MECHANICAL FACTORS IN SHIELDING AND THERMAL DESIGN OF ELECTRONICS

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EMI-SHIELDING

- EMI – Electromagnetic Interference
- EMC – Electromagnetic Compatibility

- FCC

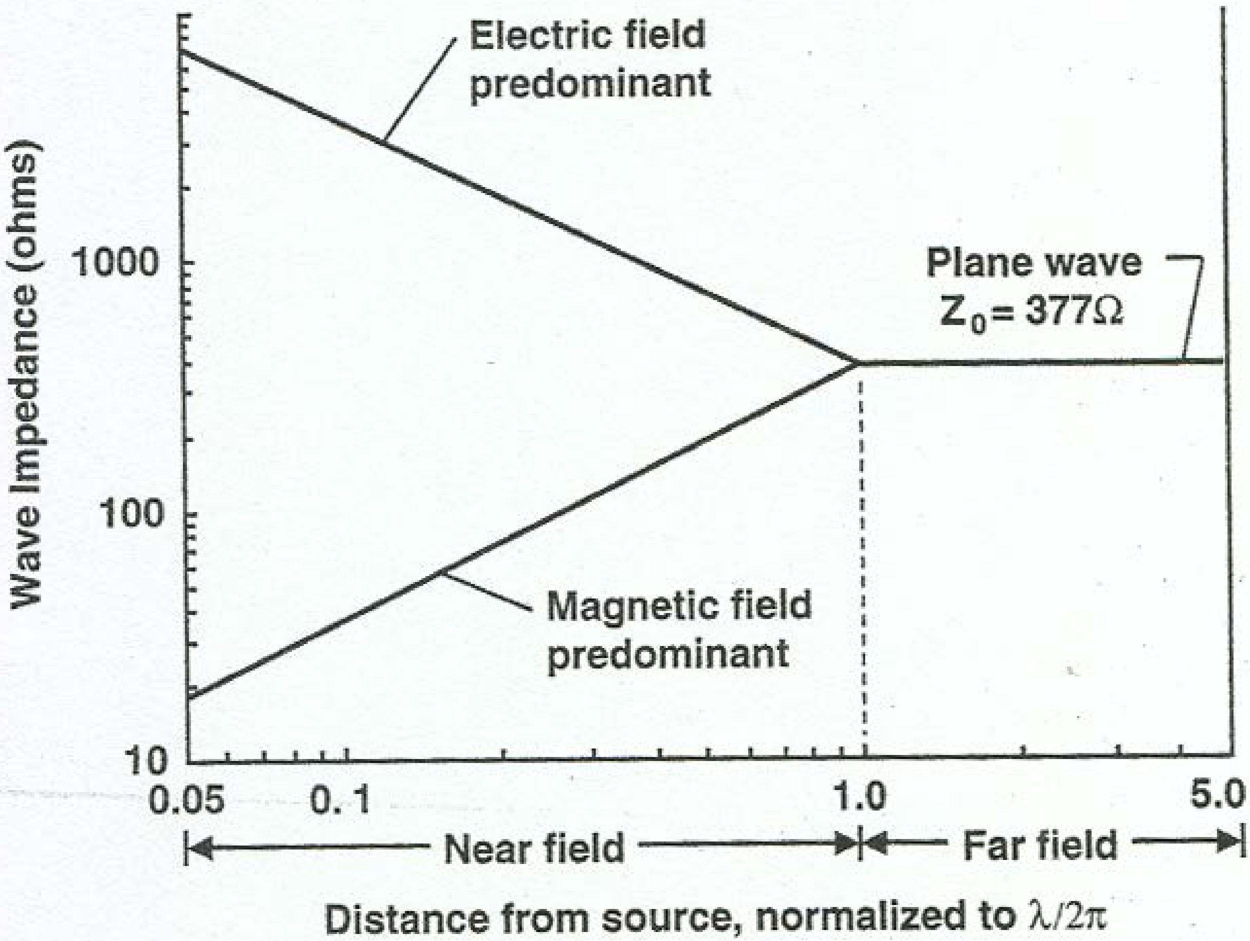
- emissions

- EMC –directives

-emissions, immunity

Near and far field

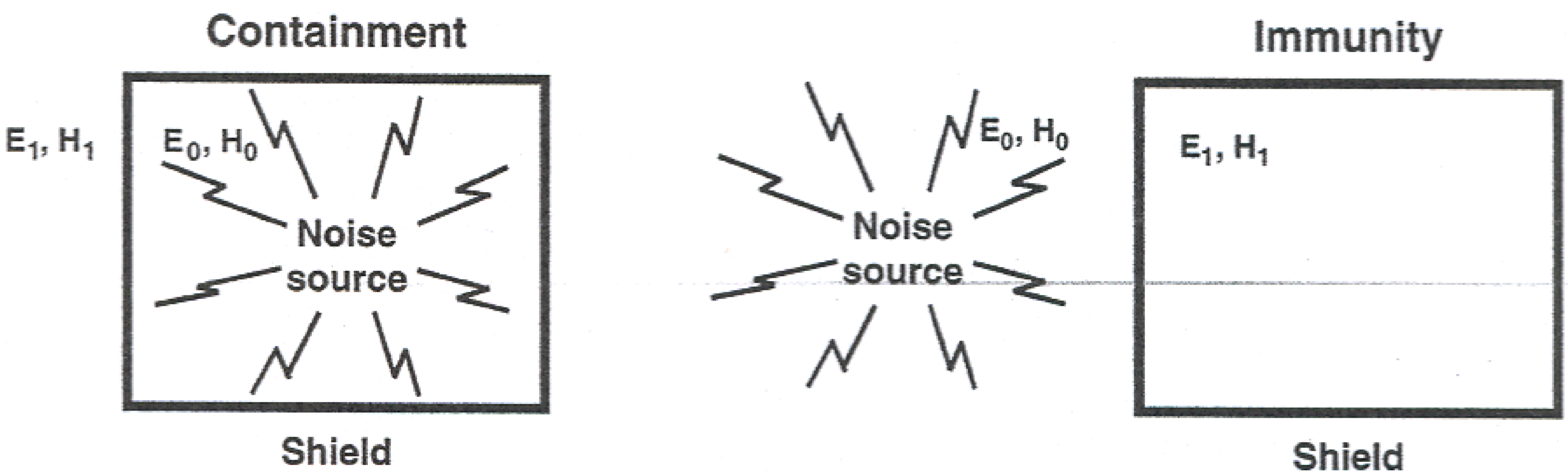
The far field as a magnetic and electronic component of equal impact but in the near field one of these dominates



Frequency	$\lambda/2\pi$
60 Hz	795 km
3 kHz	15,915 m
