Williams, Tim. *EMC for product designers*. Newnes, 2016.

Electromagnetic Interference (EMI)

the Clumpany, 2017

Electromagnetic Interference (EMI)

The Heusweiler Motorway Faraday Cage

Electronic equipment must be switched off during take-off and landing…

Clothing, shoes, and optical stores…

EMC Directive

- The ability of the system to operate without interfering with other systems
- The ability of the system to operate despite interference from other systems
- Under *typical* conditions (domestic, commercial, industrial)

RAISE Technology Co., Limited

Certificate of Conformity

VERIFICATION OF EMC COMPLIANCE

Verification No.	:	RK12E06032
Applicant	:	ZHONGSHAN KINGRONG ELECTRONICS CO.,LTD
Address	:	32, Cuihuju, YangguangMeijia, No.138 MinAn Rd South, Xiaolan, ZhongShan, Guangdong 528415 China
Manufacturer	:	ZHONGSHAN KINGRONG ELECTRONICS CO.,LTD
Address	:	32, Cuihuju, YangguangMeijia, No.138 MinAn Rd South, Xiaolan, ZhongShan, Guangdong 528415 China
Product Name	:	Switching power supply(AC/DC adaptor)
Model Number	:	KRE-XXXYYYZ "xxx"=030-480, the output voltage is: DC3.0-48.0V; "yyy"=001-450, the output current is: 0.01-4.5A; "Z" representing the input plug, 0-European plug, 1-BS plug, 2-Australian plug; 3-USA plug, 4-Japan plug, 5-China plug, 6-Korea plug, 7-South Africa plug, 8-Brazil plug, 9-Argentina plug
Trade Mark	:	KRECO, BILLY
Rating:	:	Input: AC100~240V ,50/60Hz, 1.0A max
Test Standards	:	EN 55022:2010+AC:2011 EN 61000-3-2:2006+A1:2009+A2:2009 EN 61000-3-3:2013 EN 55024:2010

As shown in the
Test Report Number(s): RK12E06032-00

This verification of EMC Compliance has been granted to the applicant based on the results of the tests, performed by laboratory of Shenzhen Raise Technology Co., Ltd. on the sample of the above-mentioned product in accordance with the provisions of the relevant specific standards and Directive 2014/30/EU. The CE mark as shown below can be used, under the responsibility of the manufacturer, after completion of an EC Declaration of Conformity and compliance with all relevant EC Directives.

Attestation By: Klan Liu (Manager)

Issued date: May 20, 2016

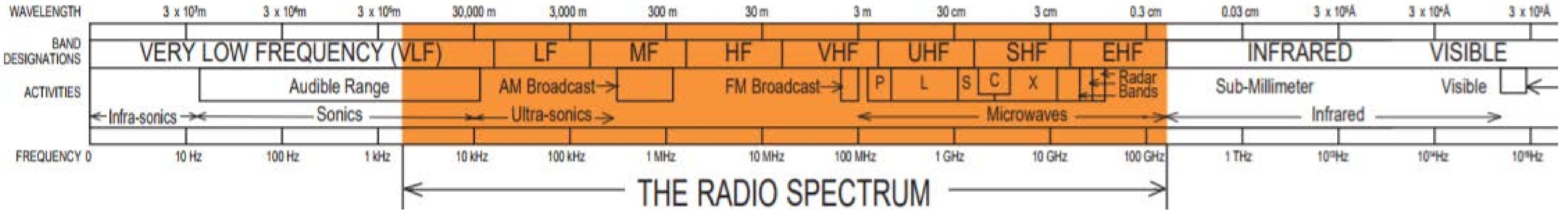
Shenzhen Raise Technology Co., Ltd
Address: Room 1208, West Building, Nanshan Digital Culture Industry Base,Nanshan District, Shenzhen, China
Tel:+86-755-26445590 Fax:+86-755-86052680
Http://www.raise-sz.com E-mail:info@raise-sz.com

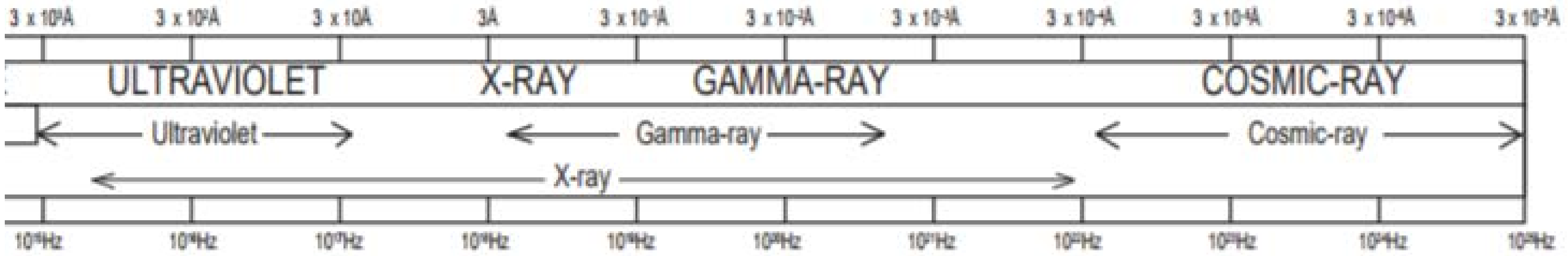

AFP

Sources of Interference

- Supply voltage interruptions: dips, surges, and fluctuations
- Transient over-voltages on supply, signal, and control lines.
- Radio-frequency fields, both pulsed (radar) and continuous, coupled directly onto equipment or onto its connected cables.
- Electrostatic discharge (ESD) from a charged object or person.
- Low frequency magnetic or electric fields.

