Shielding

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Examples and Perceptions

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Electromagnetic shielding

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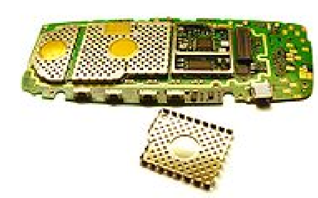
(March 2010)

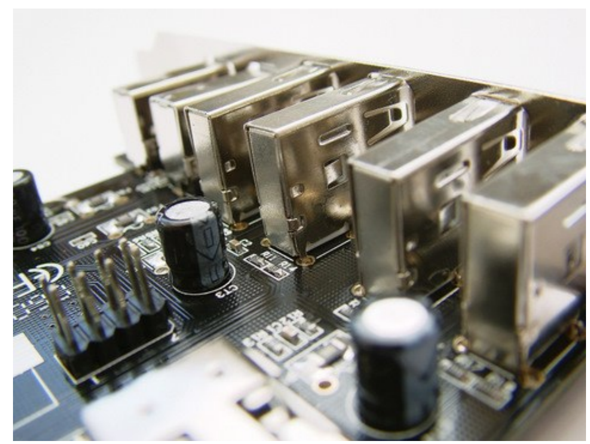
Electromagnetic shielding is the process of reducing the electromagnetic field in a space by blocking the field with barriers made of conductive and/or magnetic materials. Shielding is typically applied (1) to enclosures to isolate electrical devices from the 'outside world' and (2) to cables to isolate wires from the environment through which the cable runs. Electromagnetic shielding that blocks radio frequency electromagnetic radiation is also known as **RF shielding**.

The shielding can reduce the coupling of radio waves, electromagnetic fields and electrostatic fields, though not static or low-frequency magnetic fields[citation needed] (a conductive enclosure used to block electrostatic fields is also known as a Faraday cage). The amount of reduction depends very much upon the material used, its thickness, the size of the shielded volume and the frequency of the fields of interest and the size, shape and orientation of apertures in a shield to an incident electromagnetic field.



Electromagnetic shielding cages inside a disassembled mobile phone.

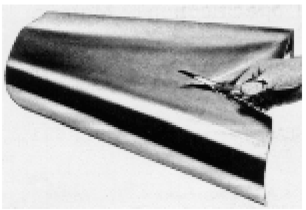
Examples and Perceptions



The Shielding Business

MAGNETIC SHIELDING FOIL

"The Best Material Available for Shielding DC, ELF & VLF Magnetic Fields"



Used for years in industry to shield delicate electronic components from EMFs, this 80% nickel alloy magnetic shielding foil is now available at affordable prices for home and office use. The thinner (0.004" thick) material is easy to trim with scissors and shape by hand. Thicker material offers better shielding performance but requires snips to cut. Can be formed into magnetic barriers on cellular phones, microwave ovens, doorbell transformers, VDTs, buried wiring, and more. With snug fitting shapes, get as much as 75% attenuation of the magnetic fi

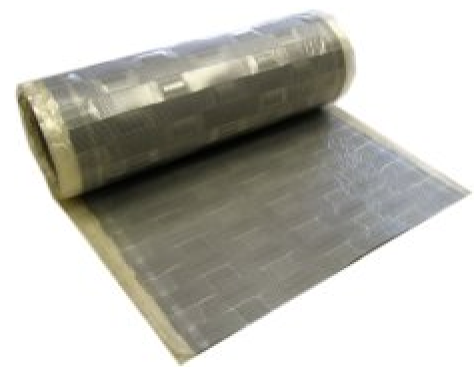
thicknesses and ca

and positioning of t

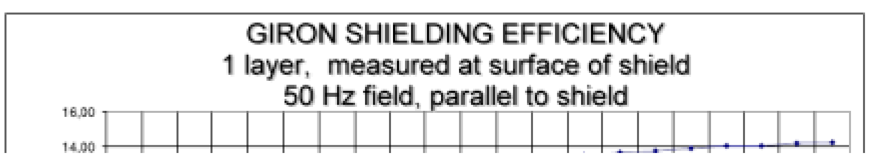
CAUTION: Foil

GIRON

Breakthrough In Magnetic Shielding Flexibility

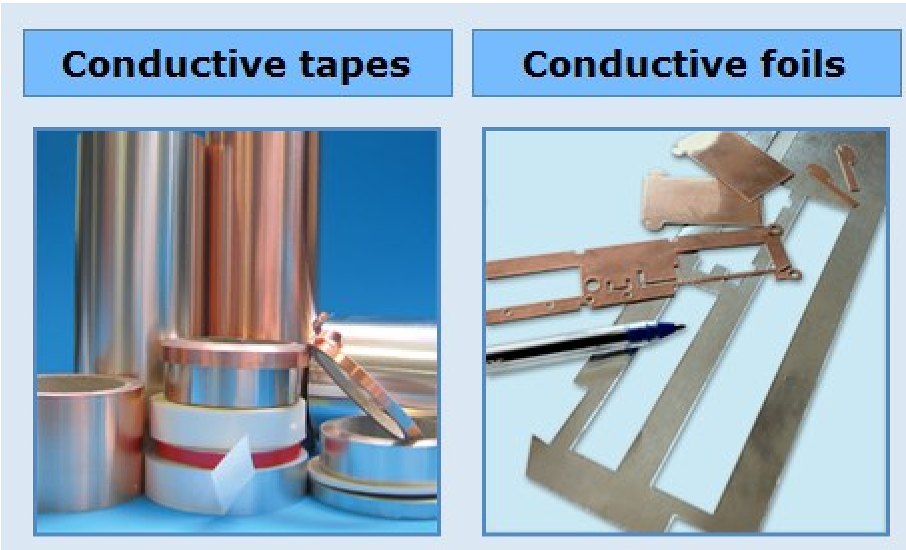


GIRON Magnetic Shielding Film, which does not contain Nickel, is unlike any other magnetic shielding material available on the market today. Suitable for high field strength applications requiring high saturation and good permeability, it is both thin and strong, and unlike Mu-metal™ it is very tolerant to bending or shaping without losing its shielding properties.



GIRON is a woven, laminated material. Cuts neatly with snips or sheet metal tools, and can be used either flat or molded into shapes for

