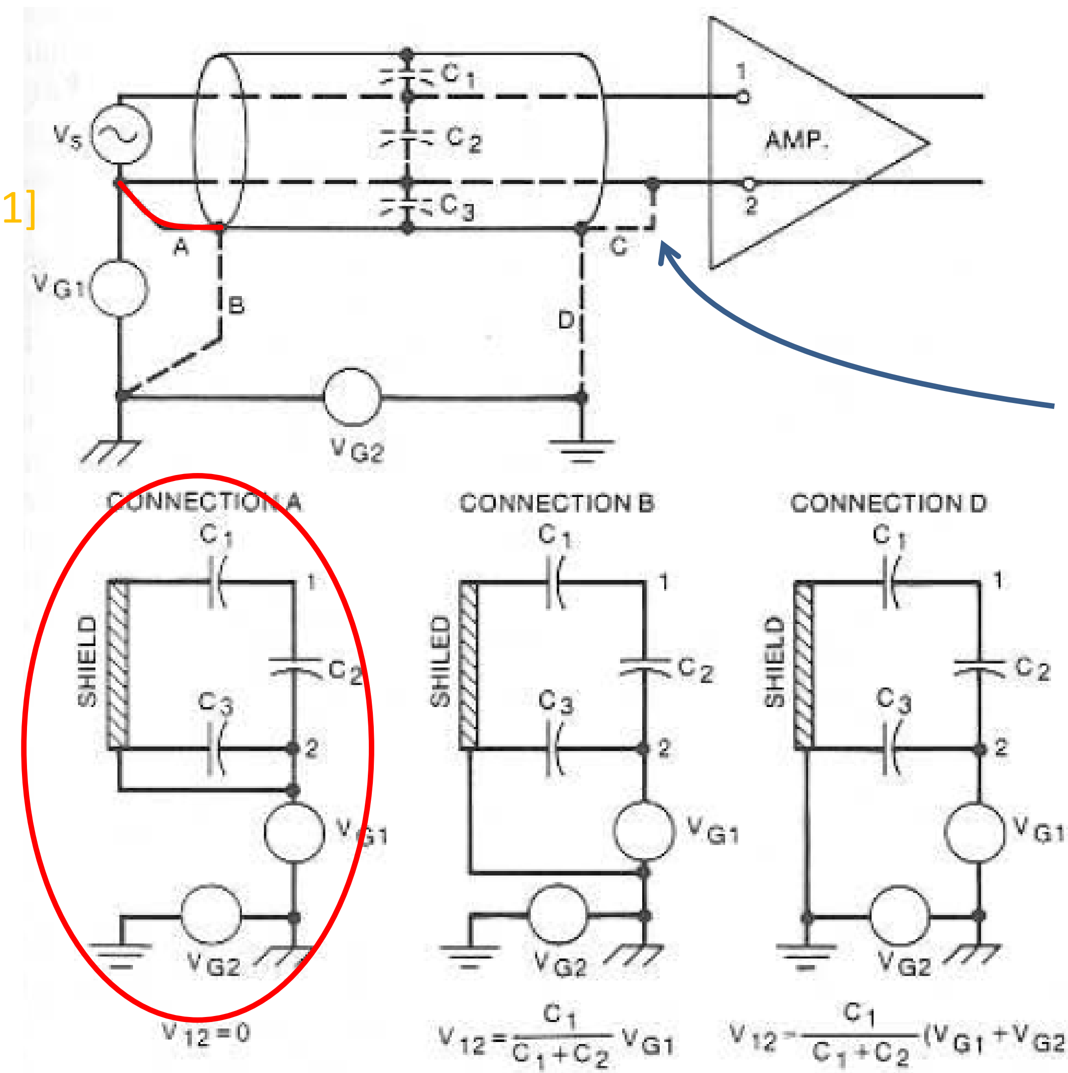


Extension of the central conductor beyond the shield must be minimized

Shield must be grounded at one point

Shield grounding – 1

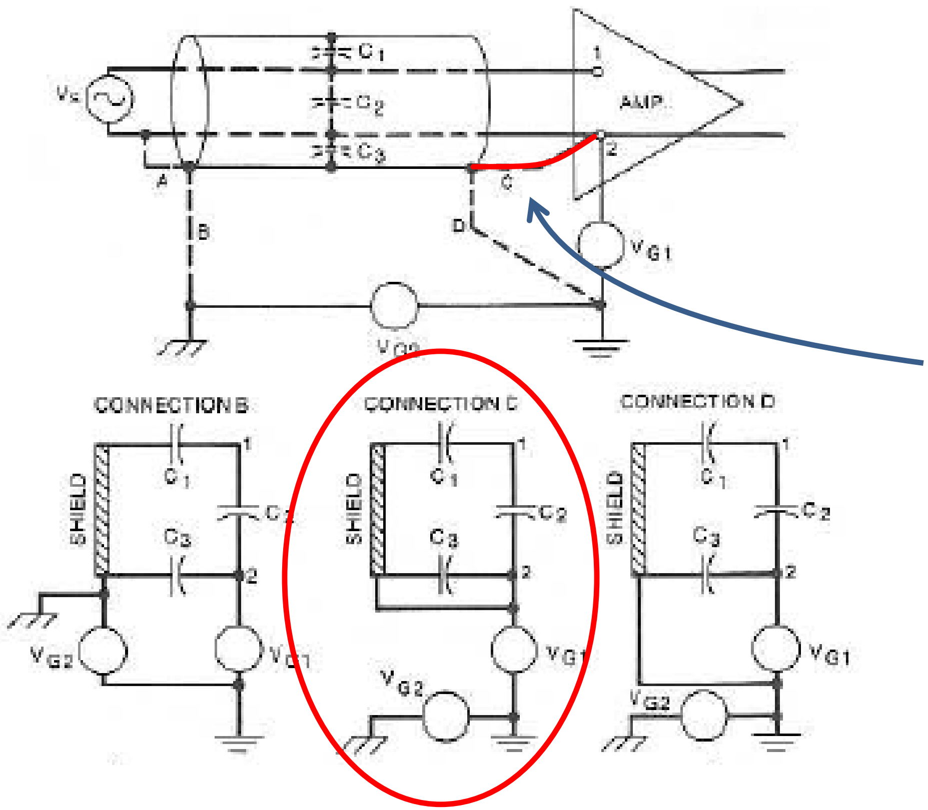
From [1]



Case C must be avoided as it allows shield noise current to flow into the signal path

Shield grounding – 2

From [1]