Radio Spectrum





UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRU

RADIO SERVICES COLOR LEGEND

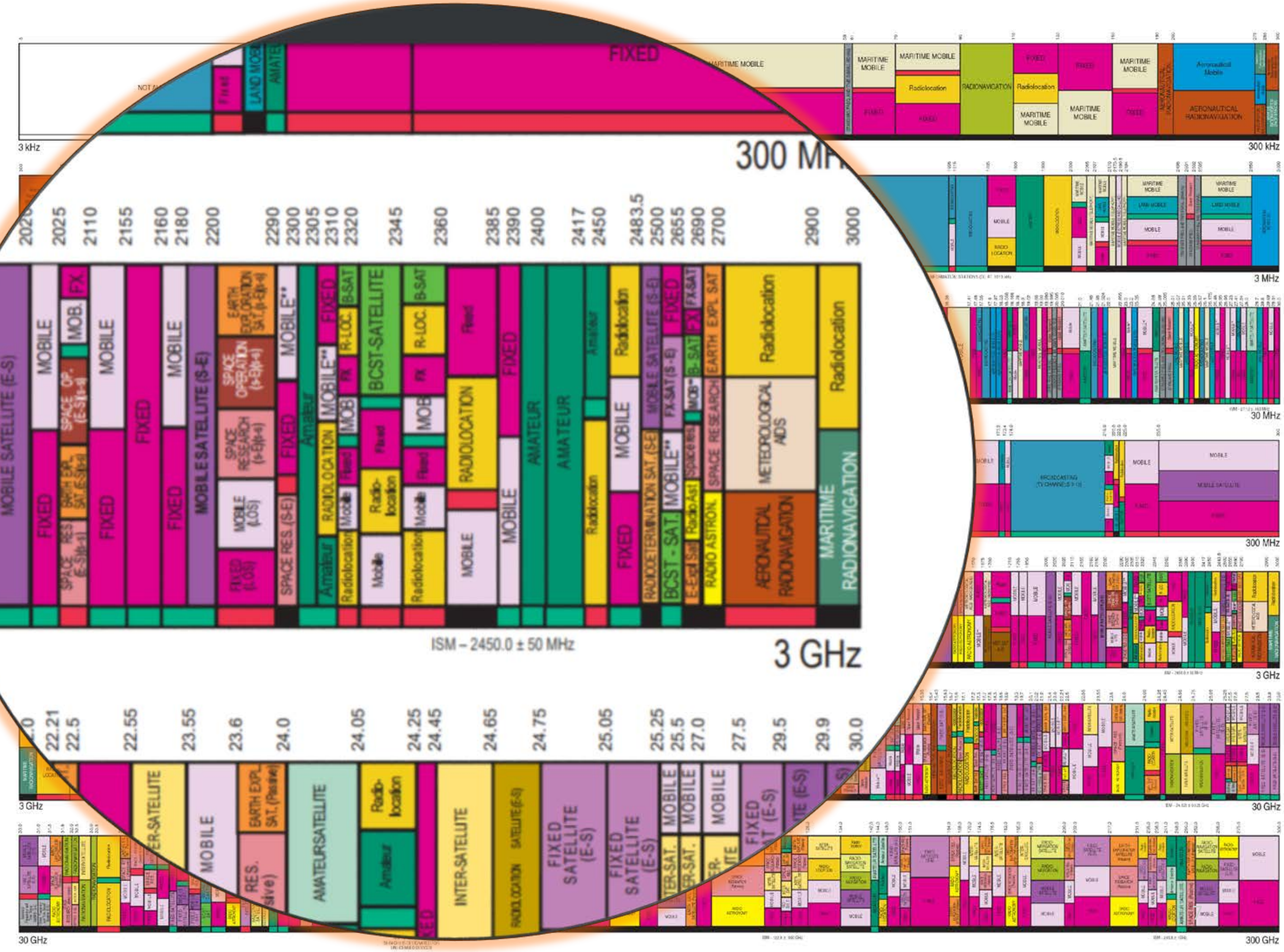
- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL AIDS
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

- GOVERNMENT EXCLUSIVE
- GOVERNMENT/ NON-GOVERNMENT SHARED
- NON-GOVERNMENT EXCLUSIVE

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters



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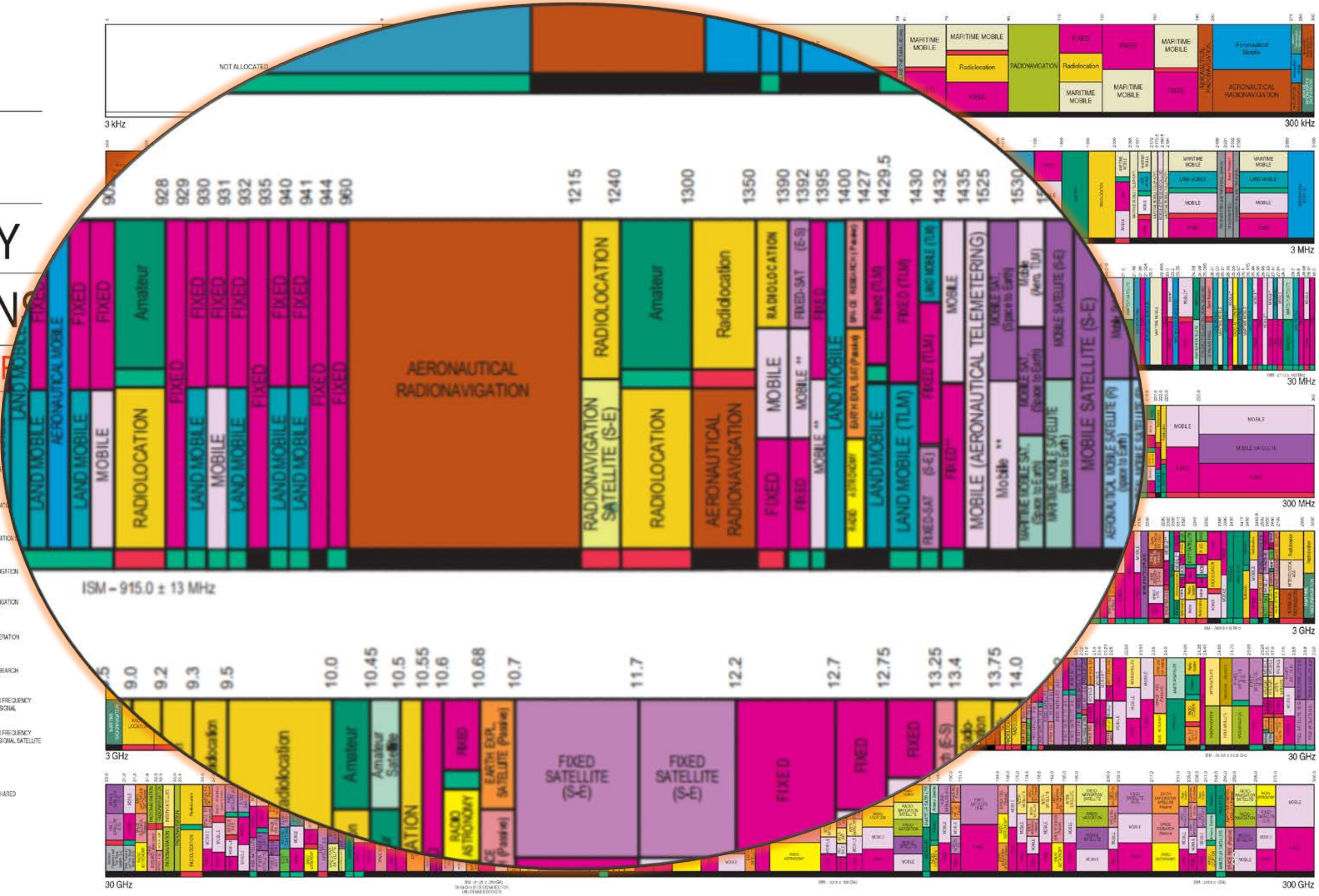