The Shielding Business



Tapes, Foils and Gaskets

The Shielding Business

Nickel coating
3801 - 3820

Metallisation
3838

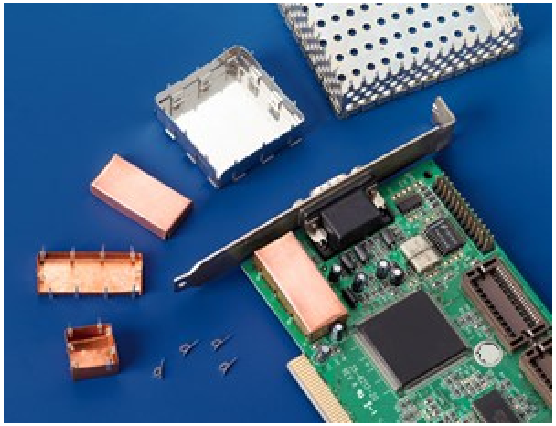
Silver coating
3850

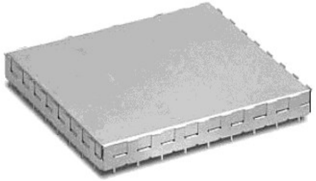
Shieldokit
3980

Shieldoseal
3990

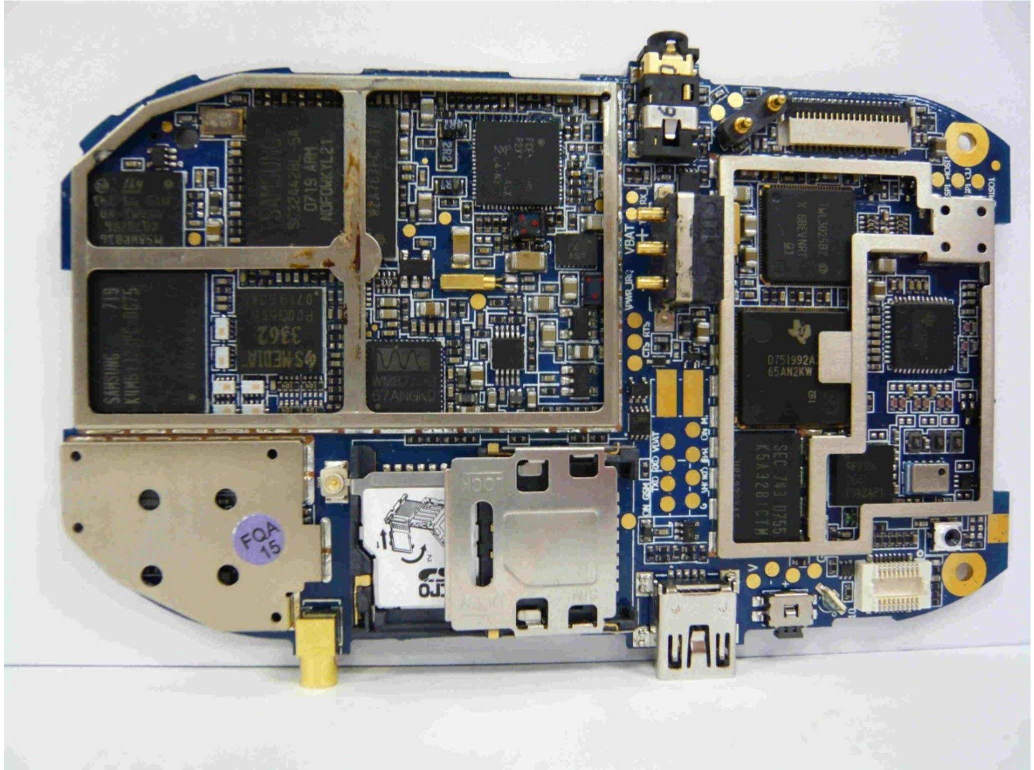
Coating,
Plating,
Glue

The Shielding Business





Circuit Board Shields

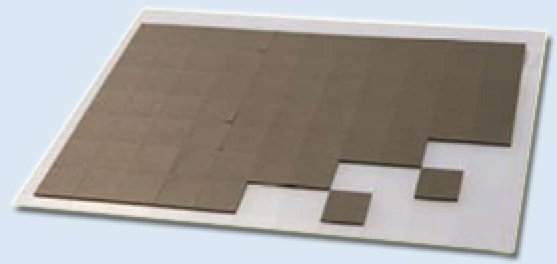


The Shielding Business

5780 Absorber sheet

Noise Suppression sheet / Absorber sheet 5780

The noise suppression serie developed by Holland Shielding Systems B.v. magnetic materials can eliminate noise effectively. You can solve EMC/EMI problems by attaching noise suppression sheets simply on the parts of noise sources.



Benefits

- Excellent suppression effect of radiation noise from 10Mhz to 6Ghz band.
- High electrical resistance ($1x10^{8}\ \Omega$)
- Flexible anc
- Can be mar thickness

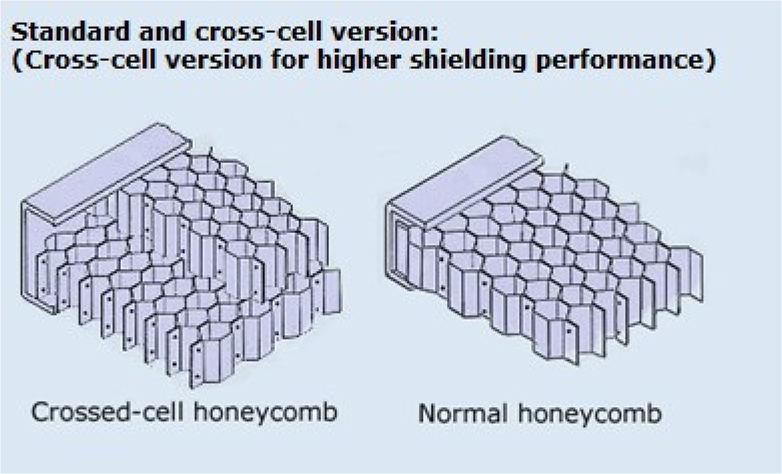
Absorber foam

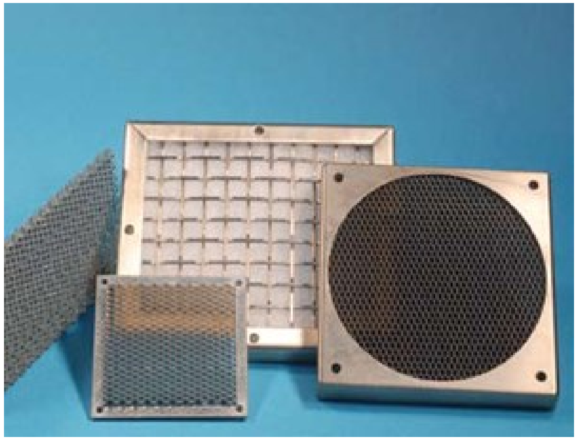
This RoHS compliant coated open cell foam is used as an absorbing material, especially for application with frequencies 1 - 17 GHz.

Typical applications are antenna hats, test boxes and PCB housings.
It can be supplied as a die cut or as sheets. Absorber sheets are available in 3, 5 and 15 mm thickness and with or without PSA.

Absorbing Materials

The Shielding Business





Shielded Air Vents

Coupling Paths

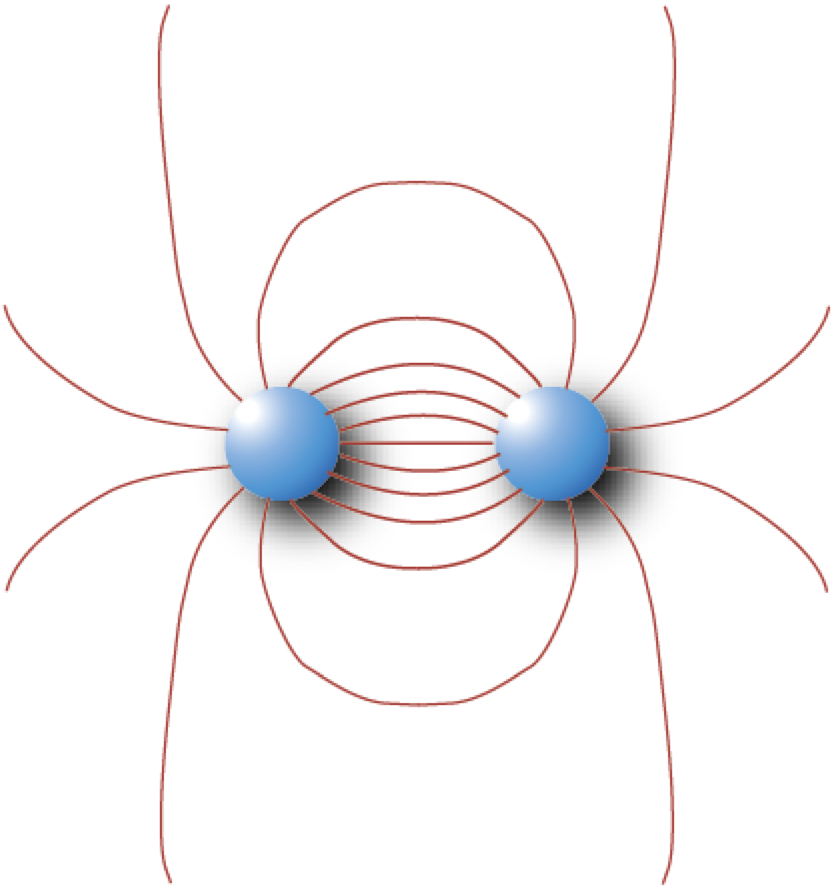
There are 4 possible EM coupling mechanisms!

- Conducted Coupling
- Electric Field Coupling
- Magnetic Field Coupling
- Radiation Coupling

Shielding strategies depend on the type of coupling.