30 kHz	1,591.5 m
300 kHz	159.1 m
3 MHz	15.9 m
30 MHz	1.59 m
300 MHz	15.9 cm
900 MHz	5.30 cm
3 GHz	1.59 cm
30 GHz	1.59 mm

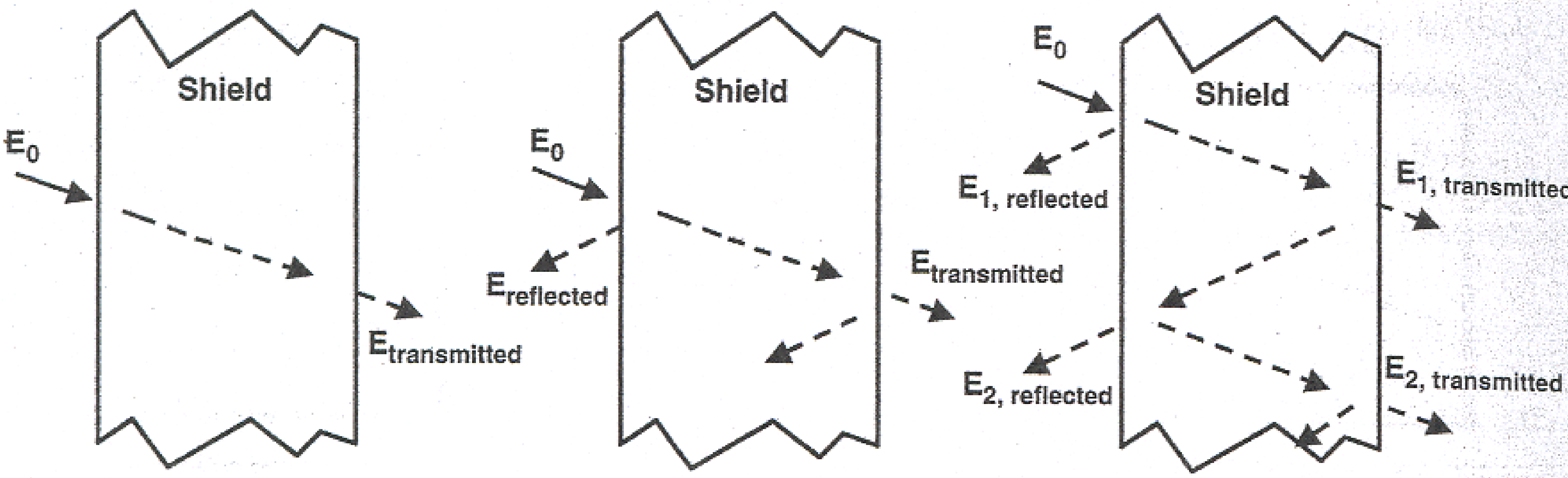
Shielding effectiveness SE

- SE is the ratio of illuminating and penetrating intensities in dB
- Generally considered as reflection (R), absorption (A) and internal reflections



$$\text{Shielding effectiveness (SE)} = 20 \log \frac{E_0}{E_1} \text{ dB (electric fields)}$$

$$\text{Shielding effectiveness (SE)} = 20 \log \frac{H_0}{H_1} \text{ dB (magnetic fields)}$$