Disturbances on the Mains Supply

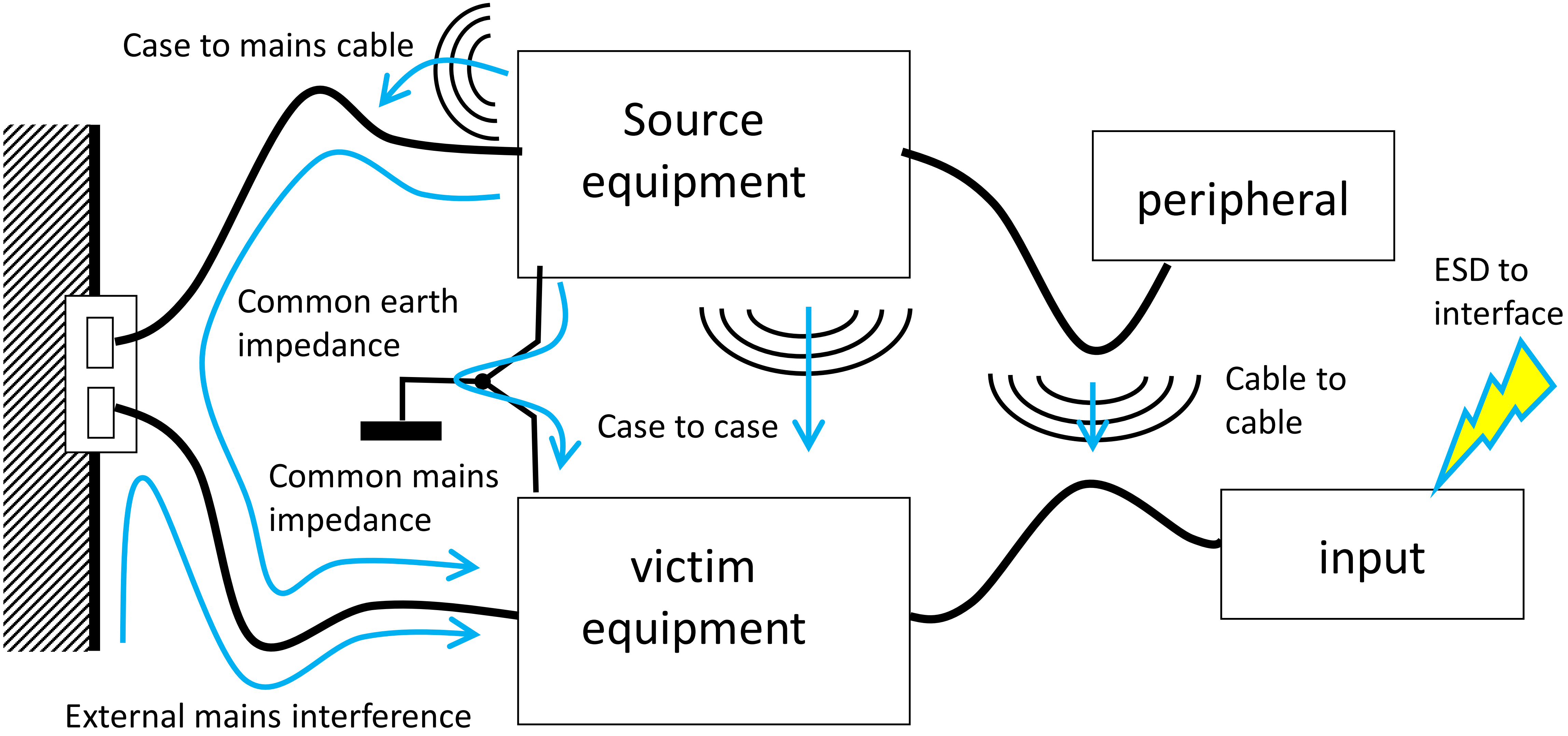
- *An perfect power supply is not cost-effective!*
- Voltage variations
- UK: ±10%
- US: National Electric Code (NEC) recommends ±3% in households
- Voltage fluctuations
- Voltage interruptions
- Waveform distortion
- Reactive impedances and harmonic currents
- Transients and surges

Disturbances on the Mains Supply

- Mains Signaling
  - Superimposed signals (3kHz-150kHz)
  - No extra wiring/aerial emission required
  - Installation can be as simple as plugging in the system components
  - No frequency variation from country to country or licensing issues