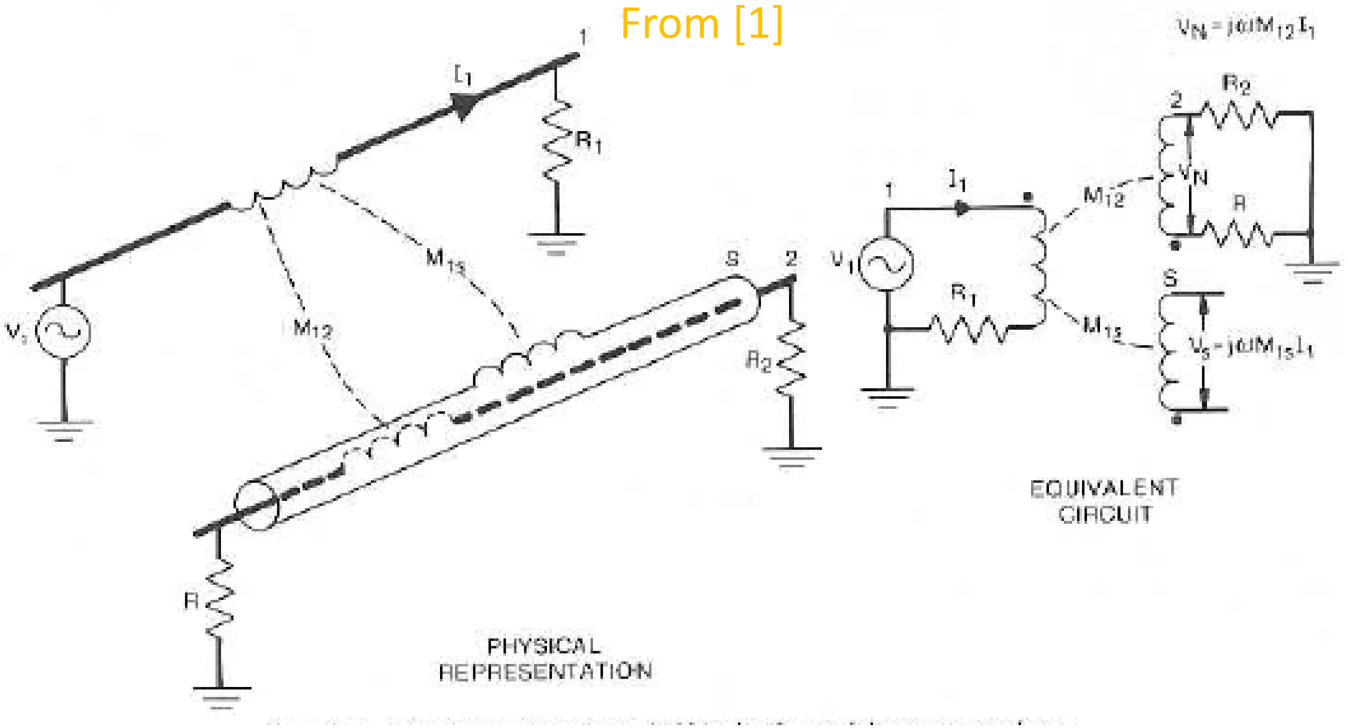


If signal reference is located at the amplifier side, C becomes the best choice

Always connect the shield to the signal reference, even if not grounded!

Cables (IC)

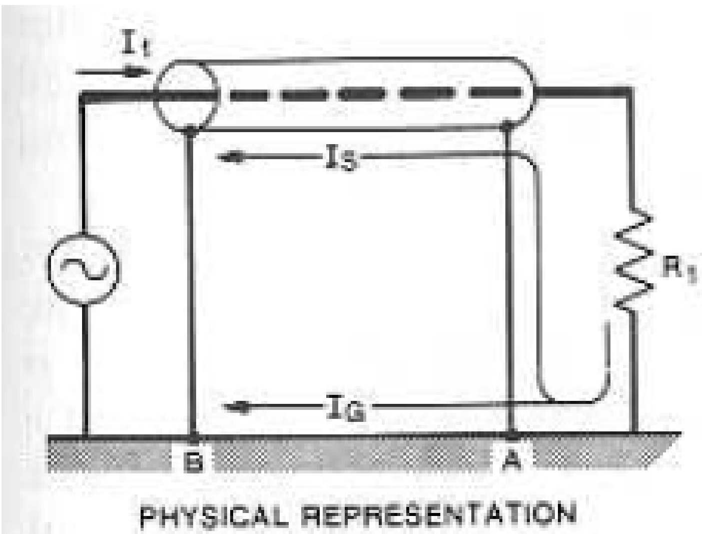
From [1]

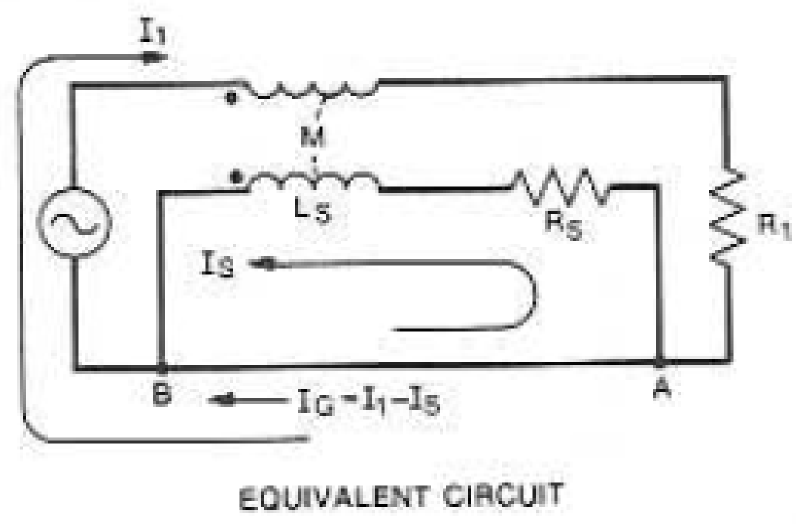


Shield does not change the geometry nor the mutual inductances (even if grounded at one point) $\Rightarrow$ no effect on the induced voltage

IC shielding

From [1]

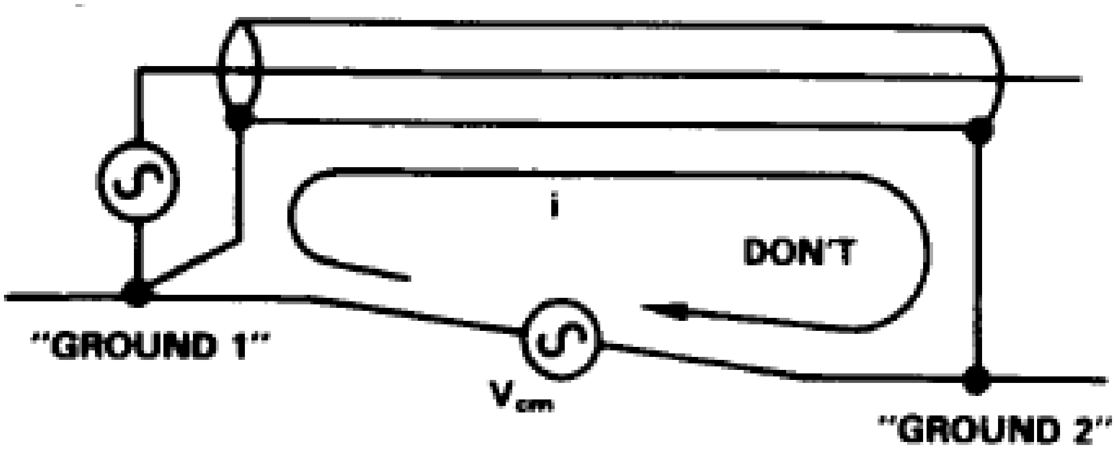




Shield must be grounded at two points

Mutual inductance forces a return current which reduces the loop area

Shield connection

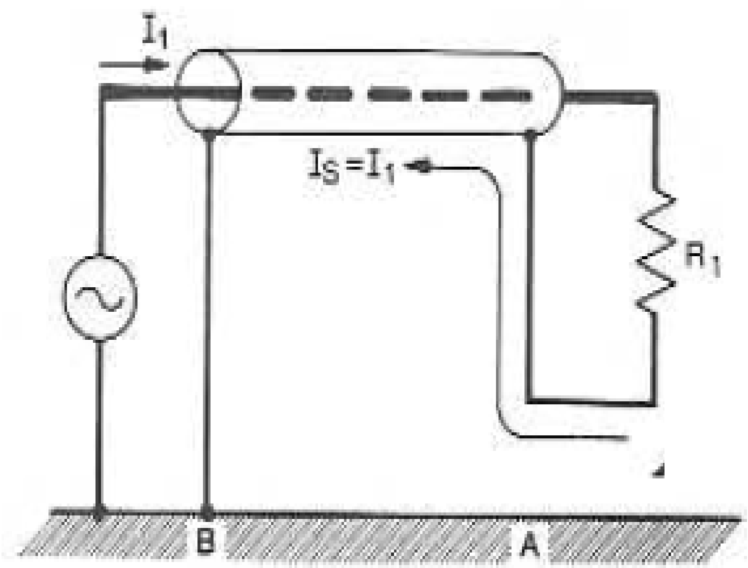


From [2]