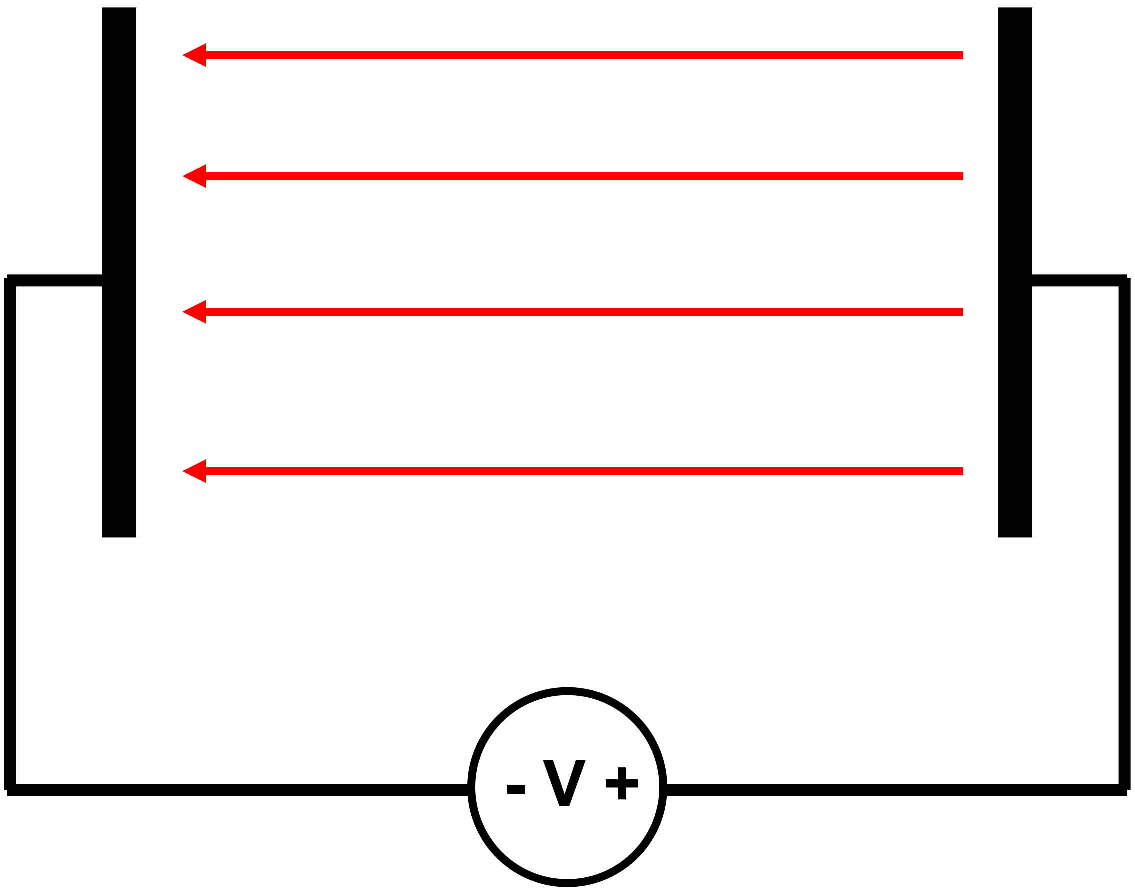
Electric-Field Shielding

Charge, Voltage and Electric Fields

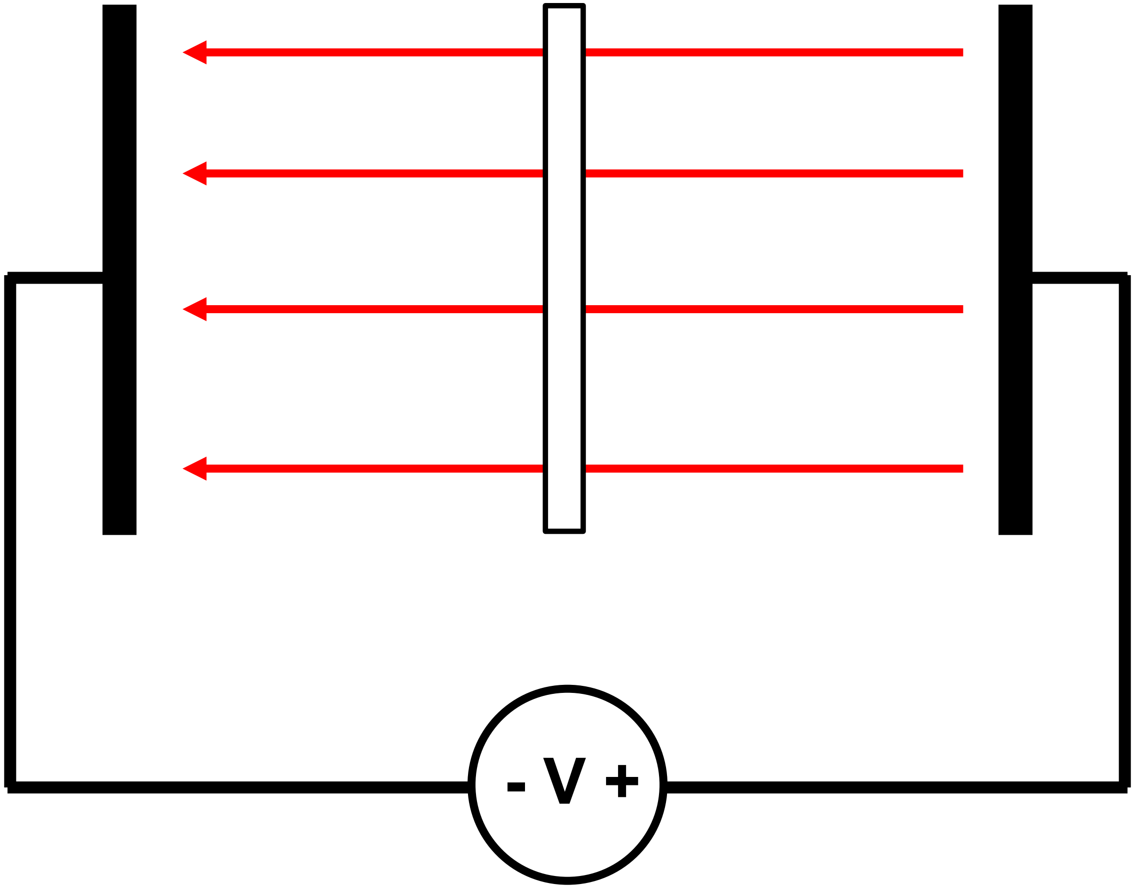


- Electric field lines start on positive charge and end on negative charge.
- Electric field lines start on conductors with one voltage and terminate on conductors with a lower voltage.