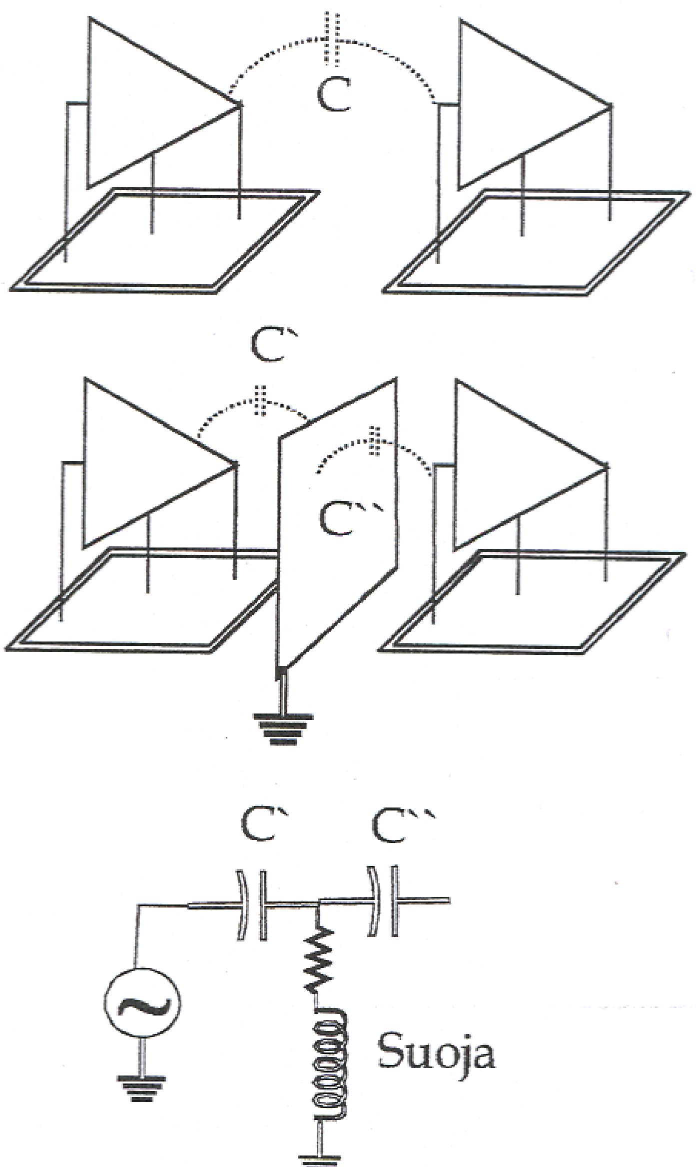
Absorption loss (A)

Reflection loss (R)

Multiple reflection correction factor (M)

Shielding effectiveness (SE) = A + R + M dB
Electric and magnetic fields, near fields and far fields

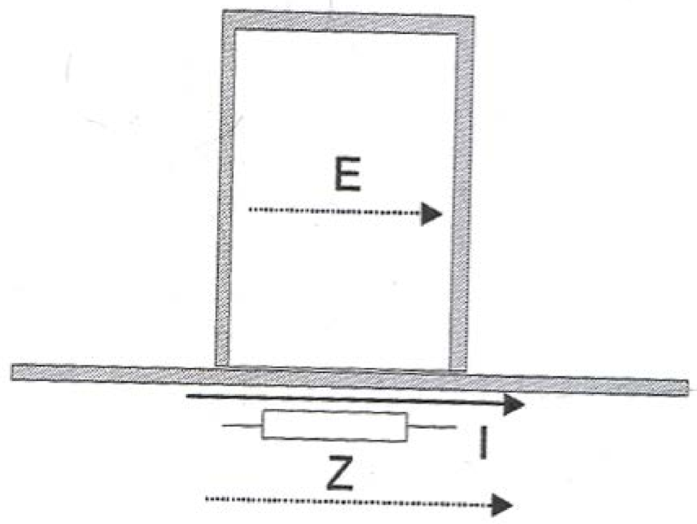
Shielding against electric fields



- A conductive layer between circuits
- Low capacitance towards the protective earth

BE AWARE OF THIS !

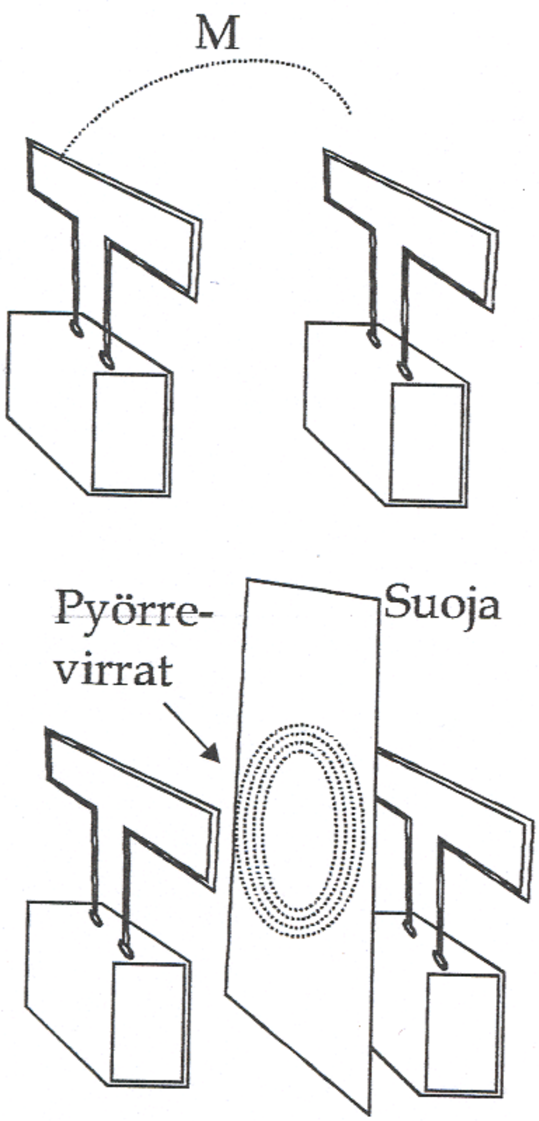
Suojakotelo kiinnitetty painetun piirin maatasoon. Maatasossa kulkee virta I. Suojakotelon sisään syntyy häiritsevä sähkökenttä.