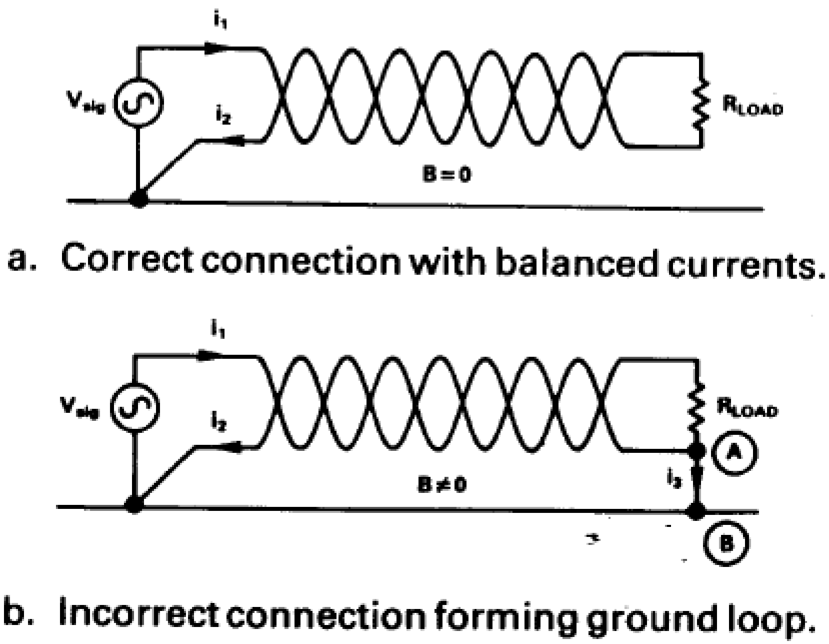
- Two-point connection is effective for magnetic shielding at $\omega > \omega_s = R_s/L_s$, but
- Ground fluctuations at low frequencies generate a return current via the shield, limiting the efficacy

Optimum solutions

From [1]



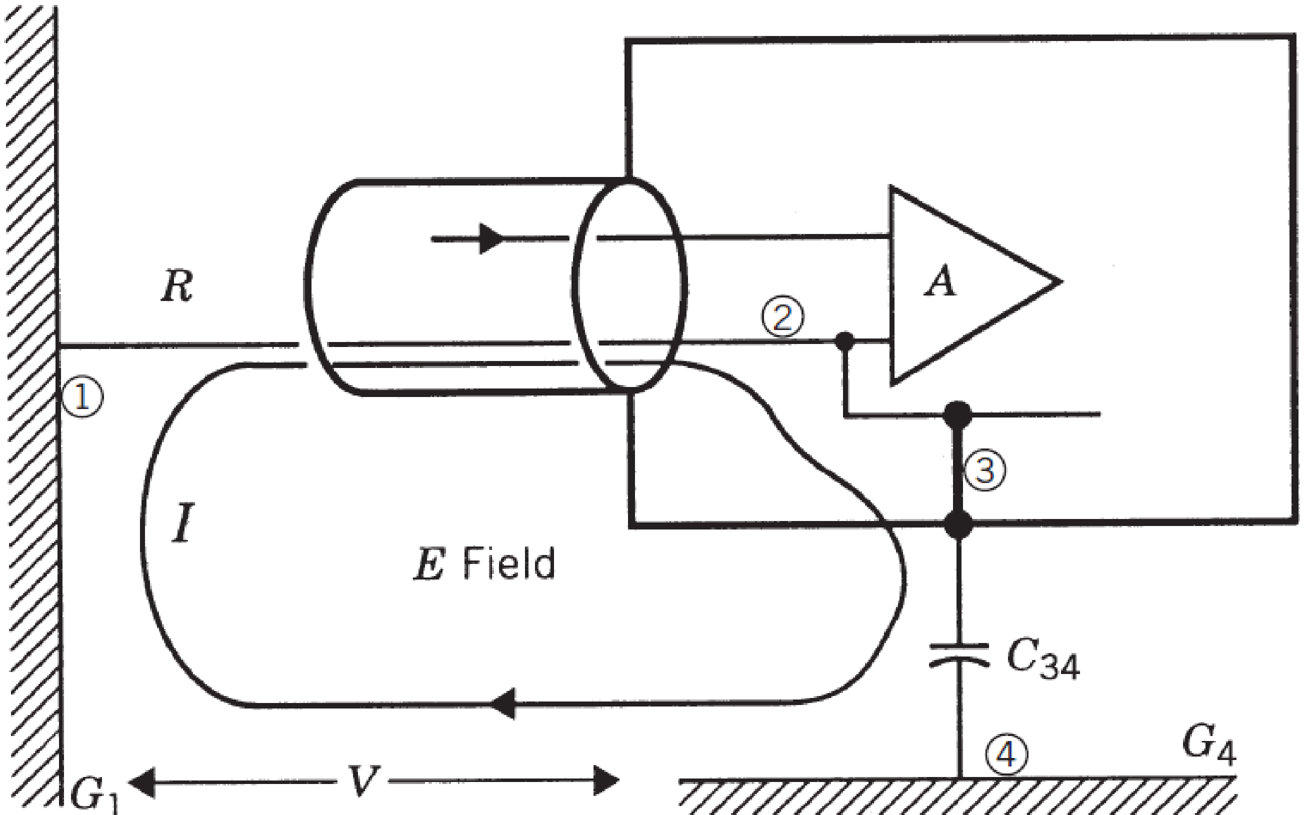
From [2]



Twisted pairs can also be useful but have lower bandwidth (≈100 kHz) than coaxial cables