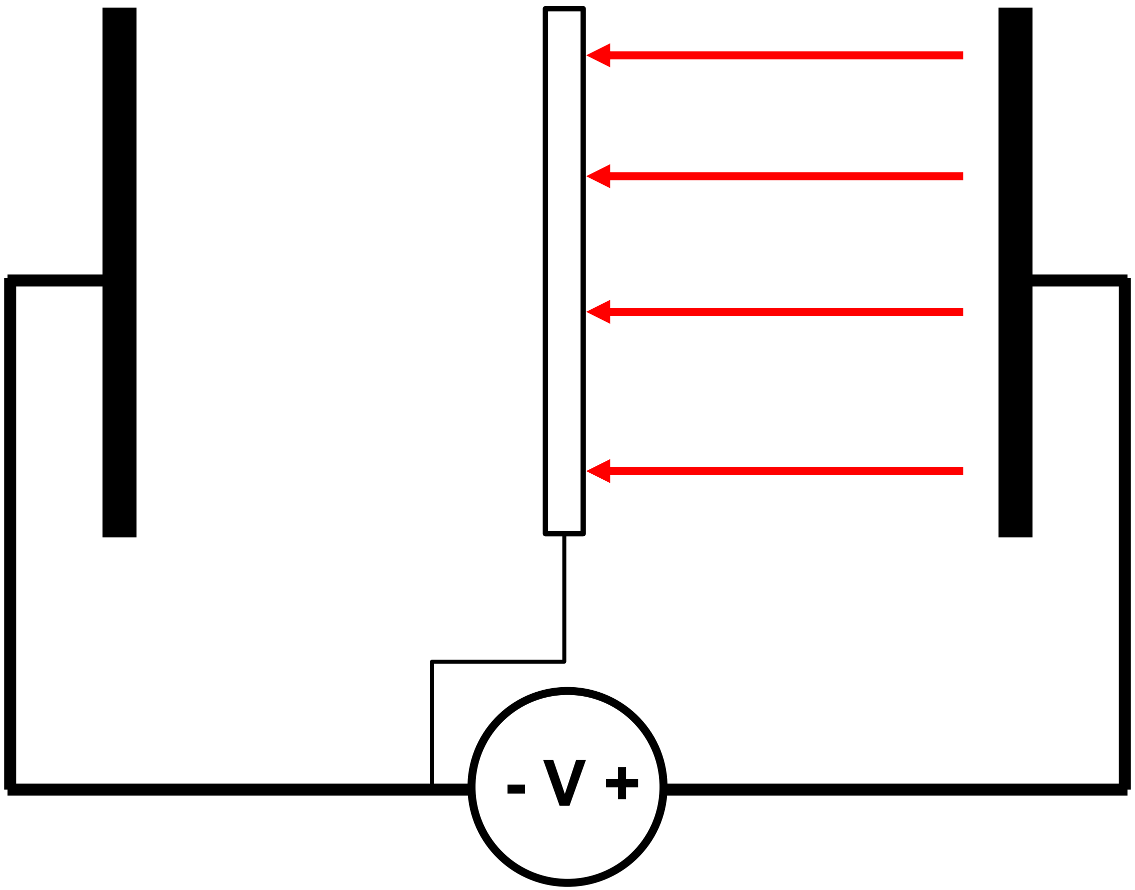
Electric Field Shielding



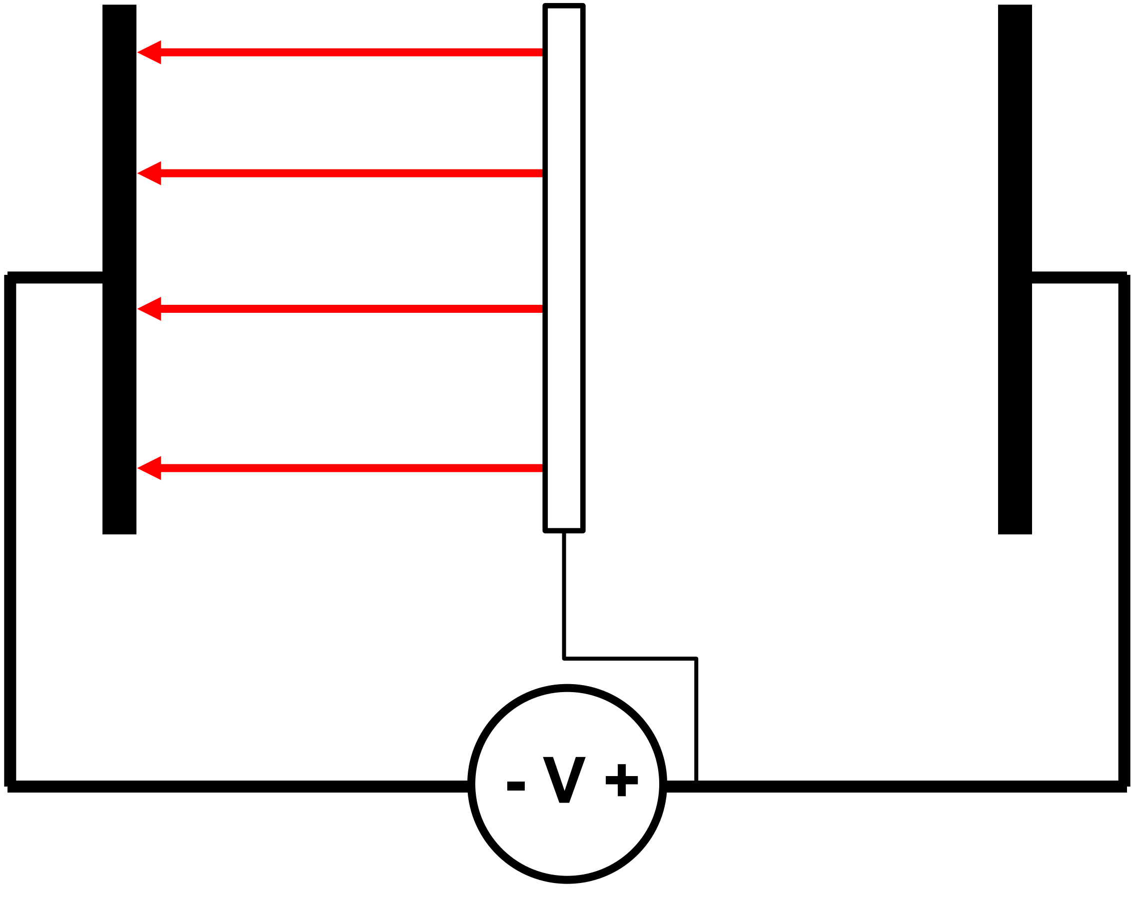
Electric Field Shielding



Electric Field Shielding

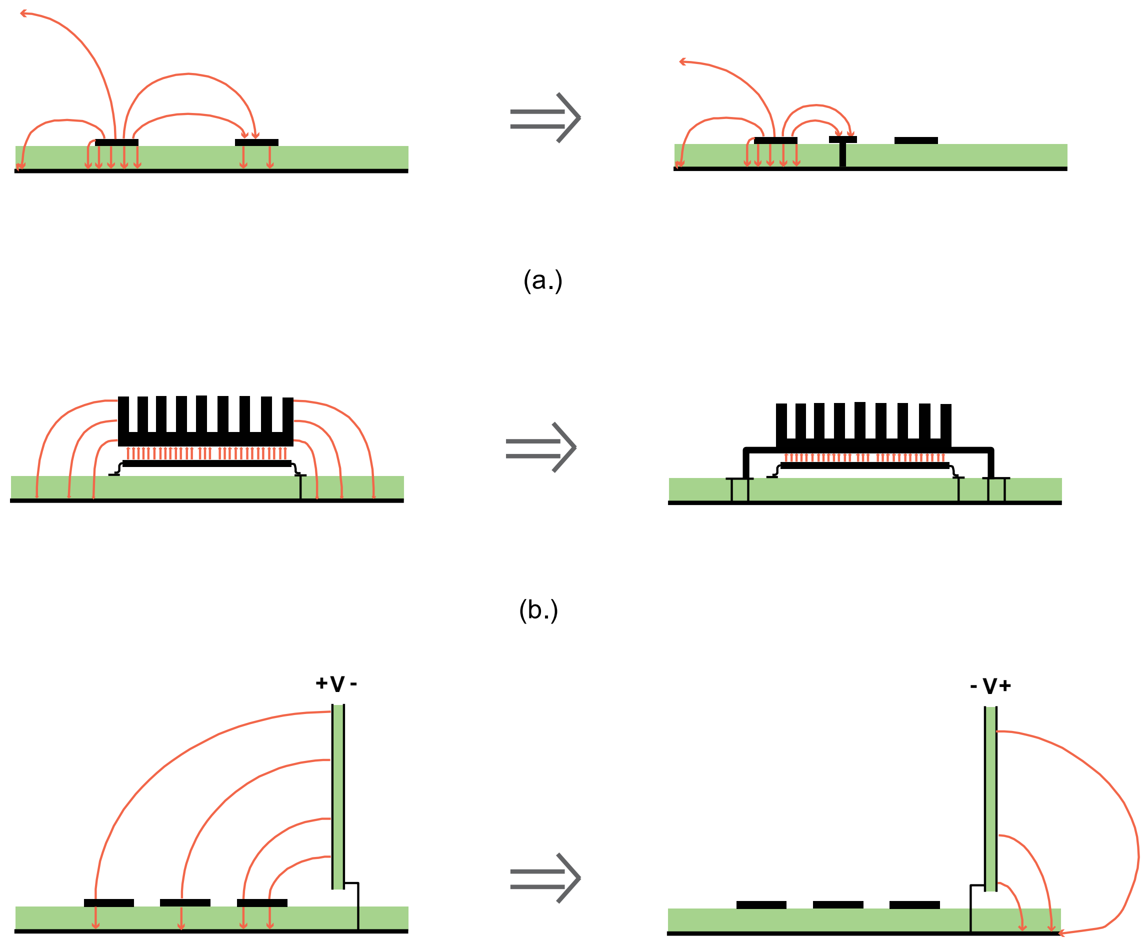


Electric Field Shielding



Shielding

Electric Field Shielding



(c.)

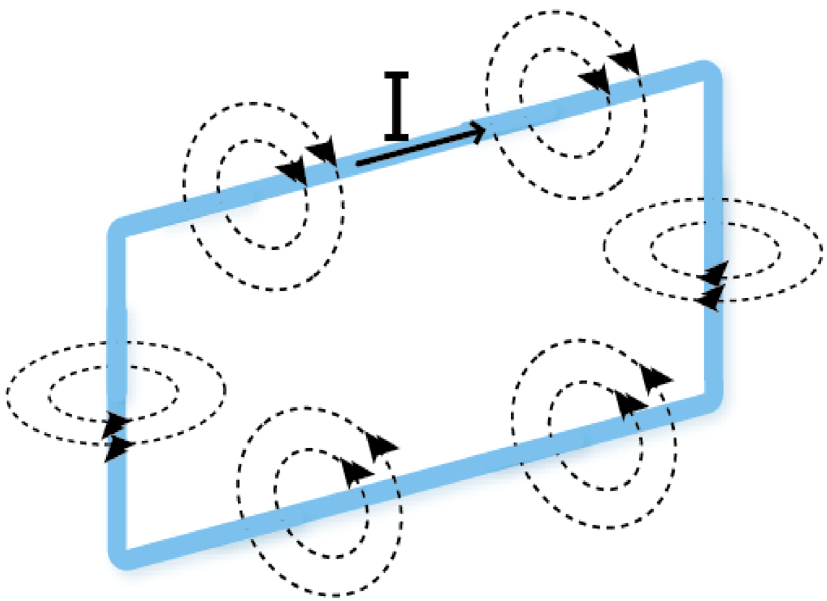
Field lines are intercepted and redirected

Summary of Electric Field Shielding

- Any two conductors at different potentials (voltages) have electric field lines between them.
- It is important to be able to visualize the electric field in order to mitigate coupling effectively.
- Shielding involves capturing and redirecting the electric field.
- Materials to use: Good conductors such as copper, aluminum, steel, etc.
- Electric field shields are usually connected to something labeled “ground”.