$$U = \overline{I} \cdot \overline{Z}$$

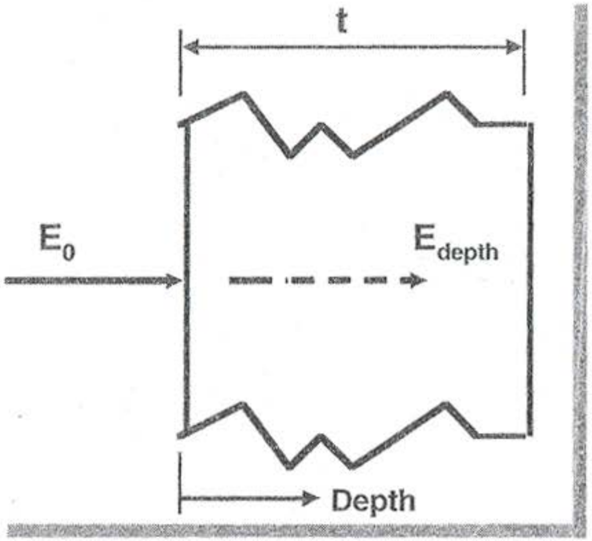
Maatasossa kulkeva virta I aiheuttaa impedanssin Z yli jännitteen U. Jännitettä U vastaava sähkökenttä E syntyy suojakotelon sisään.

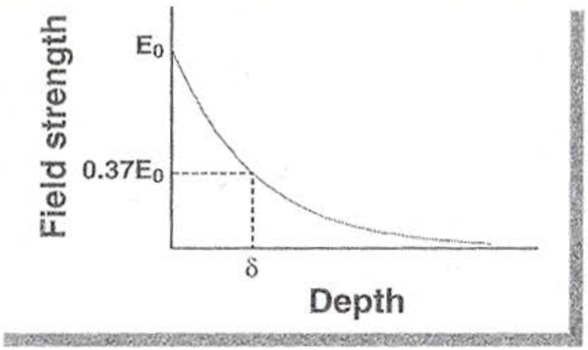
Shielding against a magnetic field



- a good conducting layer, no grounding
- Ferromagnetic materials (steels, μ)
- Super conductors
- Combinations

A comparison of some metals





- Applies to electric fields, magnetic fields, and plane waves $A = 3.34\,t\sqrt{f\mu_r\sigma_r} = 8.69\,t/\delta$ dB
- Thin materials provide effective absorption losses at high frequencies
- Skin depth (δ): $\delta = 1/\sqrt{\pi f \mu \sigma}$ in
  - —Distance needed for wave to be attenuated to 37% of its original strength
  - —Varies with material and frequency

Frequency	δ, *copper*	δ, *aluminum*	δ, *steel*	δ, *mumetal*
60 Hz	0.335	0.429	0.034	0.019
100 Hz	0.260	0.333	0.026	0.011
1 kHz	0.082	0.105	0.008	0.003
10 kHz	0.026	0.033	0.003	—
100 kHz	0.008	0.011	0.0008	—
1 MHz	0.003	0.003	0.0003	—
10 MHz	0.0008	0.001	0.0001	—
100 MHz	0.00026	0.0003	0.00008	—
1 GHz	0.00008	0.0001	0.00004	—

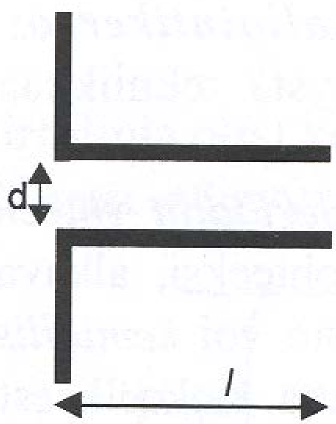
Thicknesses in inches

Shielding material that is one skin depth thick ($t/\delta = 1$) provides approximately 9 dB of absorption loss; doubling the thickness doubles the dB loss

f = frequency (Hz), μ = permeability (H/in), σ = conductivity (mho/in), t = thickness (in), μ_r = relative permeability (free space), σ_r = relative conductivity (copper)