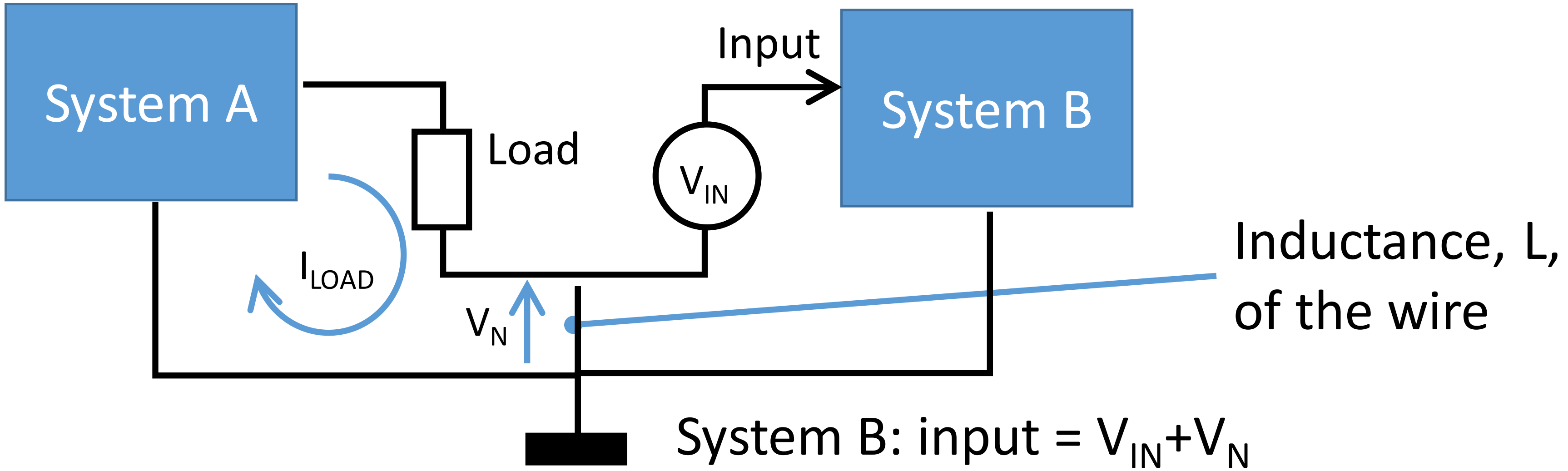
- ….Same frequency band as motors, power supplies, fluorescent

Electromagnetic Interference

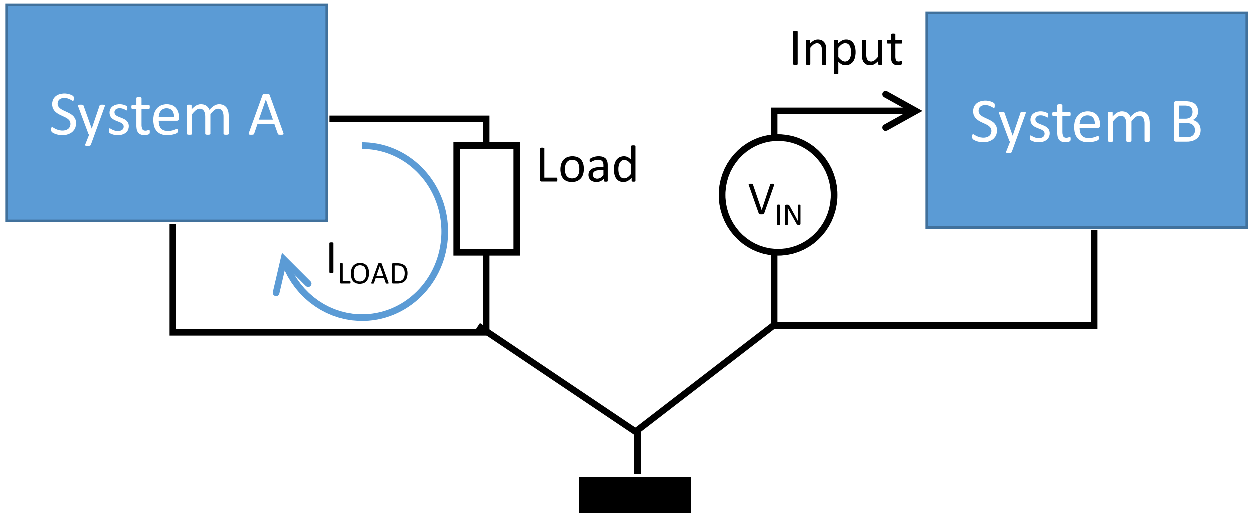


Common Impedance Coupling

PROBLEM:

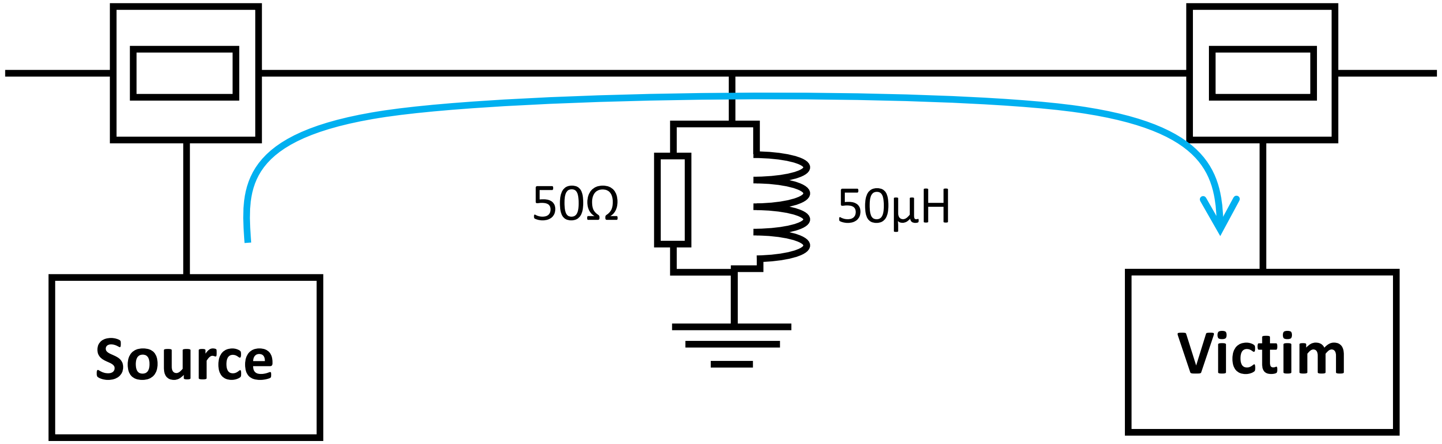


SOLUTION:

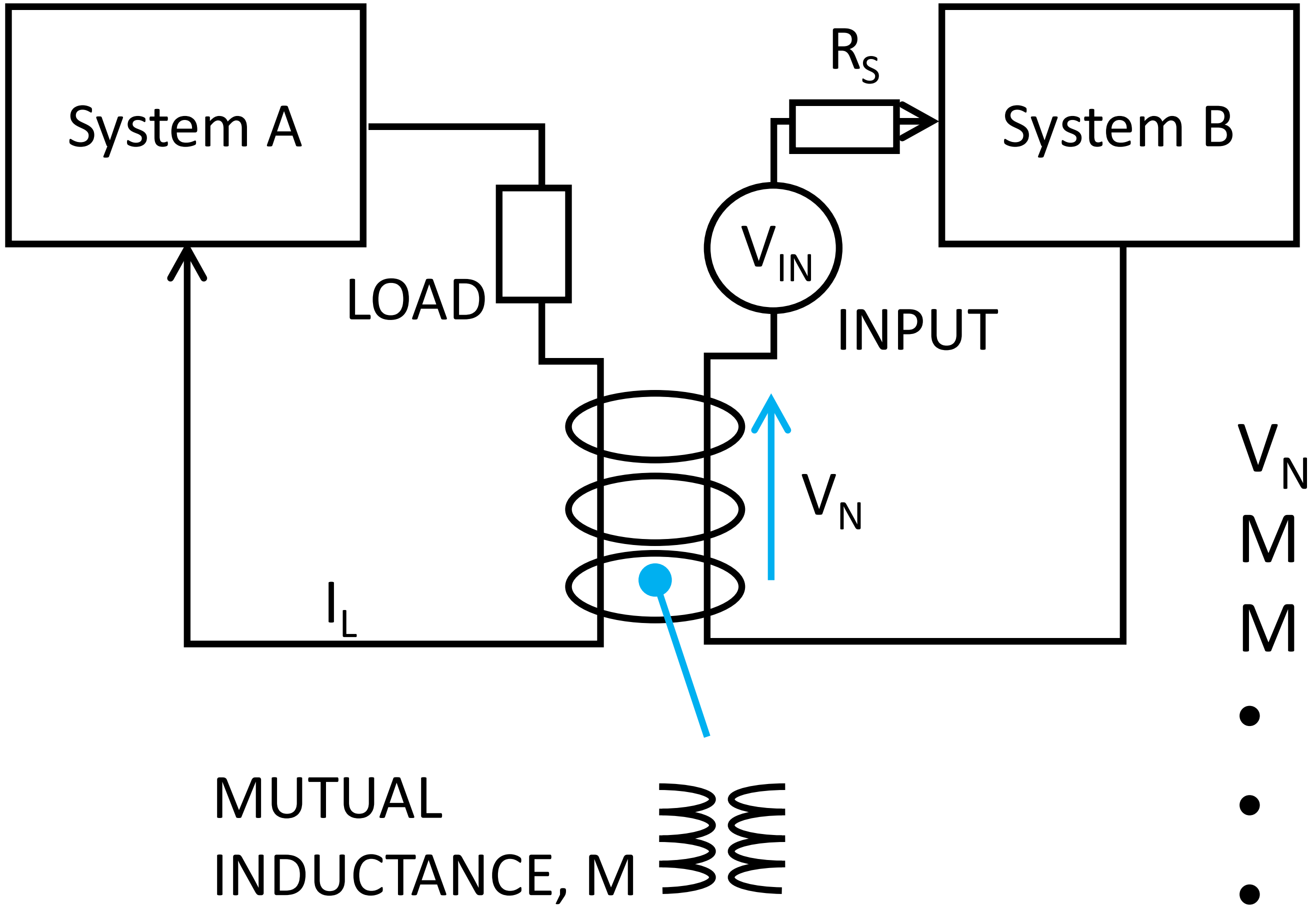


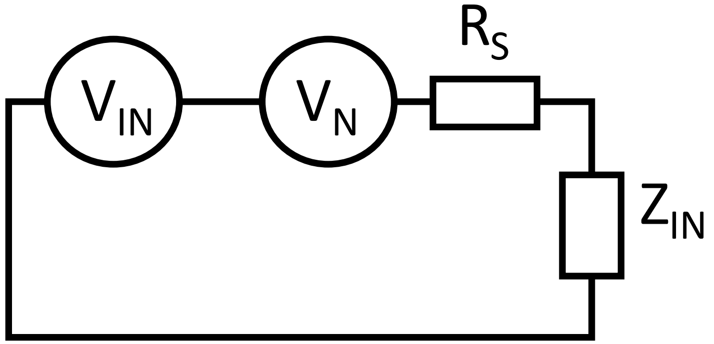
Mains Coupling

Mains equivalent circuit model



Magnetic Inductance





EQUIVALENT CIRCUIT
(magnetic coupling)