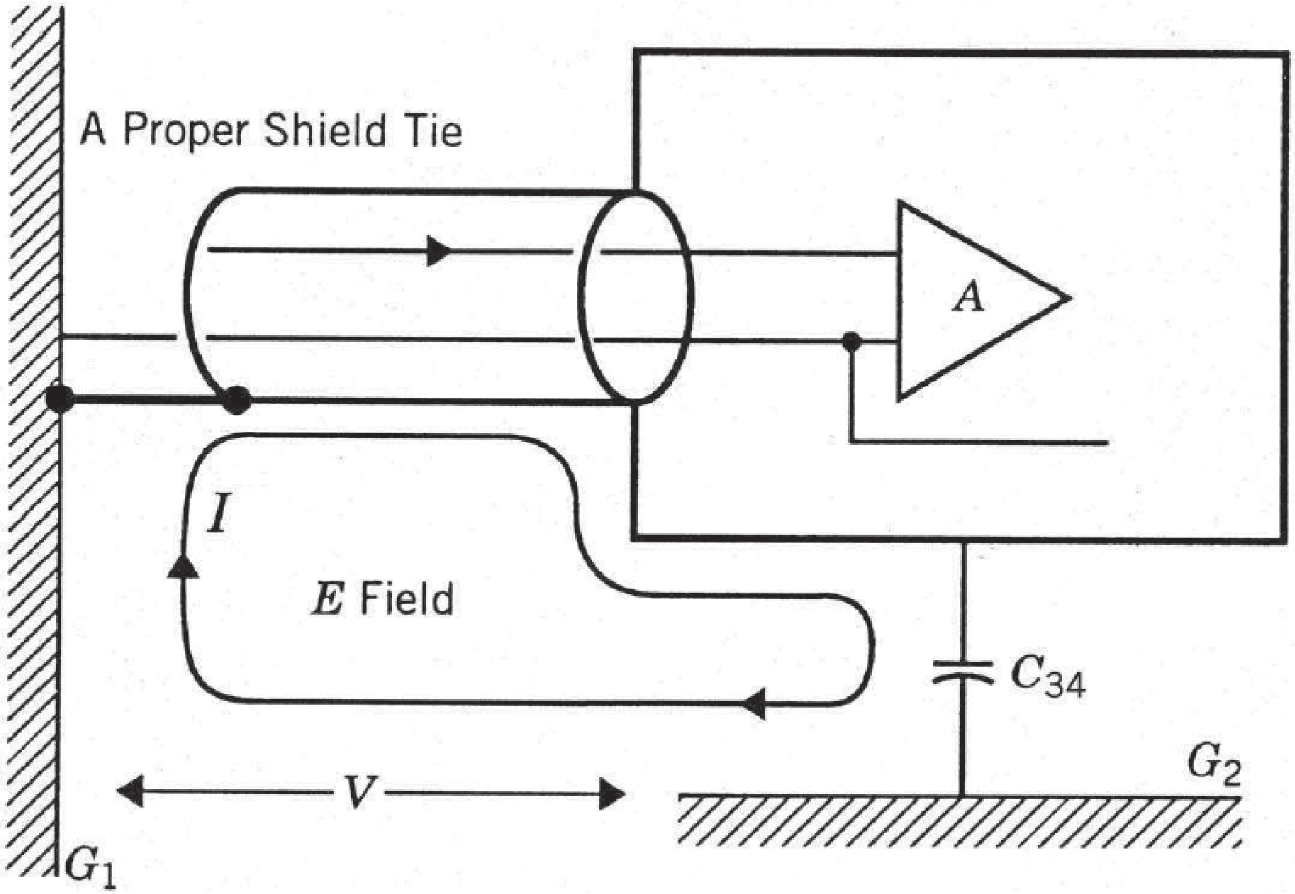
Amplifiers

From [3]



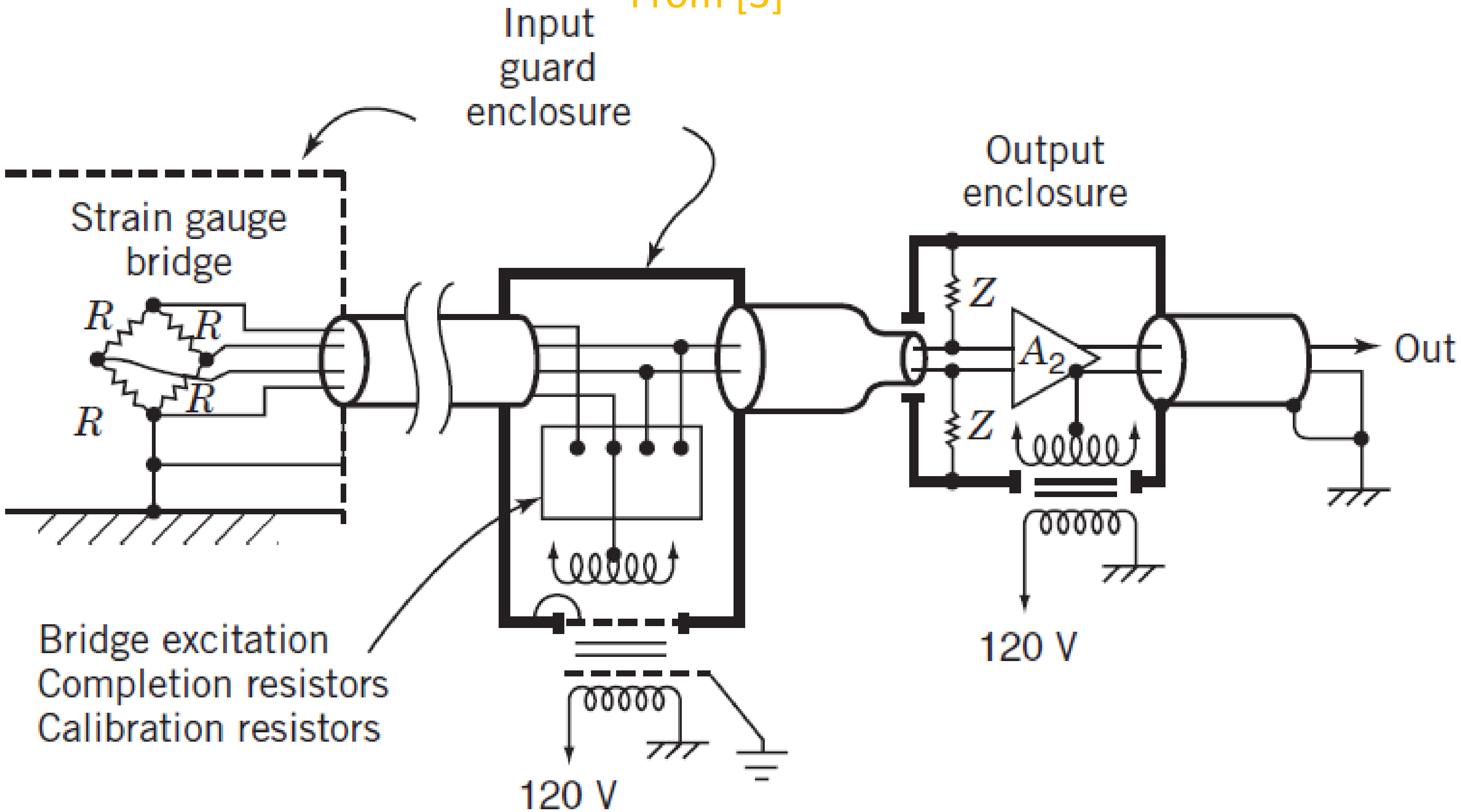
A good connection

From [3]