Low-Frequency Magnetic-Field Shielding

Magnets, Current and Magnetic Fields

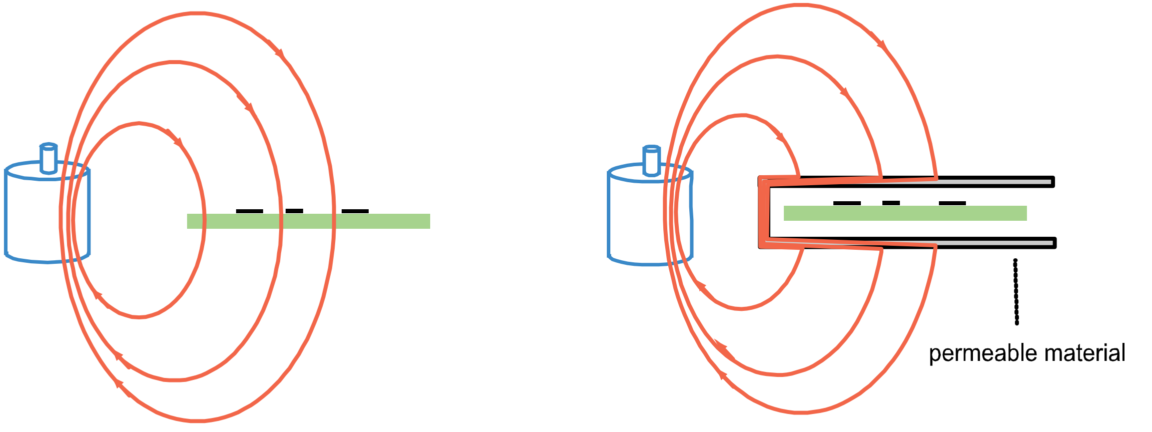


- Magnetic field lines circulate around flowing electric charge (current).
- Lines of magnetic field do not start or stop. They always close on themselves.

Shielding

Magnetic Field Shielding

(at low frequencies)



(a.) (b.)

LF Magnetic Shielding Materials

Material	Relative Permeability
Gold, copper, aluminum	1
Concrete, water, air, vacuum	1
Ferrite U60 (UHF Chokes)	8
Common Steel	
Pure Nickel	600
Ferrite M33 (inductors)	750
Pure Iron	5,000
Permalloy (20% iron, 80% nickel)	8,000
Ferrite T38 (RF Transformers)	10,000
Mu-metal	20,000 – 50,000
Supermalloy (recording heads)	100,000

Summary of LF Magnetic Field Shielding

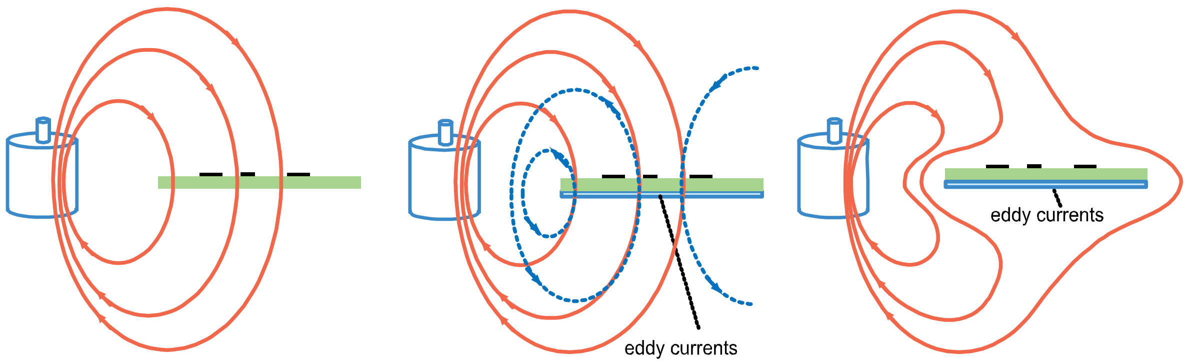
- You can't stop a magnetic flux line; you can only redirect it.
- It is important to be able to visualize the magnetic field in order to mitigate coupling effectively.
- Shielding involves capturing and redirecting the magnetic field.
- Materials to use: high permeability materials such as steel or iron-nickel alloys.
- Grounding does not affect the shielding effectiveness of LF magnetic field shields.

High-Frequency Magnetic-Field Shielding

Shielding

Magnetic Field Shielding

(at high frequencies)



(a.) (b.) (c.)

Summary of HF Magnetic Field Shielding

- You can't stop a magnetic flux line; you can only redirect it.
- At frequencies above a few kHz, magnetic flux lines will not pass through good conductors due to eddy currents induced in these conductors.
- Shielding involves redirecting the magnetic field.
- Materials to use: thick aluminum, copper or steel plates.
- Grounding does not affect the shielding effectiveness of HF magnetic field shields.