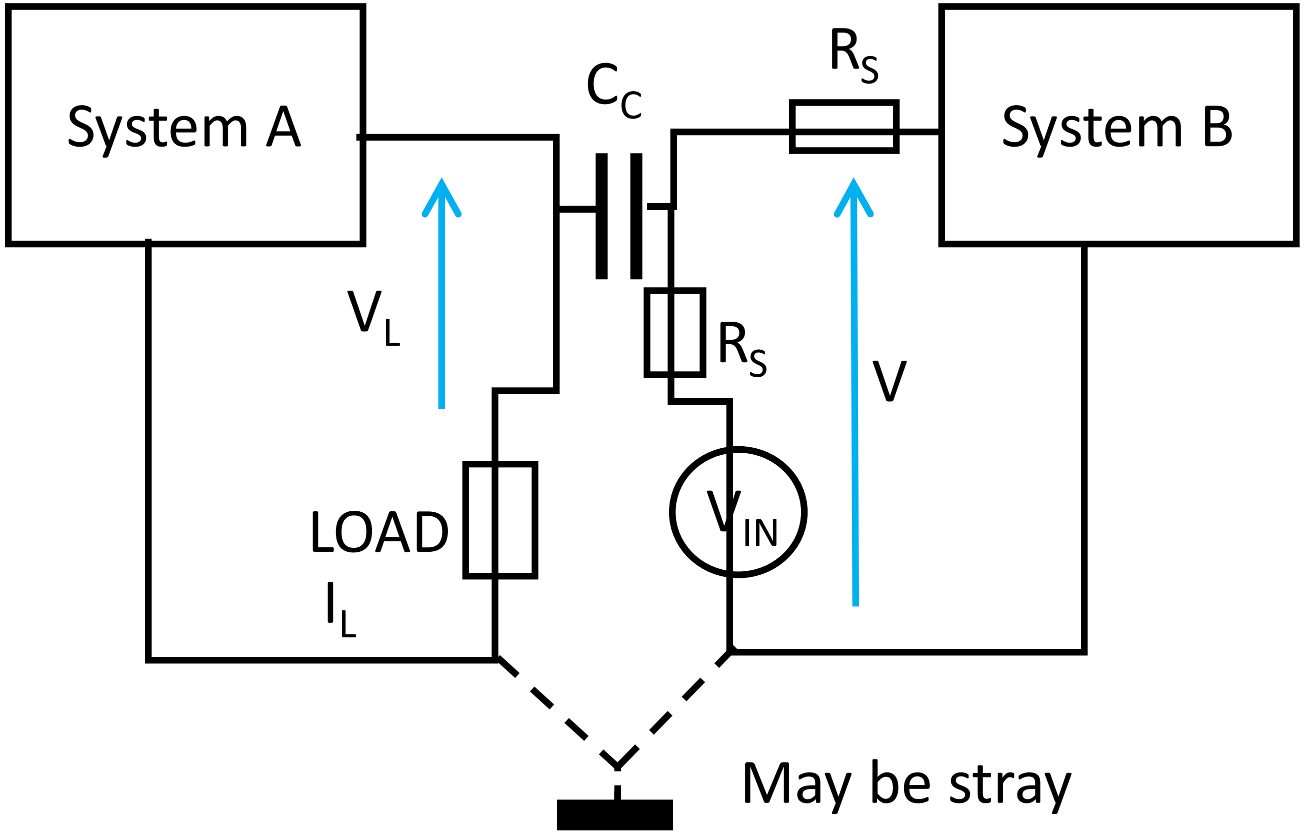
$V_N = -M*dI_L/dt$

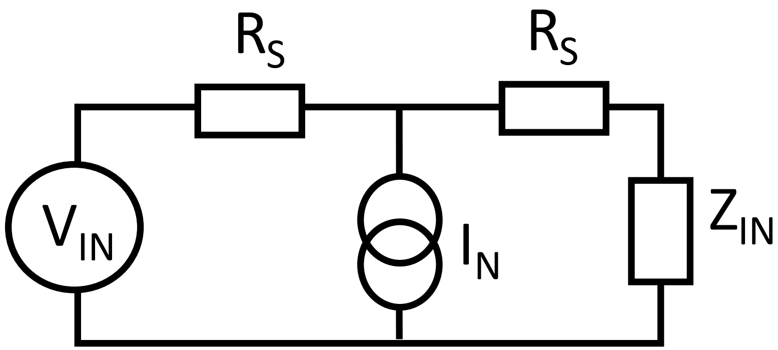
M = mutual inductance [H]

M depends on…

- Loop area
- Loop orientation
- Distance between loops
- Screening material

Electric Inductance





EQUIVALENT CIRCUIT
(electric coupling)