Wheatstone bridge scheme

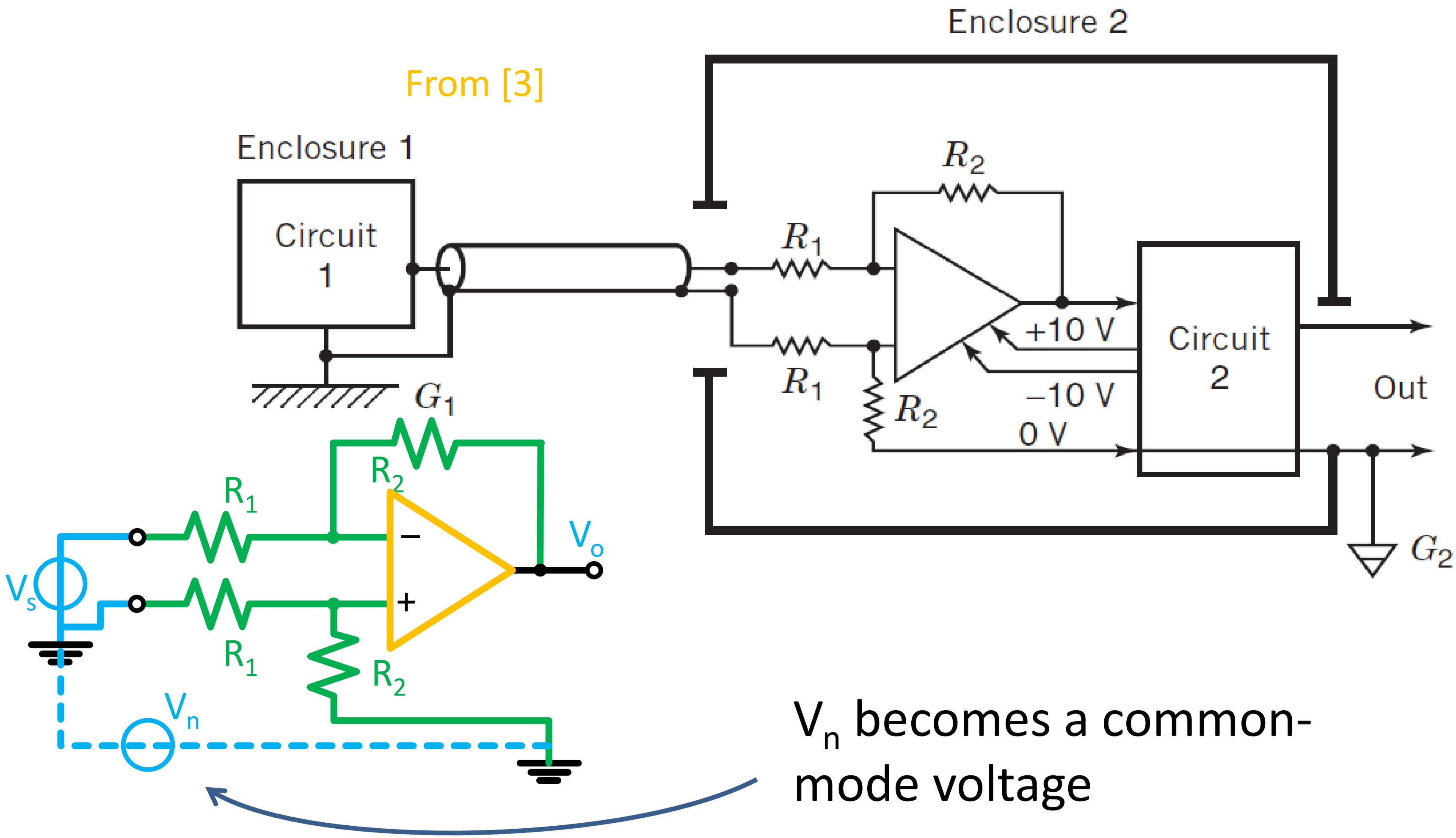
From [3]



Notes

- Ground the bridge at the structure and connect the guard shield to this ground to reduce capacitance
- If the structure is not a reference conductor, current flow can arise $\Rightarrow$ in a quiet environment the connection may not be required (guard shield should still be connected)
- Coupling capacitances to the structure are difficult to control and can degrade signal – they can only be rejected by limiting the bandwidth

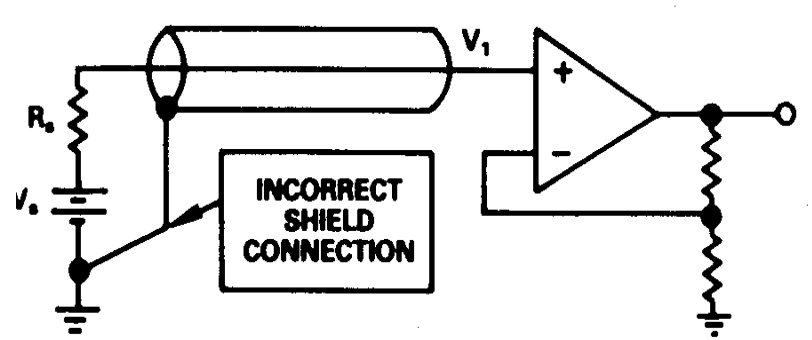
Single-ended to differential amps

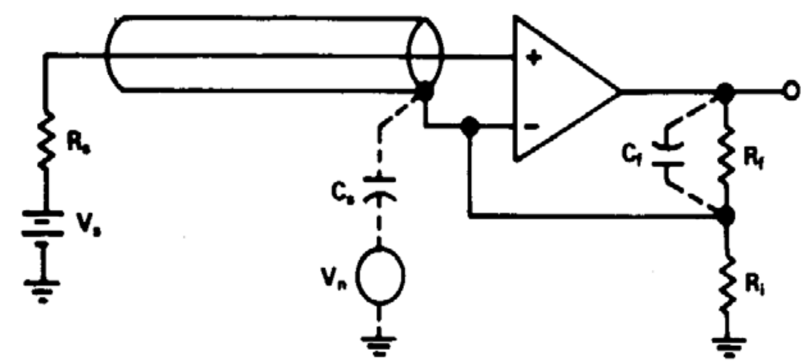


V_n becomes a common-mode voltage

Driven shield

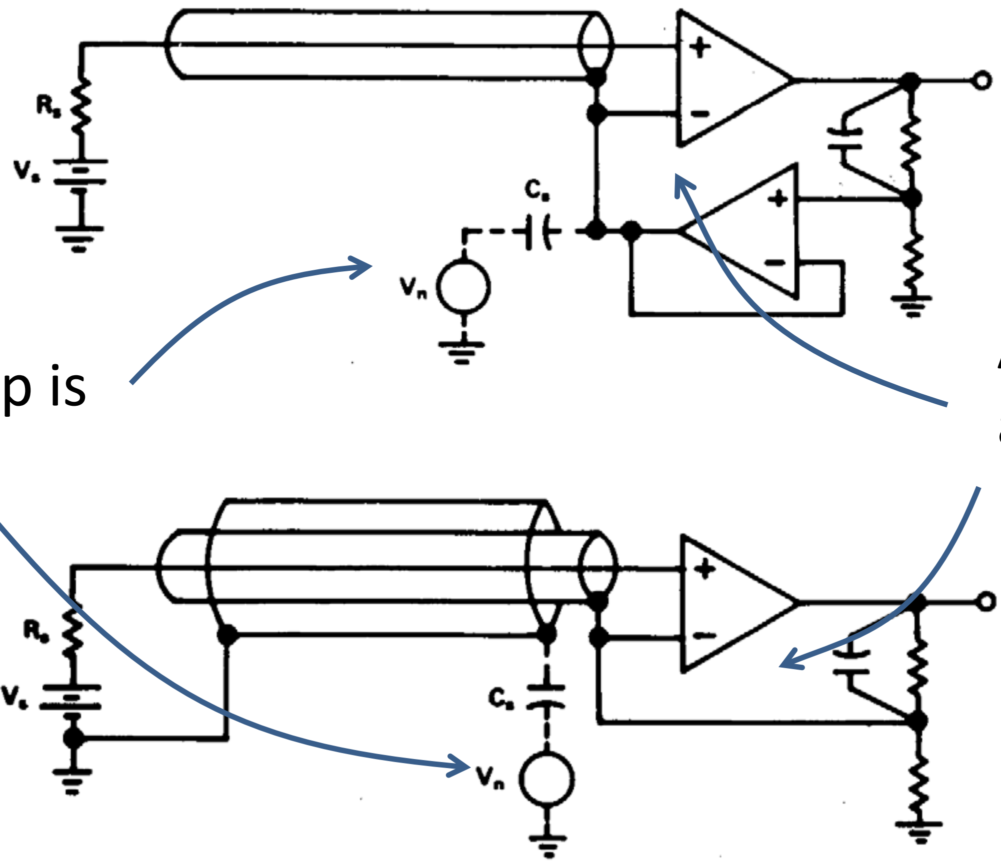
- For high-impedance (e.g., capacitive) sensors, the standard shield connection does not work
  - Shield-cable resistance degrades signal
  - Shield-cable capacitance limits bandwidth
- Shield must be kept at the signal potential