Shielding to Reduce Radiated Emissions

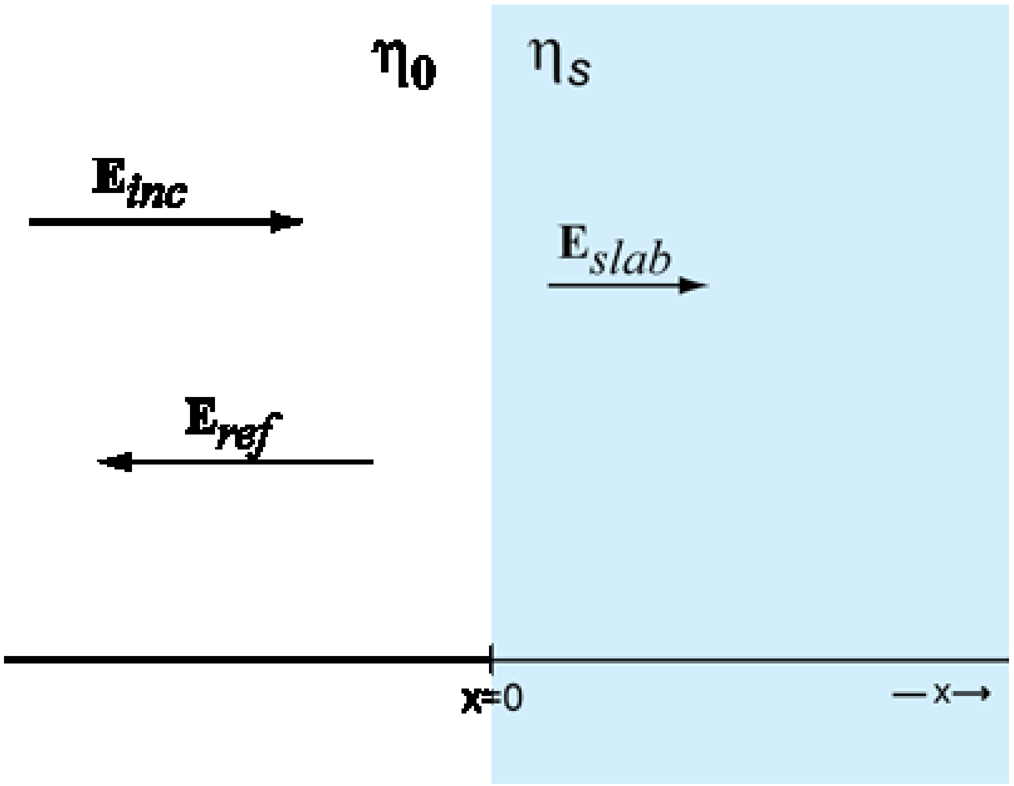
Shielding Theory

$$\left|\mathbf{E}_{ref}\right| = \left|\mathbf{E}_{inc}\right| \Gamma_E$$

$$\Gamma_E = \frac{\eta_s - \eta_0}{\eta_s + \eta_0}$$

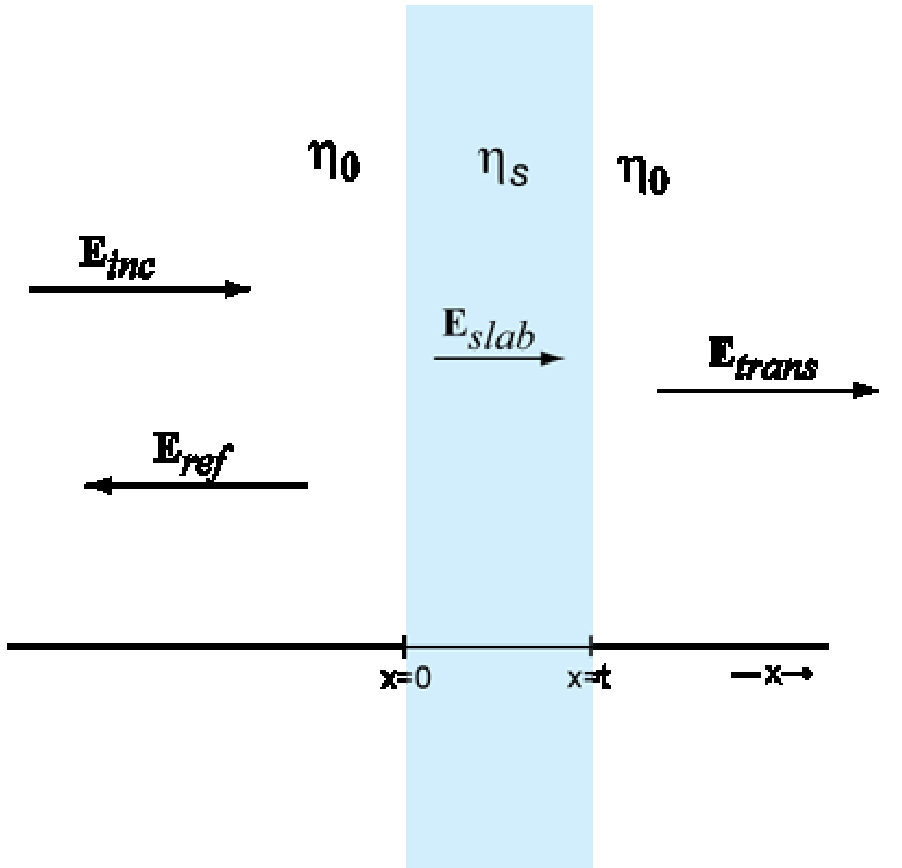
$$\left|\mathbf{E}_{slab}\right| = \left|\mathbf{E}_{inc}\right| T_{E_1}$$

$$T_{E_1} = \frac{2\eta_s}{\eta_s + \eta_0}$$



Shielding Theory

$$|\mathbf{E}_{trans}| = |\mathbf{E}_{inc}| \frac{2\eta_s}{\eta_0 + \eta_s}\left(\frac{2\eta_0}{\eta_0 + \eta_s}\right) e^{-t/\delta}$$



For good conductors:

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}} \approx \sqrt{\frac{j\omega\mu}{\sigma}} = \sqrt{\frac{\omega\mu}{\sigma}} e^{j\pi/4}$$

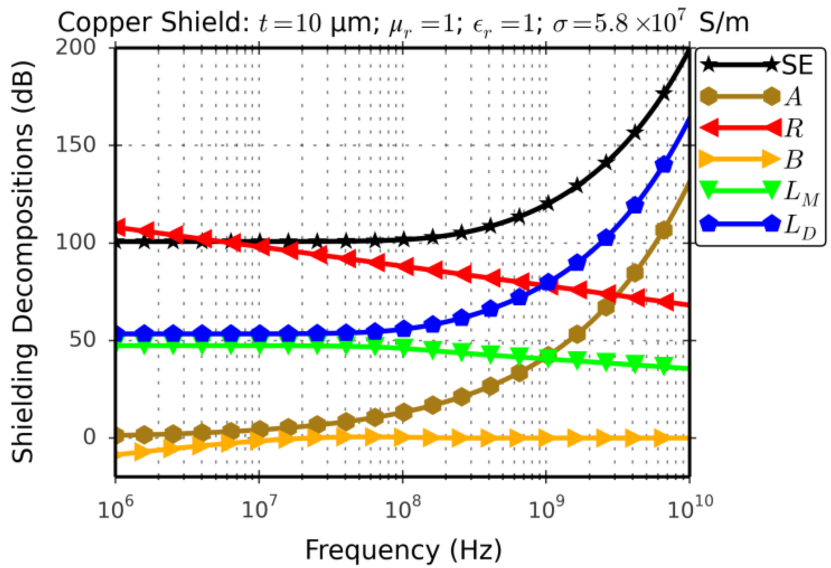
$$S.E. = 20\log\frac{E_{inc}}{E_{trans}}$$

$$S.E. = 20\log\frac{\eta_0}{4\eta_s} \quad + \quad 20\log e^{t/\delta} = R(dB) \quad + \quad A(dB)$$

Note: These are NOT accurate representations of the relative amounts of power reflected and absorbed.

Shielding Theory

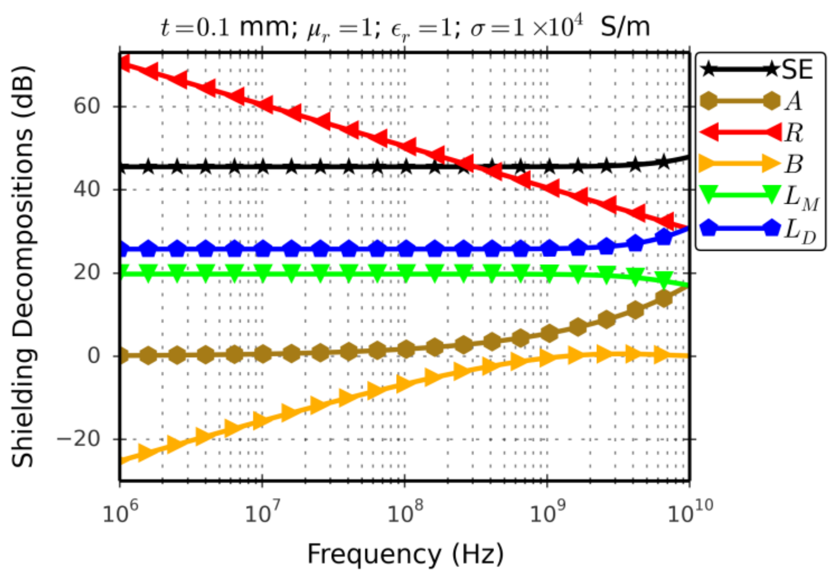
Copper
(10 μm thick)



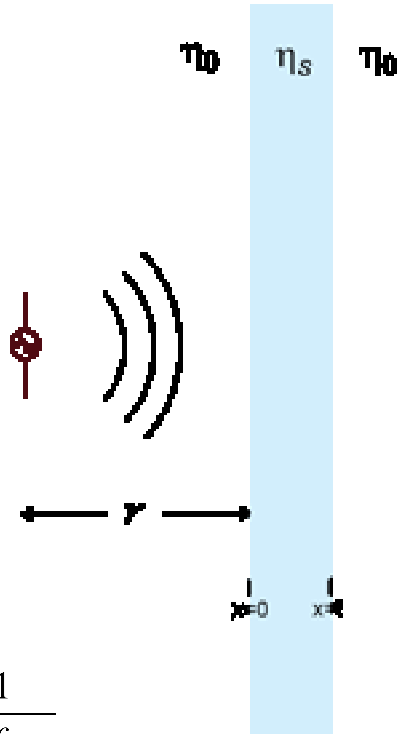
Schelkunoff decomposition:
SE (dB) = R(dB) + A(dB) + B(dB)

Mismatch decomposition:
SE (dB) = L_M(dB) + L_D(dB)

Nanofiber Composite
(100 μm thick)

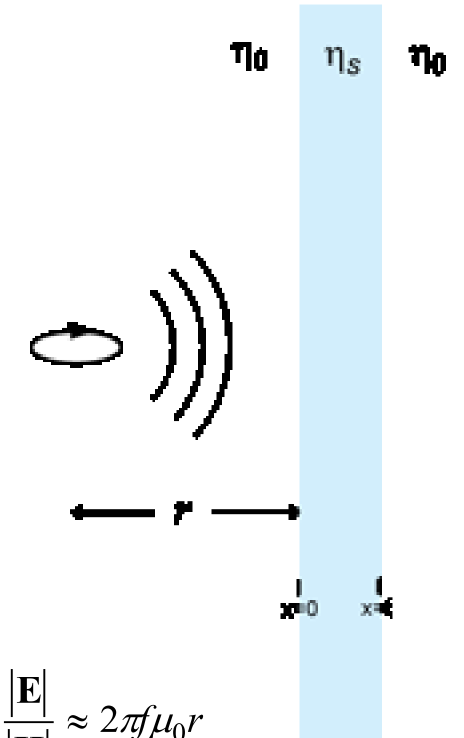


Shielding Theory



$$Z_{W_E} = \frac{|\mathbf{E}|}{|\mathbf{H}|} \approx \frac{1}{2\pi f \varepsilon_0 r}$$

(a.)