$V_N = C_C*dV_L/dt * Z_{in}//R_S$

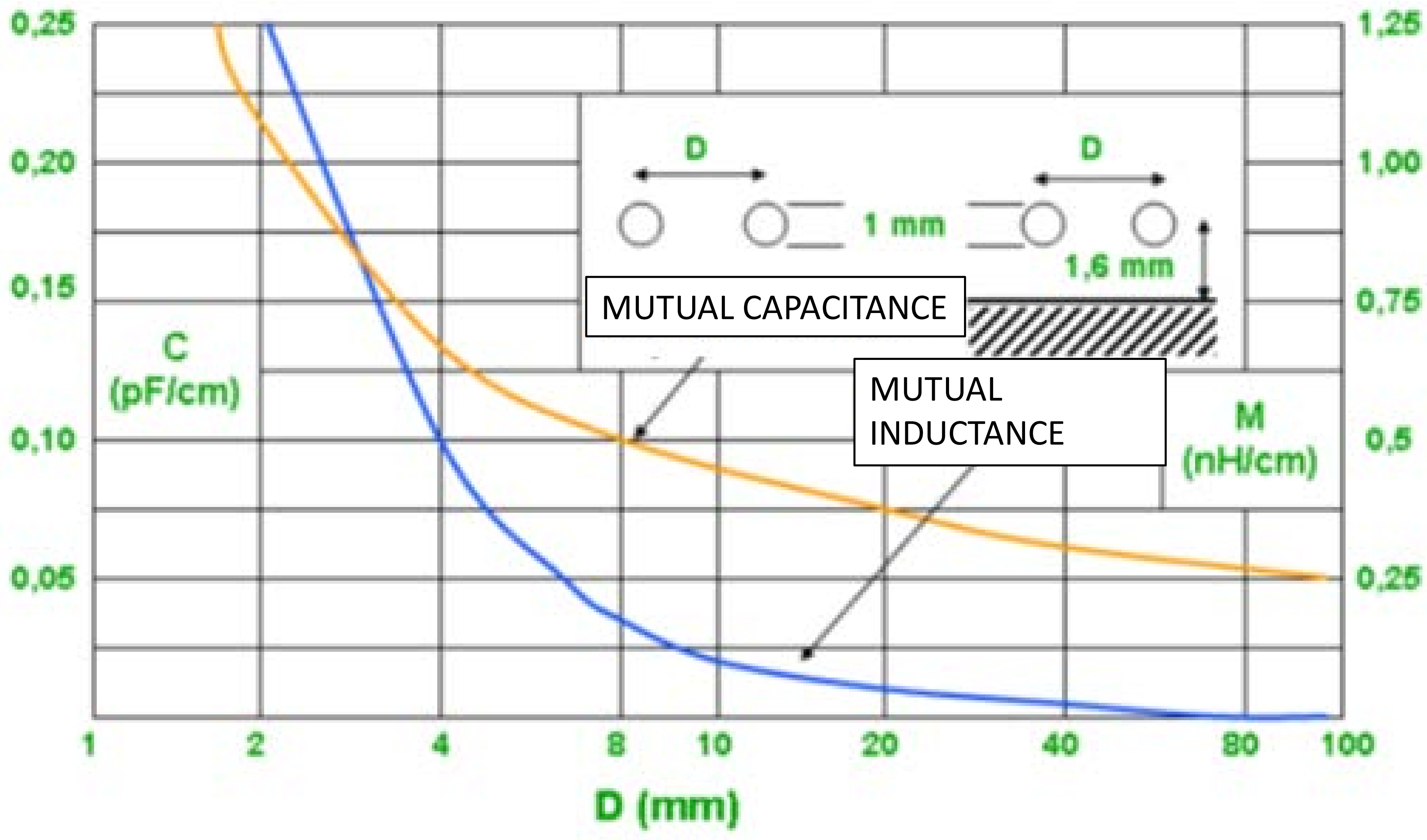
C_C is the coupling capacitance

$Z_{IN}//R_S$ is victim impedance to ground

C_C depends on…

- Distance between conductors
- Their effective areas
- Screening material

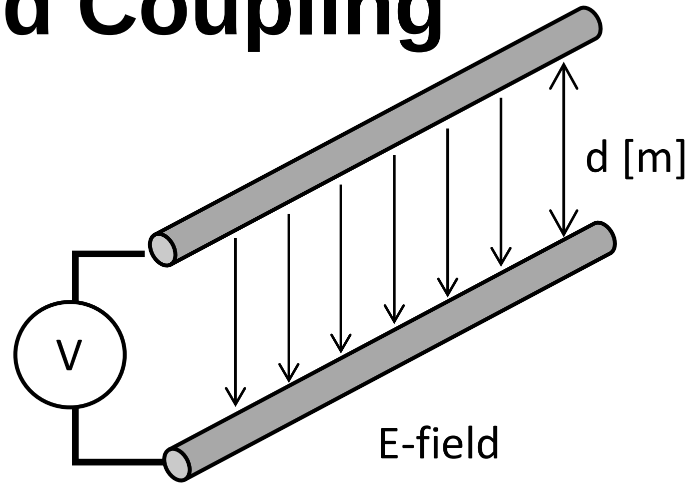
Mutual Capacitance and Inductance

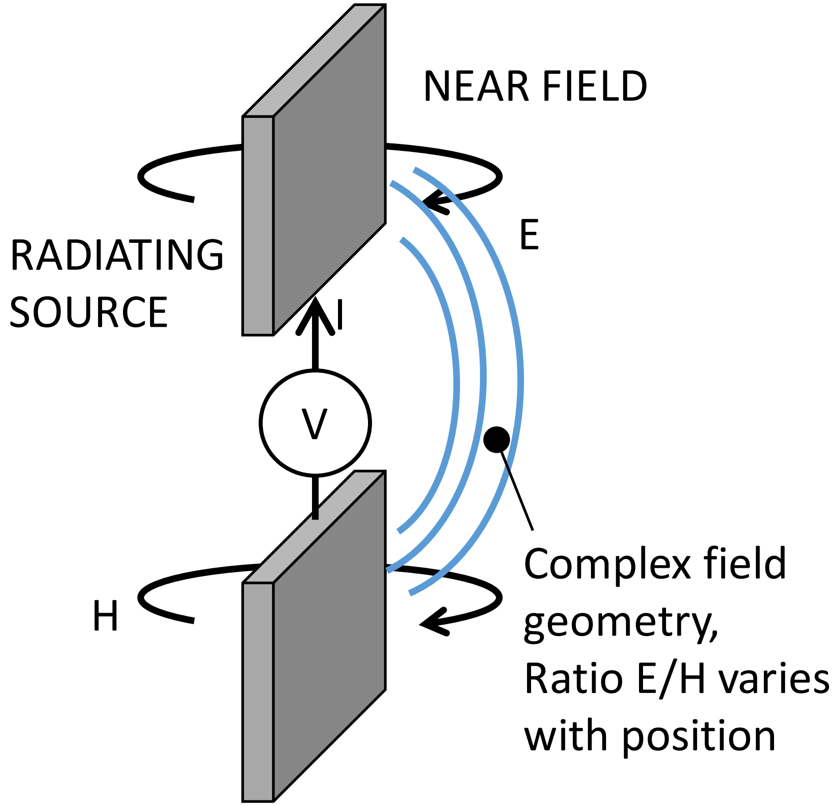


Mutual Capacitance and Inductance

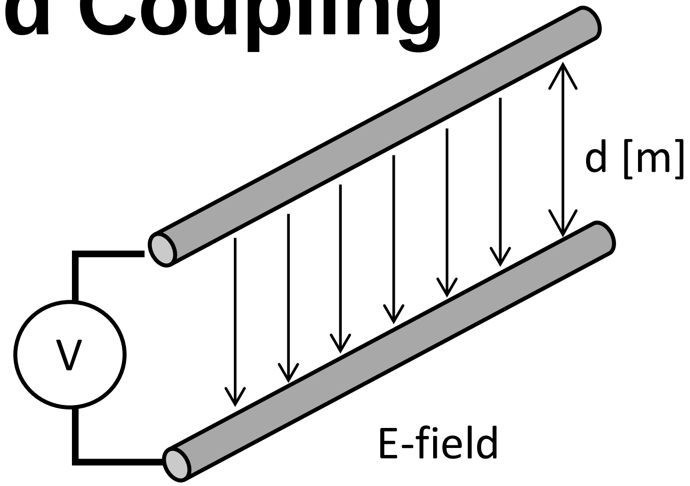
- Electric field coupling increases with increasing Z_{IN}
- Electric coupling is more of a problem for high impedance circuits
- Magnetic field coupling decreases with increasing Z_{IN}
- Magnetic coupling is more of a problem for low-impedance circuits