From [2]

Improved solutions



Noise pick-up is reduced

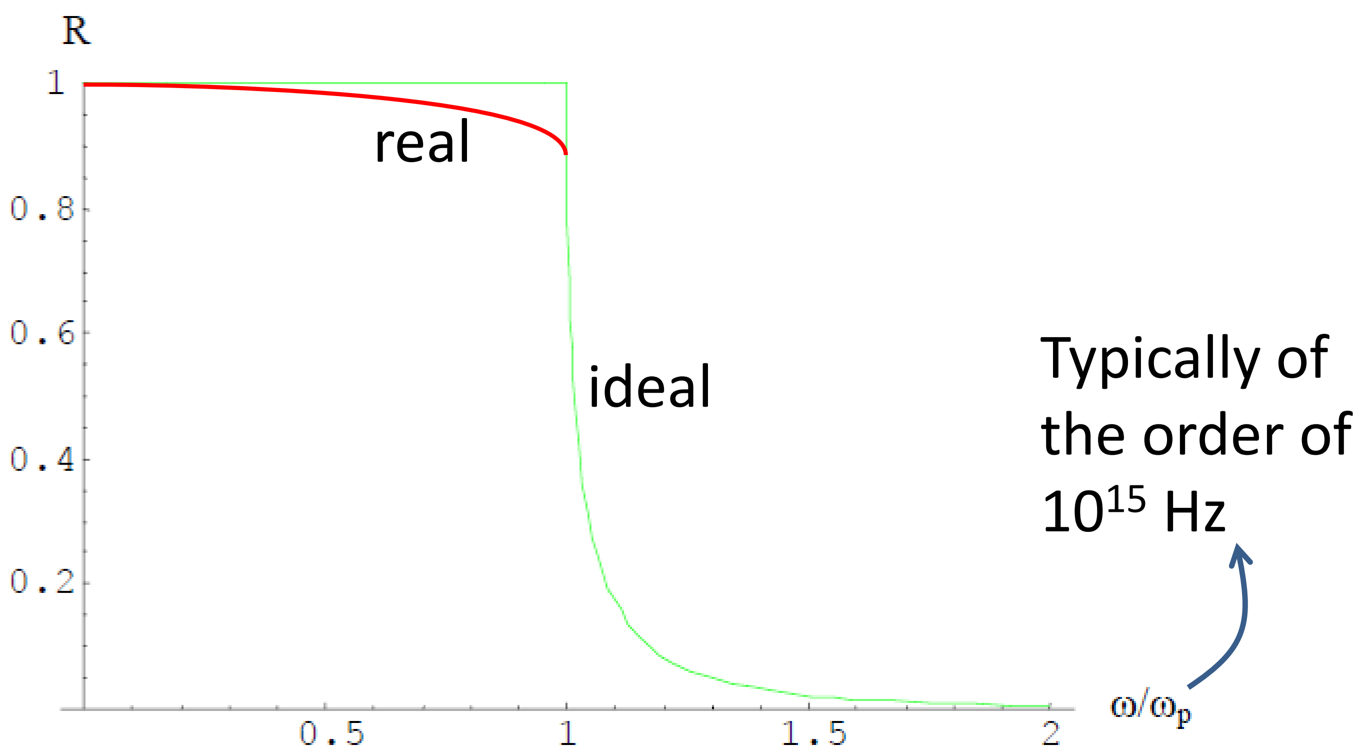
A loop is formed and stability must be checked

From [2]

Shields

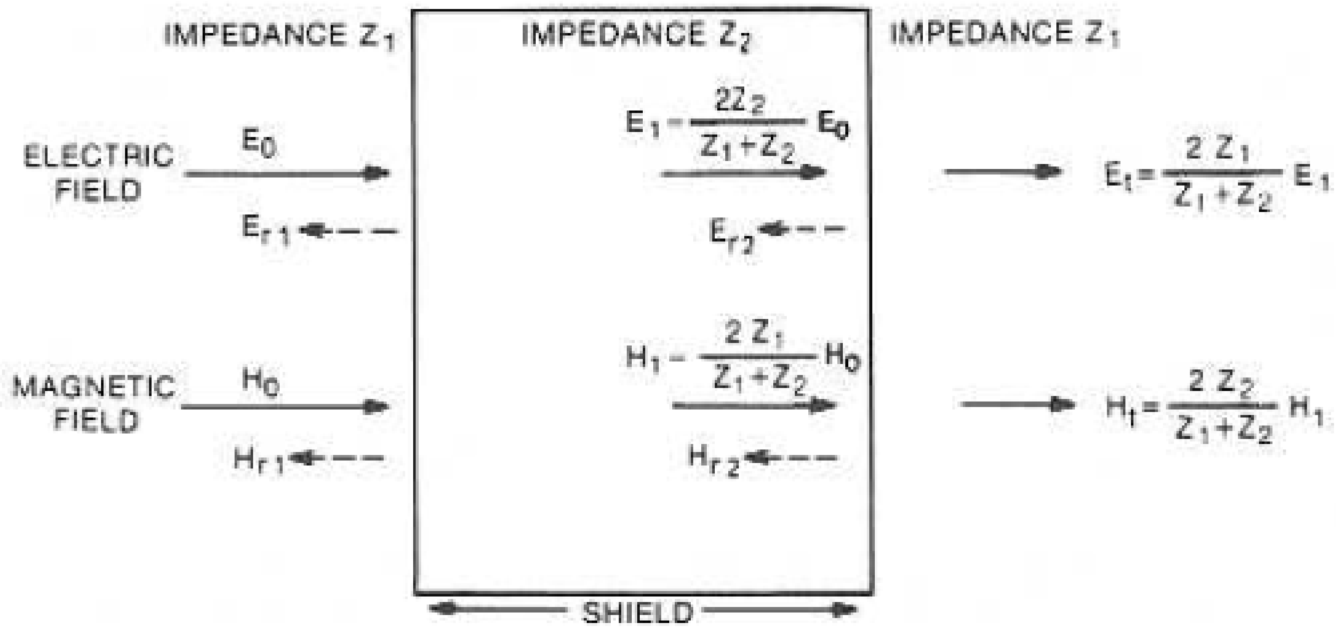
Reflection coefficient of metals

From [4]



Reflection loss

From [1]



$$R_{dB} = 20\log_{10}\frac{Z_{wave}}{Z_{screen}}$$

($Z_{wave} \gg Z_{screen}$, neglecting multiple reflections)