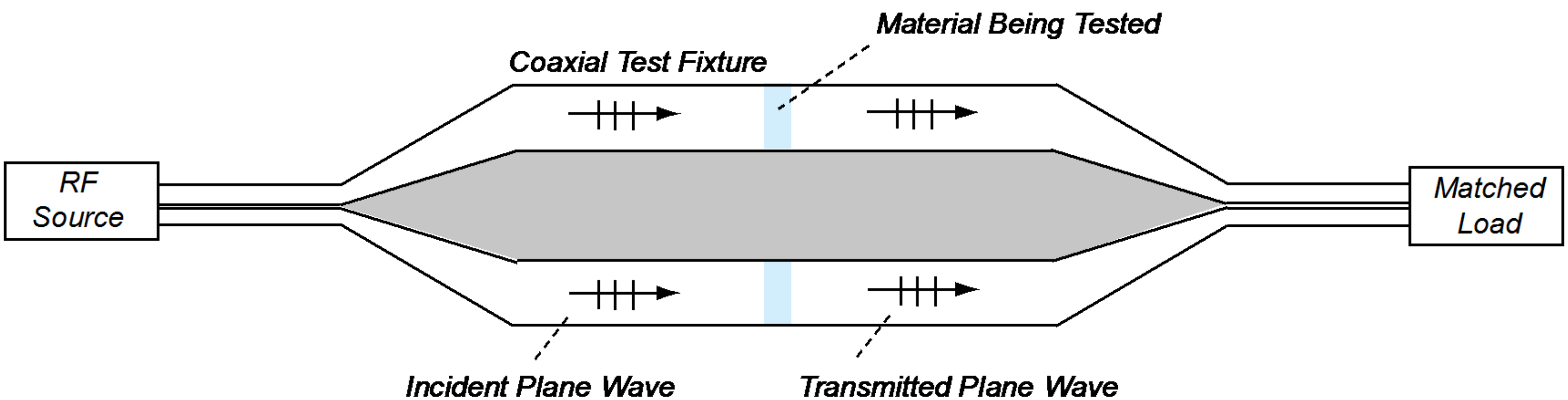


$$Z_{W_H} = \frac{|\mathbf{E}|}{|\mathbf{H}|} \approx 2\pi f \mu_0 r$$

(b.)

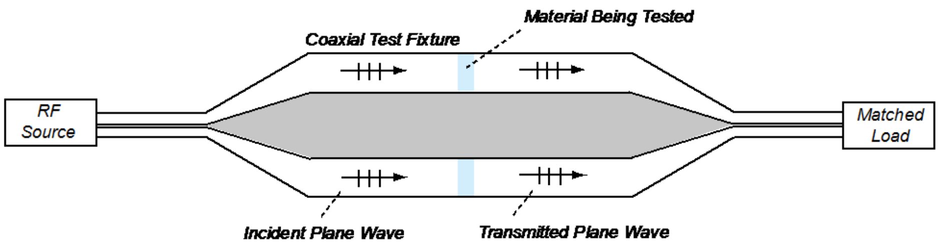
Shielding Effectiveness

Shielding Effectiveness Measurements



$$S.E. = 10\log\frac{\text{power received at the termination}}{\text{forward power from the source}}$$

Quiz



A shield made of a material with a shielding effectiveness of **100 dB** will reduce the radiation from an enclosed source by,

a.) 100 dB

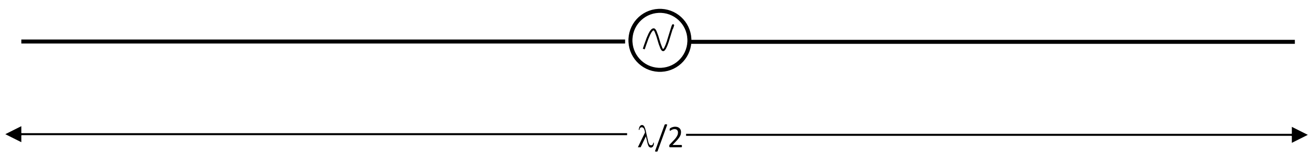
b.) at least 100 dB

c.) between 0 dB and 100 dB

d.) possibly less than 0 dB

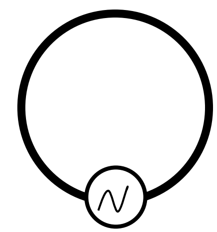
Identifying Antennas

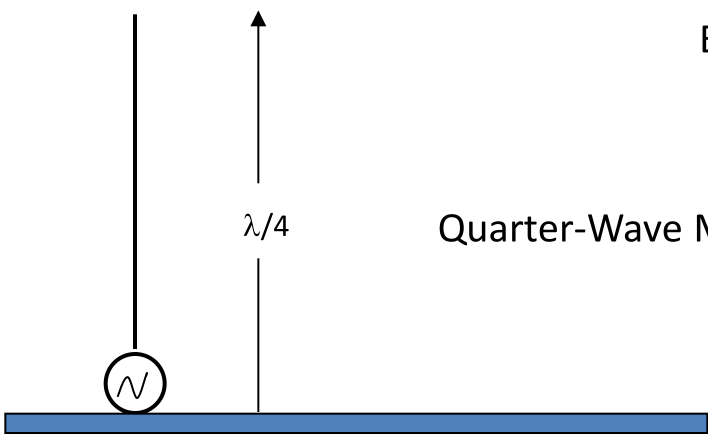
What makes an efficient antenna?