Openings and holes

YMPYRÄN MUOTOINEN AUKKO



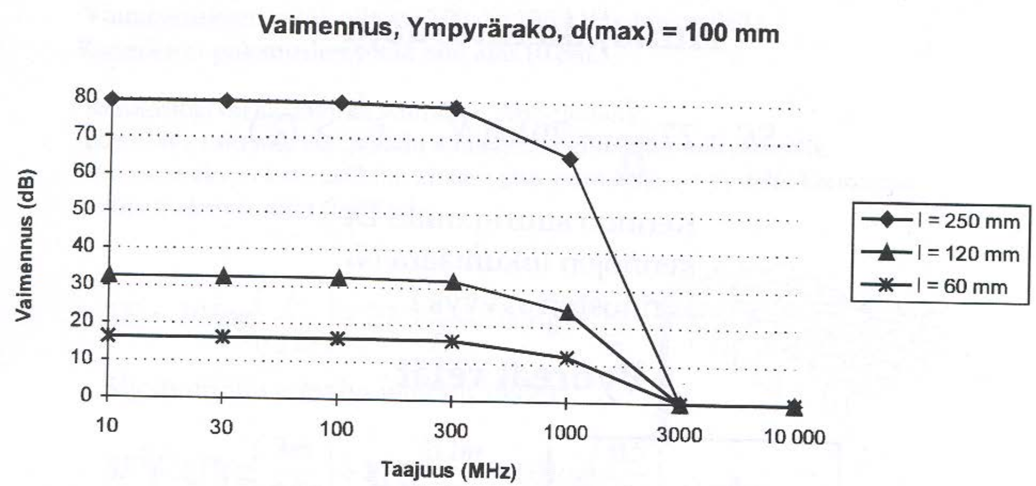
$$A \approx 1{,}8 \cdot 10^{-4} \cdot l \cdot f_{MHz} \sqrt{\left(f_c / f_{MHz}\right)^2 - 1}$$

$$f_c = 1{,}76 \cdot 10^5 / d \left[MHz\right]$$

l: Aukon syvyys [mm]

d: Aukon suurin mitta [mm]

f_{MHz}: Taajuus [MHz]



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Suorakulmainen aukko

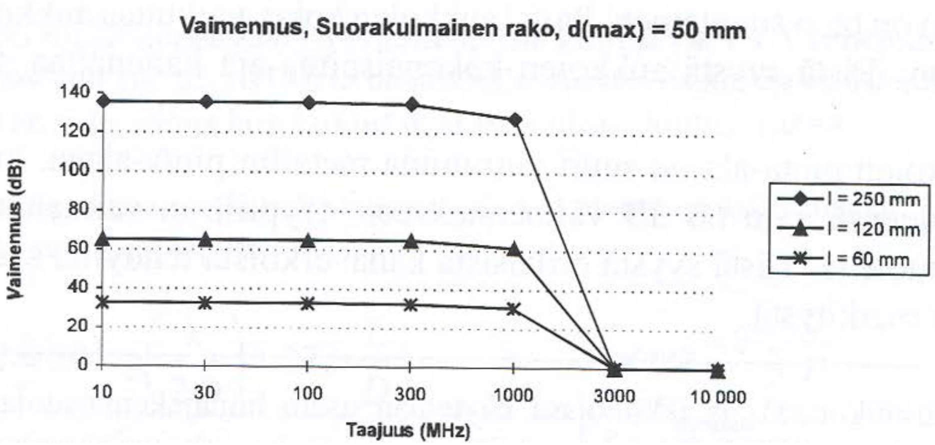
$$A \approx 1{,}8 \cdot 10^{-4} \cdot l \cdot f_{MHz} \sqrt{\left(f_c / f_{MHz}\right)^2 - 1}$$

$$f_c = 1{,}5 \cdot 10^5 / d \left[MHz\right]$$

l: Aukon syvyys [mm]

d: Aukon suurin mitta [mm]

f_{MHz}: Taajuus [MHz]

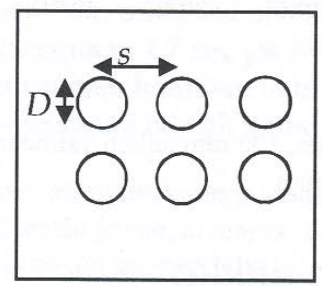


Hunajakennosuoja

$$SE \approx 27 \frac{l}{D_k} - 20 \log N_k \qquad \left(\frac{\lambda}{2} > D_k\right)$$