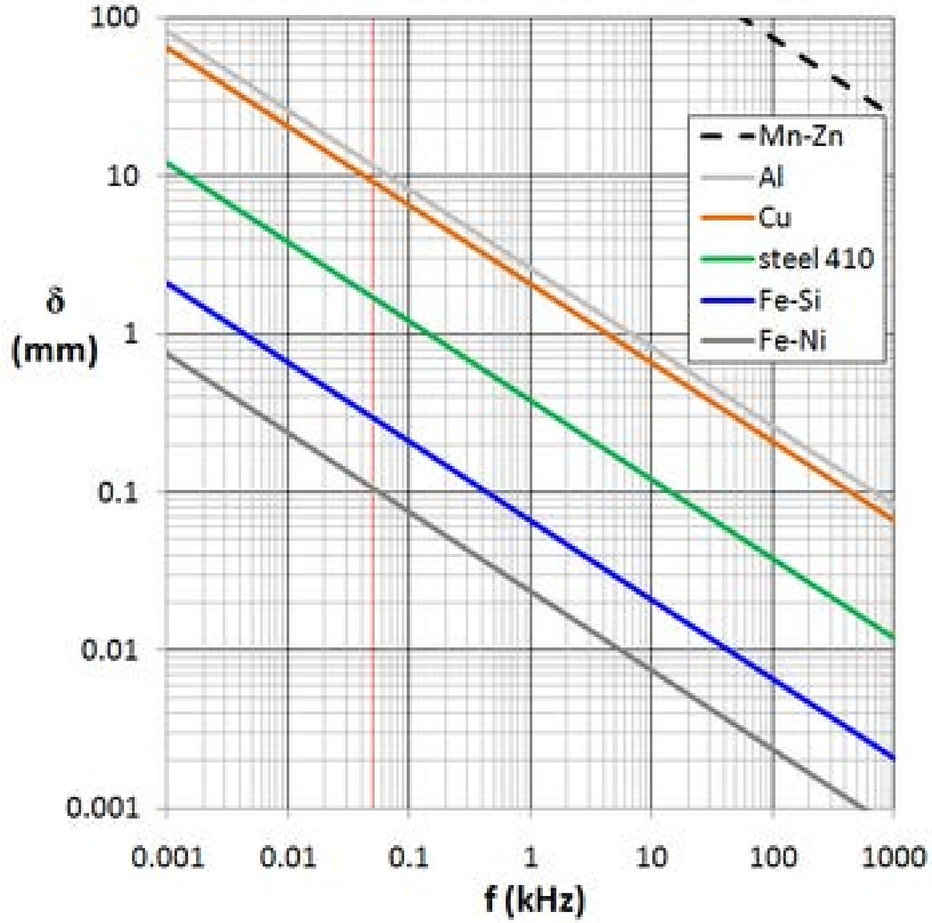
Absorption of em waves

$$I = I_0 e^{-x/\delta}$$

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} =$$

$$= \frac{1}{\sqrt{\pi\mu_0}}\sqrt{\frac{\rho}{\mu_r f}}$$

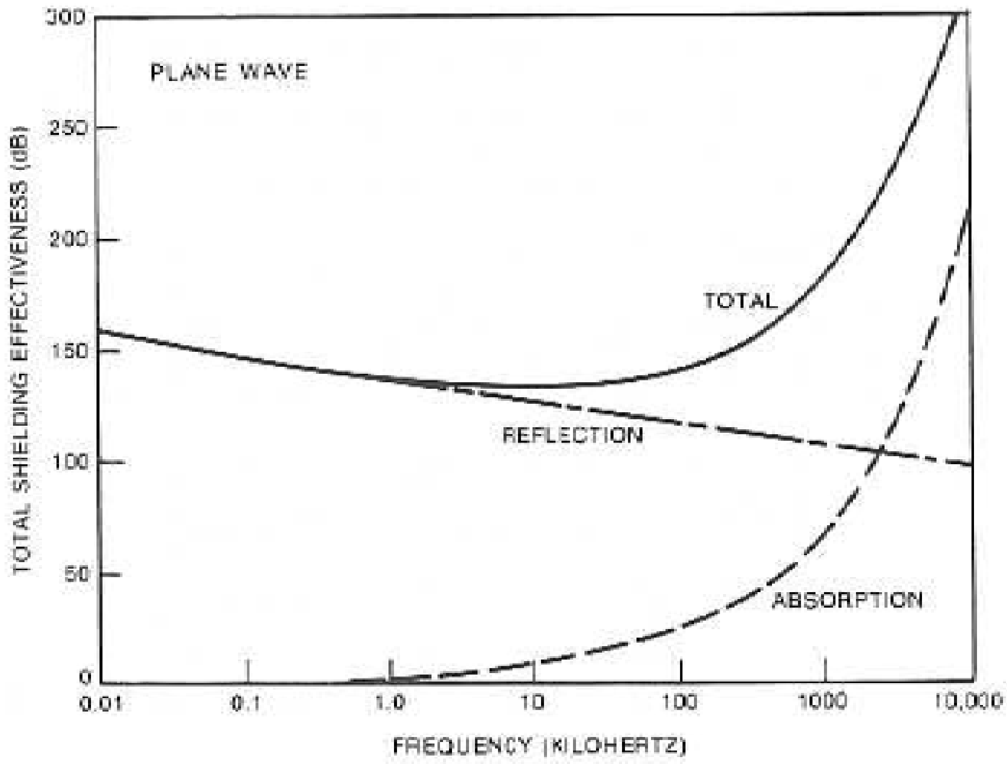
(skin depth)



From [5]

Shielding effectiveness

From [1]



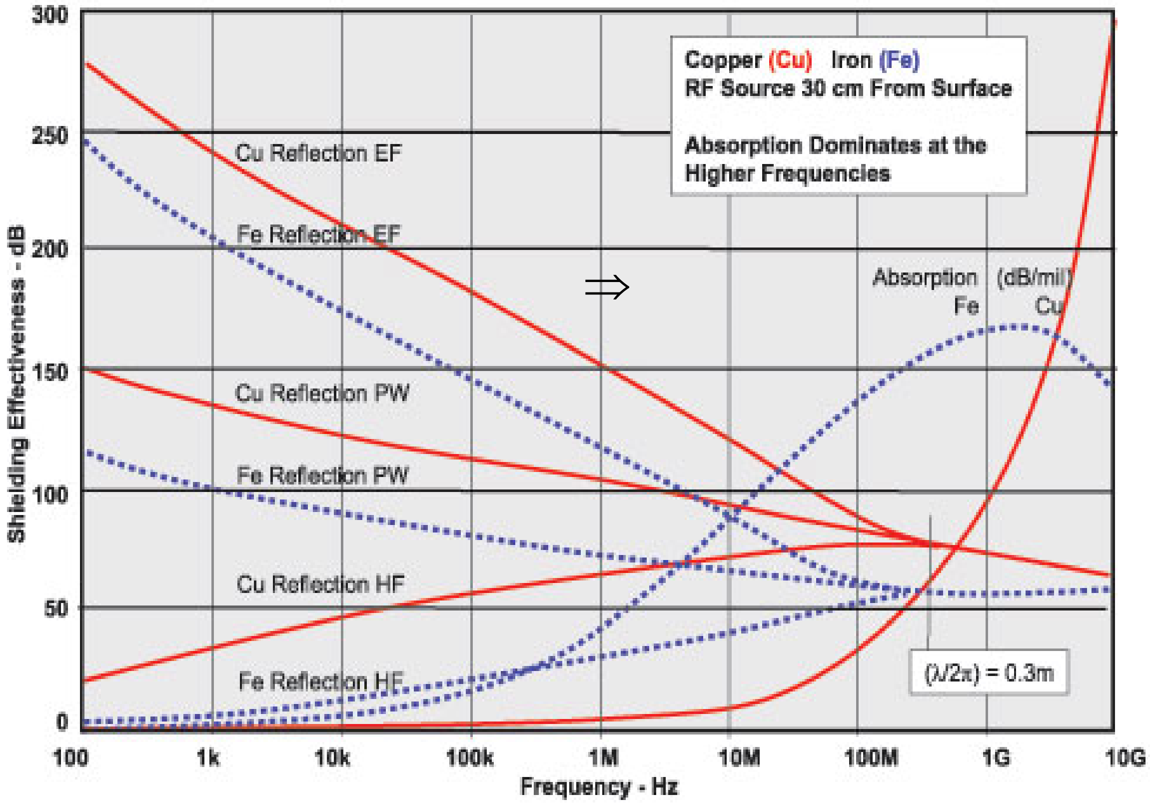
0.5 mm copper plate in the far-field limit