Half-Wave Dipole ↑

Electrically Small Loop ↓





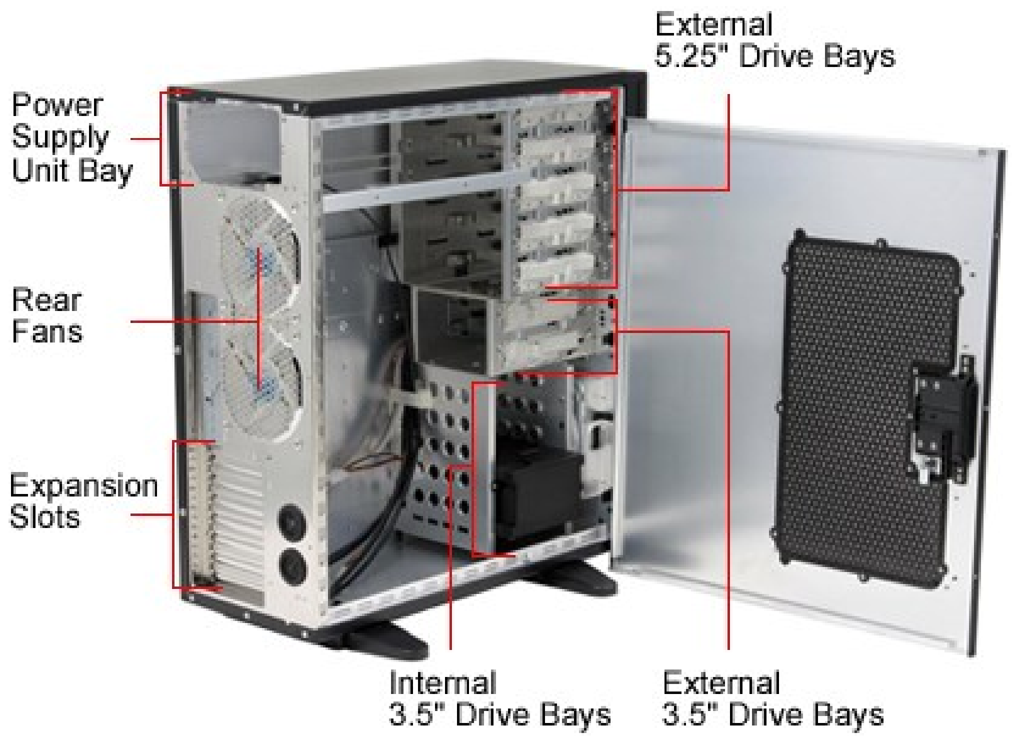
Quarter-Wave Monopole ↑

- **Size**
- **Two Halves**

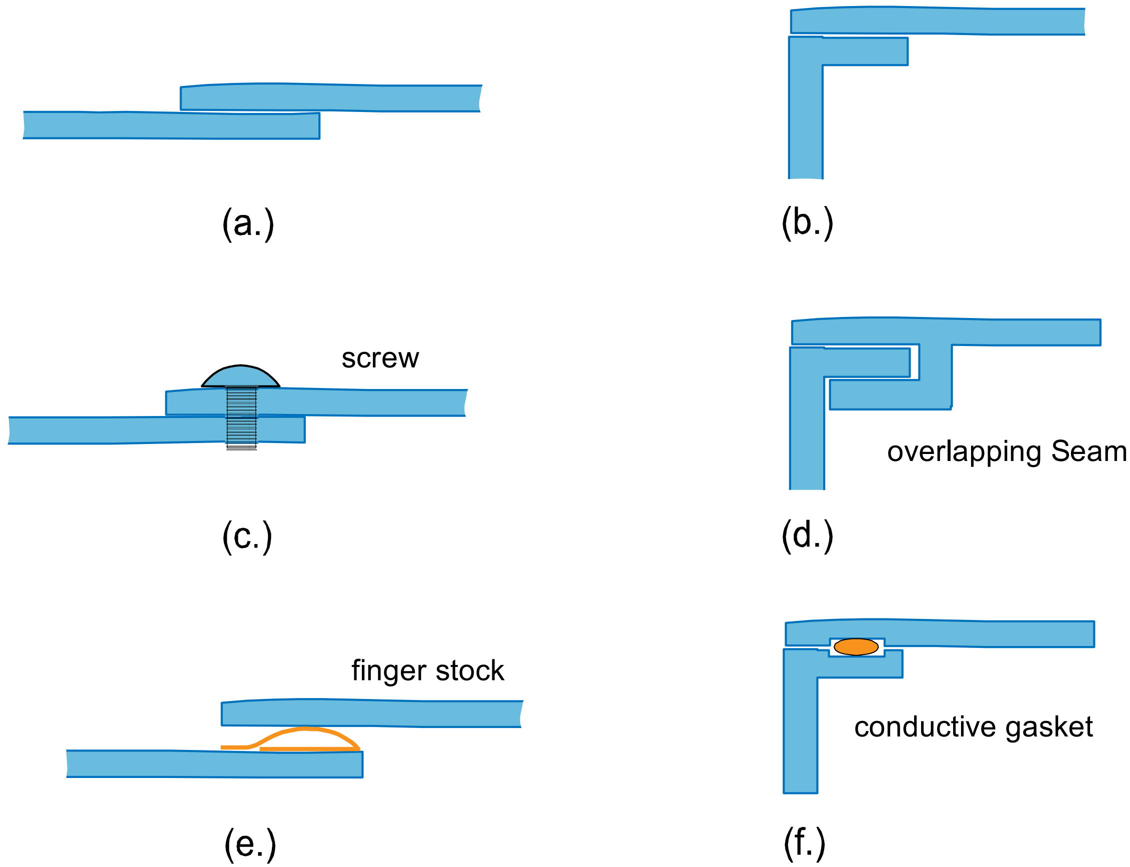
Gauss' Law and the Faraday Cage

Enclosure Shielding

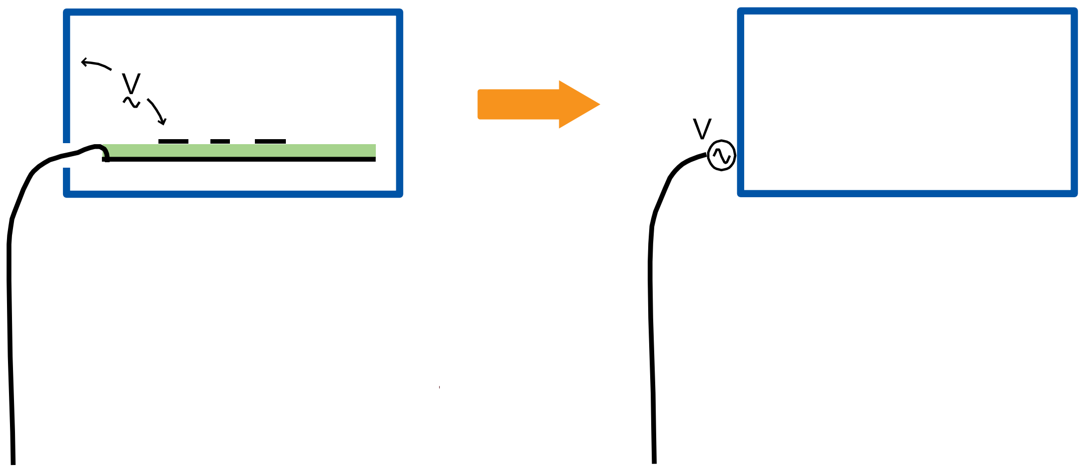
Shielded Enclosure

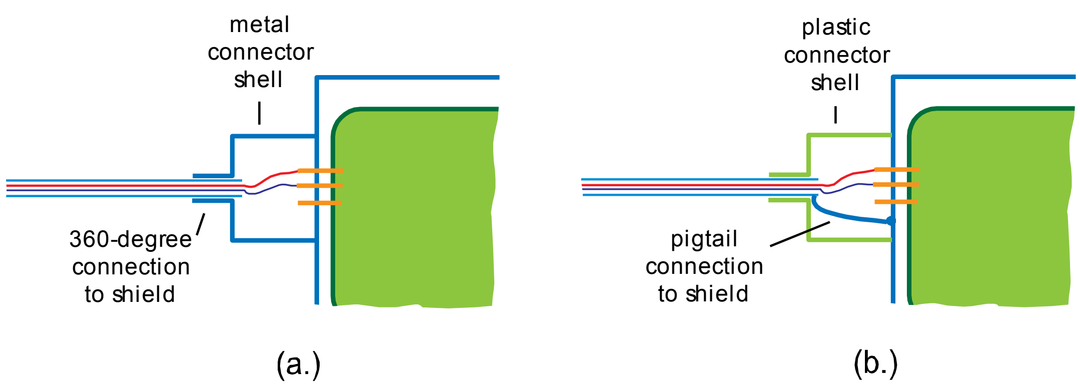


Shielding Enclosures



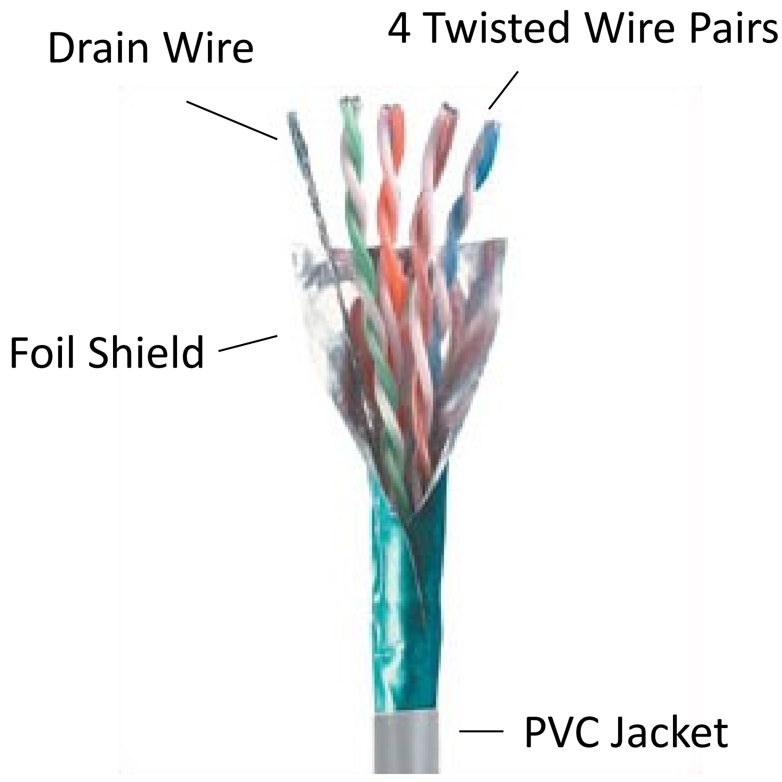
Shielding Enclosures





Cable Shielding

Anatomy of a Cable Shield



CAT5e Cable

- Foil provides high-frequency shielding.
- Drain wire carries most of the low-frequency current.

Anatomy of a Cable Shield

- Foil provides high-frequency shielding.
- Braid carries high-currents.

Summary of Cable Shielding

- Serves different purposes in different applications.
- Sometimes carries intentional signal currents. This is an example of self-shielding.
- May prevent coupling of external electric or magnetic fields to signals carried by wires in the cable.
- Beware of transfer impedance data. It should only be used to compare similar cables for a similar application measured with the same test set-up.

Summary of Main Points

- Electric field shielding, magnetic field shielding, cable shielding and shielded enclosures are very different concepts requiring different materials and approaches.
- It is important to be understand the coupling mechanism you are attempting to attenuated before coming up with a shielding strategy.

Summary of Main Points

- Electric field shields terminate or redirect electric fields. Where they are “grounded” is often critical.
- Magnetic fields cannot be terminated. Magnetic field shields redirect the magnetic field.
- Low frequency (<kHz) magnetic fields must be redirected with high permeability materials.
- High frequency magnetic fields can be redirected with good conductors of sufficient thickness.

Summary of Main Points

- Shields and imperfect shielded enclosures can significantly increase radiated emissions.
- Shields reduce radiated emissions by disrupting the coupling from near-field sources and the “antennas” in a system.
- In the near field, shields are either electric or magnetic field shields that redirect high-frequency current flow.