Kennon suurin mitta D_k
kennojen lukumäärä N_k
kennoston syvyys l

Pyöreät reiät

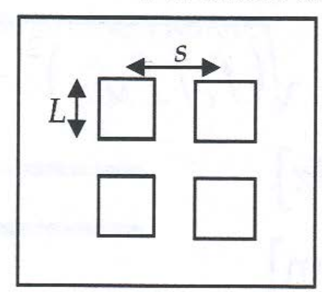


$$SE \approx \frac{32d}{D} + 20 \log \left(\frac{s}{D}\right)^2$$

Suojan paksuus d

$$\frac{\lambda}{2} > D$$

Neliön muotoiset reiät



$$SE \approx \frac{27d}{L} + 20 \log \left(\frac{s}{L}\right)^2$$

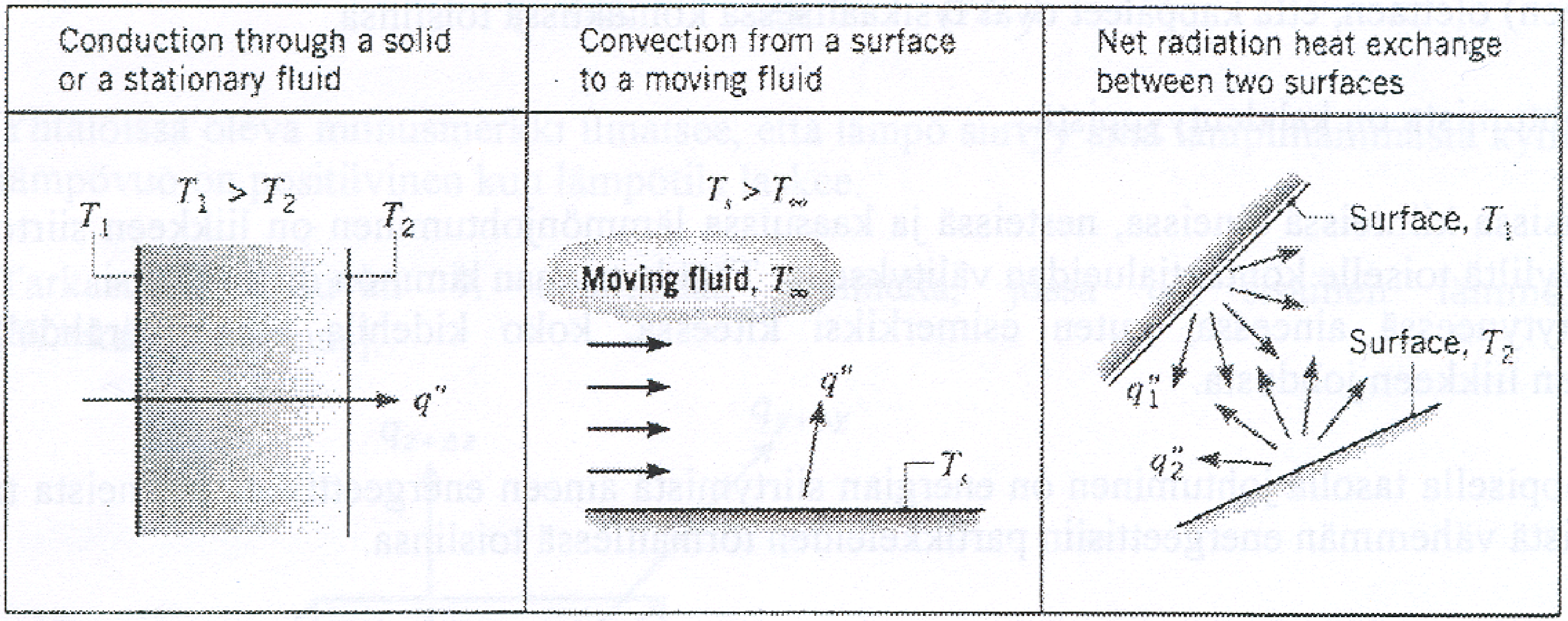
Suojan paksuus d

$$\frac{\lambda}{2} > L$$

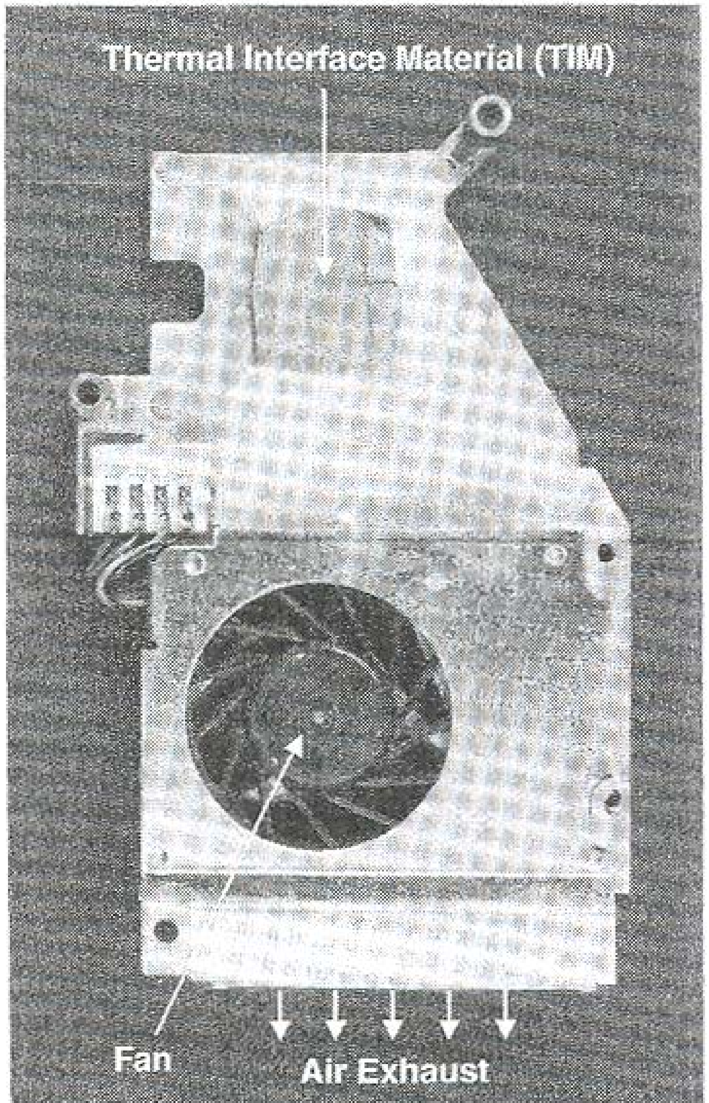
Conclusions