Near and far field

- Far field (radiation region)
  - $d \gg \lambda/2\pi$
  - Field properties mainly depend on the medium
    - $F/H = Z_m$
- Near field (induction region)
  - $d \ll \lambda/2\pi$
  - Field properties mainly depend on the source
    - High voltage, low current $(F/H > Z_m) \Rightarrow$ electric field
    - High current, low voltage $(F/H < Z_m) \Rightarrow$ magnetic field

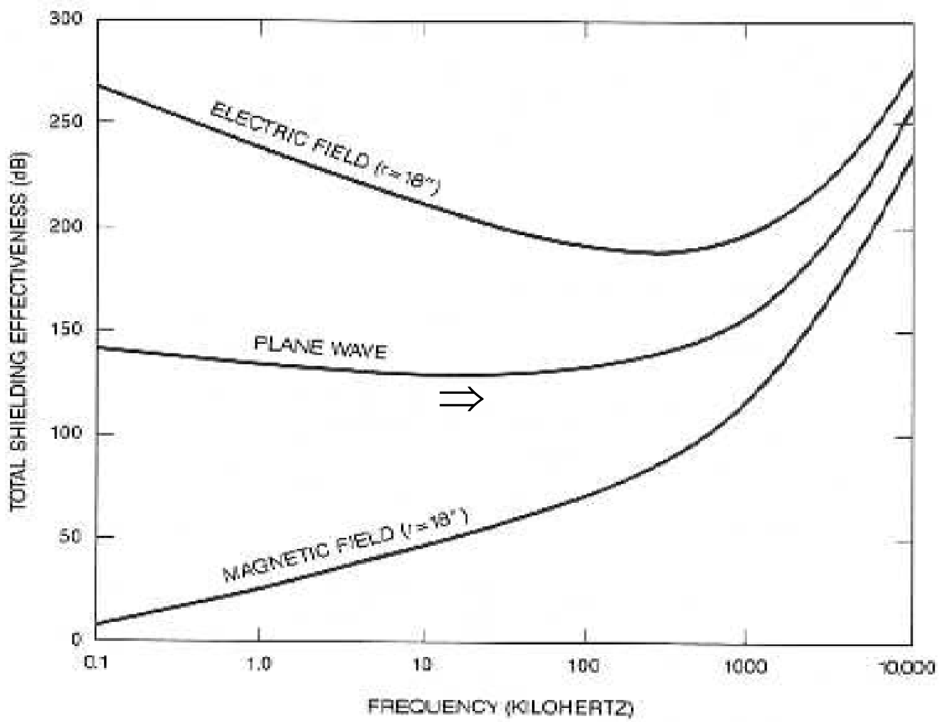
Near and far field shielding

From [6]



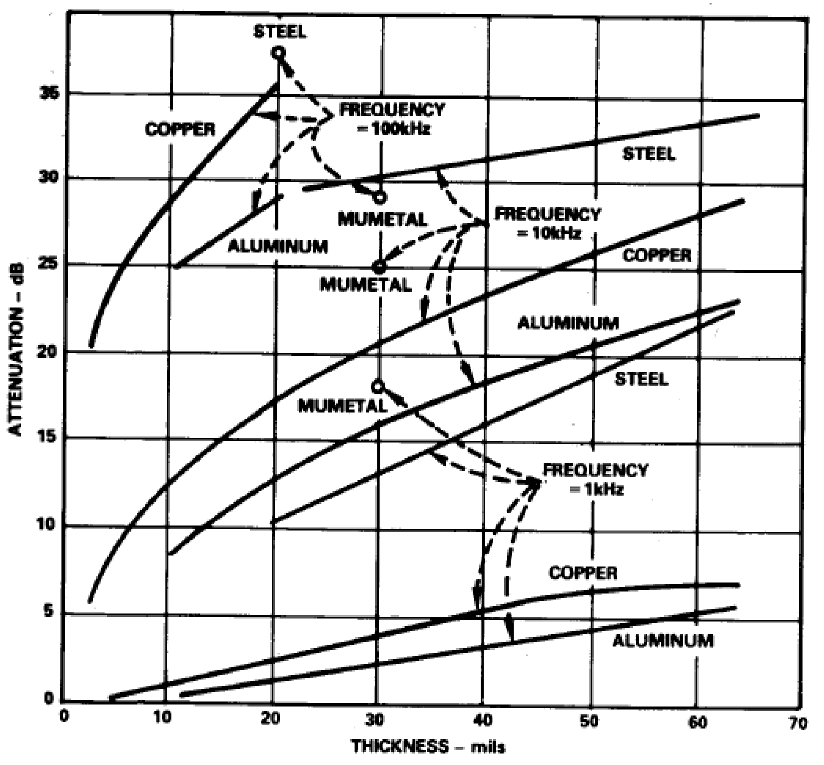
Total shielding effectiveness

From [1]



- It is hard to shield low-frequency magnetic fields
- Can we find any high-permittivity material?

Mu-metal

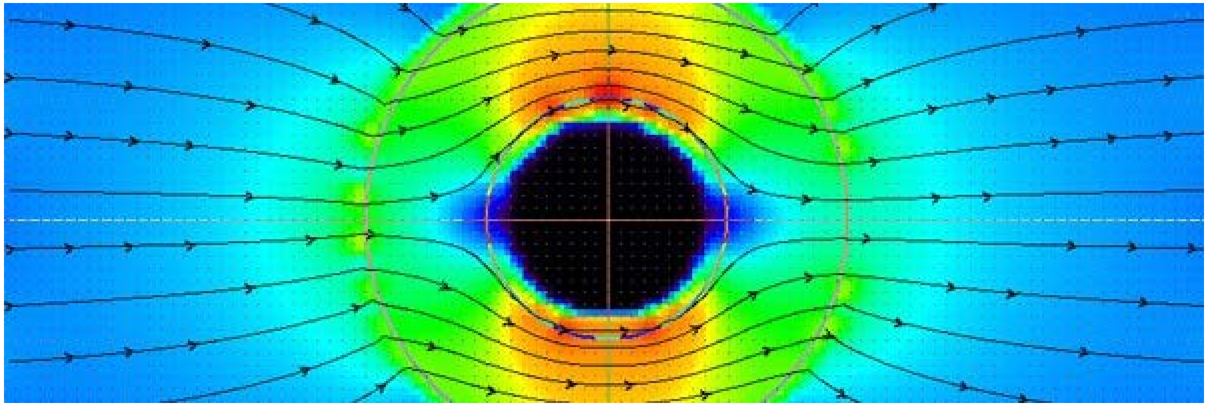


From [2]

- Only good for low frequencies
- Only works if the field is lower than the (usually low) saturation limit

Magnetic screening

From [7]



- A magnetic shield provides a low-reluctance path
- The magnetic field flows in the screen, bypassing the area inside

Apertures

- Real shield effectiveness is limited by apertures
- The shield leakage is determined by
  - The maximum linear dimension of the aperture
  - The frequency (i.e., wavelength) of the wave
  - The wave impedance

References

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