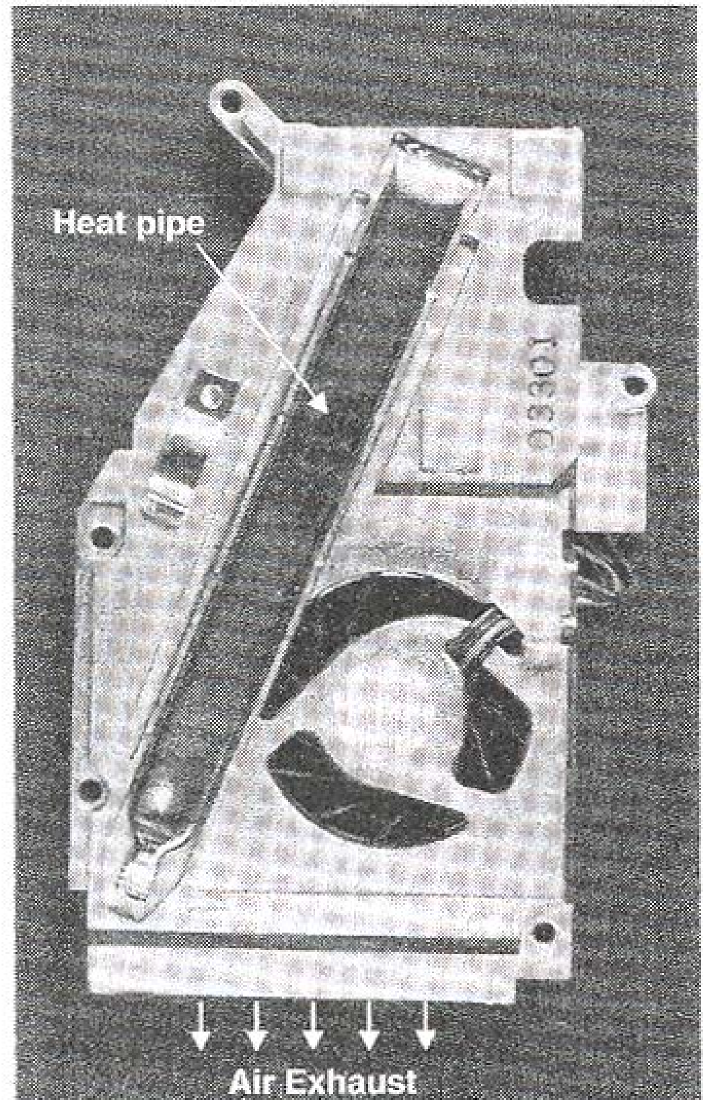
- We have to know what has to be protected and which is the threat
- Multilayer solutions tend to give good results
- Improper feedthroughs spoil the result
- Conductivity of joints must be guaranteed

Thermal issues and cooling



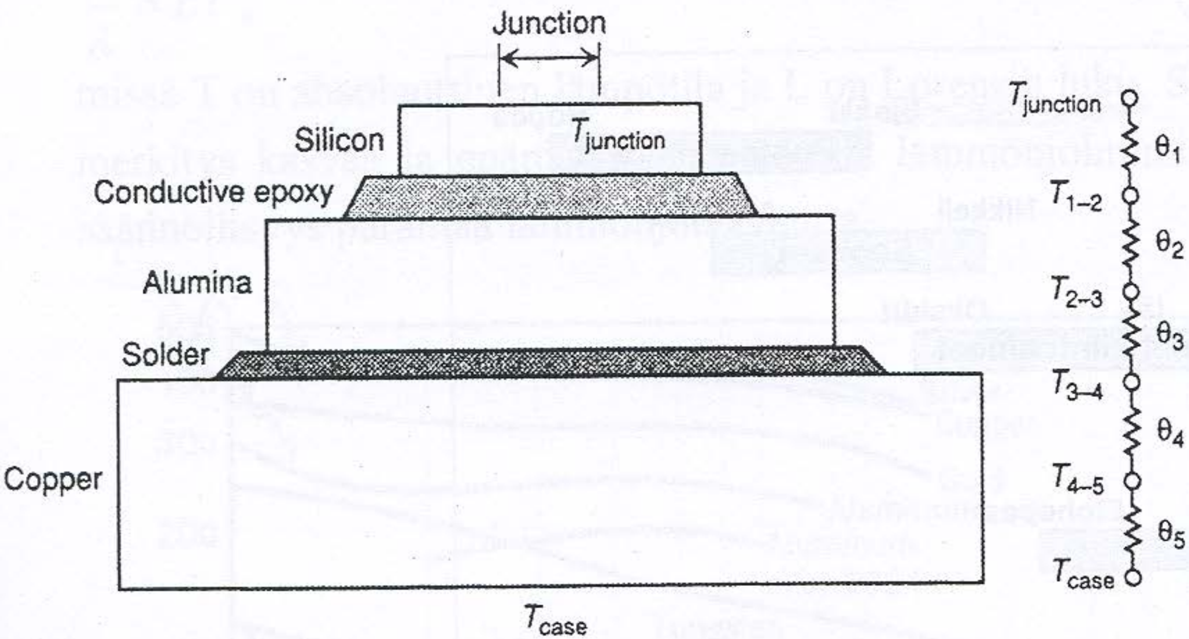
Convection cooling





Thermal conduction and radiation

$$\theta_{\text{equiv}} = \theta_1 + \theta_2 + \theta_3 + \theta_4 + \cdots + \theta_N$$



θ_1 = thermal resistance of die

θ_2 = thermal resistance of die attach

θ_3 = thermal resistance of substrate

θ_4 = thermal resistance of substrate attach

θ_5 = thermal resistance of package

T_j = junction temperature

T_{case} = case temperature

TDP

- Thermal Design Power = power consumed

$$P = Cv^2 f$$

- Controlling the supply voltage or clock frequency

$$TDP = \frac{T_{die,\max} - T_{external}}{\theta_{die-external}}$$

- Chip architecture

Temperature and mechanical strength

- Joints on printed circuit boards
- Components, enclosures
- Stability of EMC

Stack factor

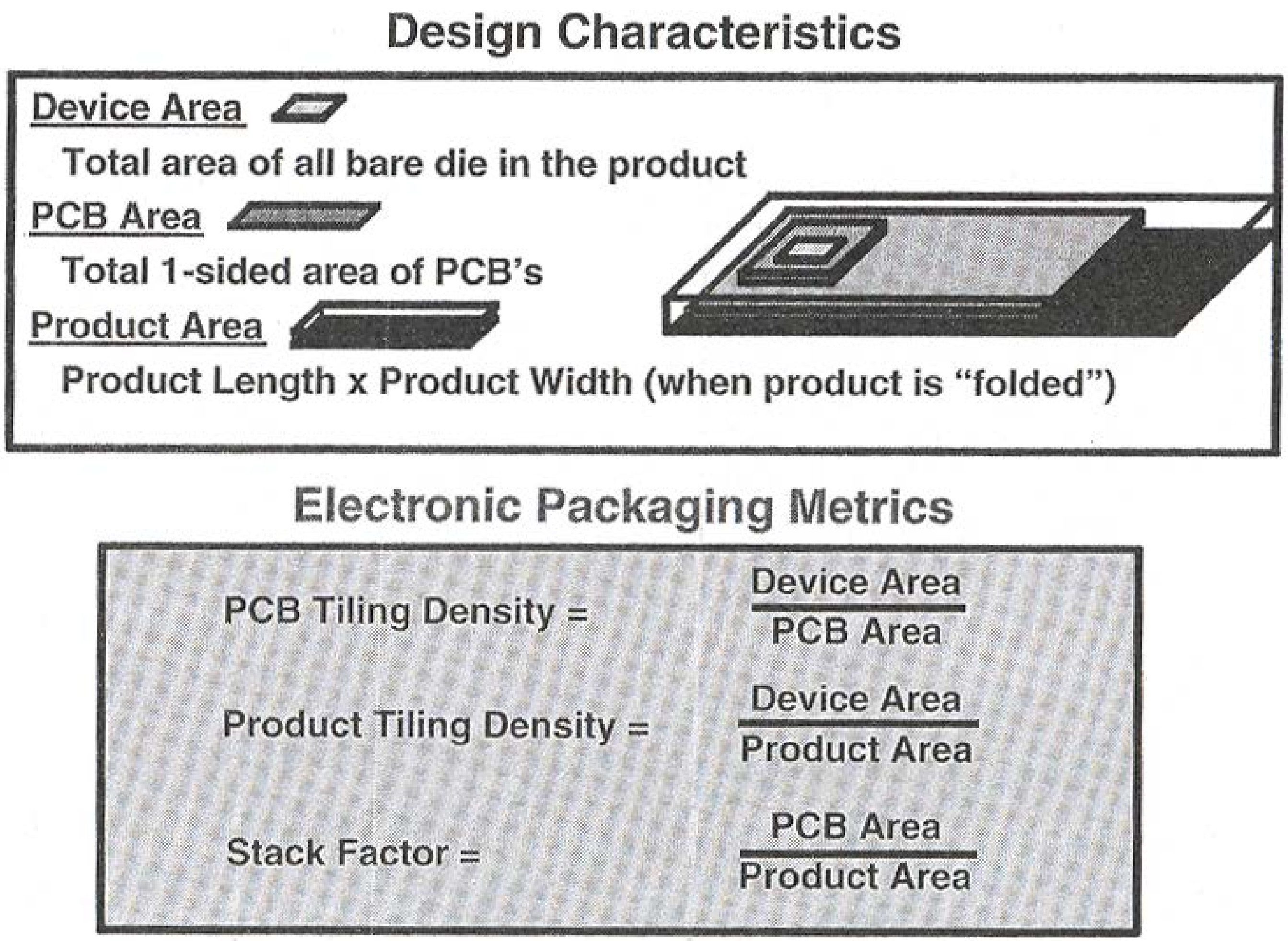


Figure 6.25 Stack factor.