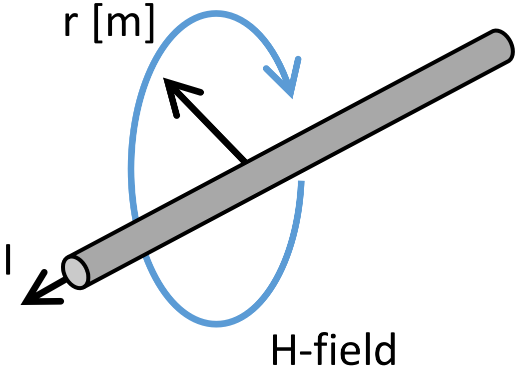
Radiated Coupling

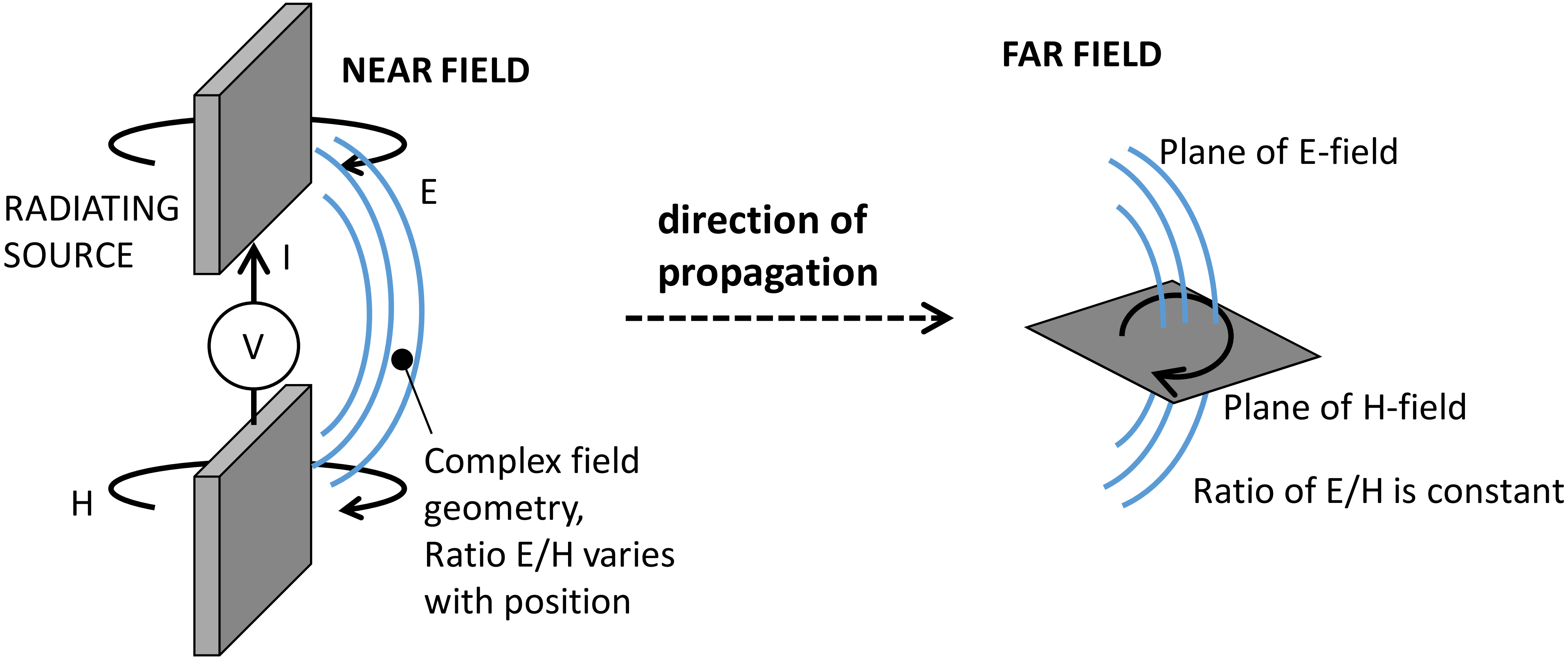




Radiated Coupling

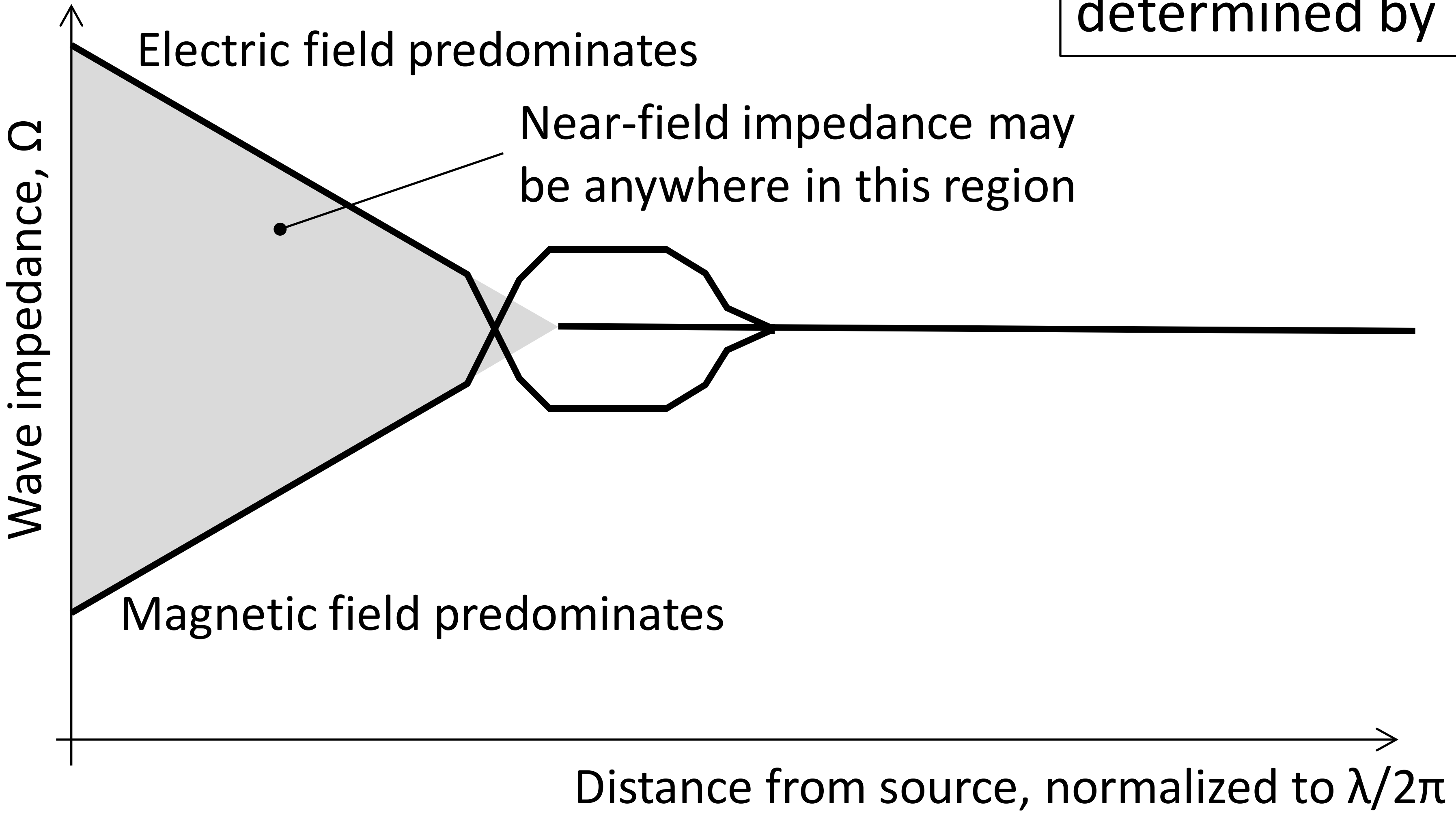




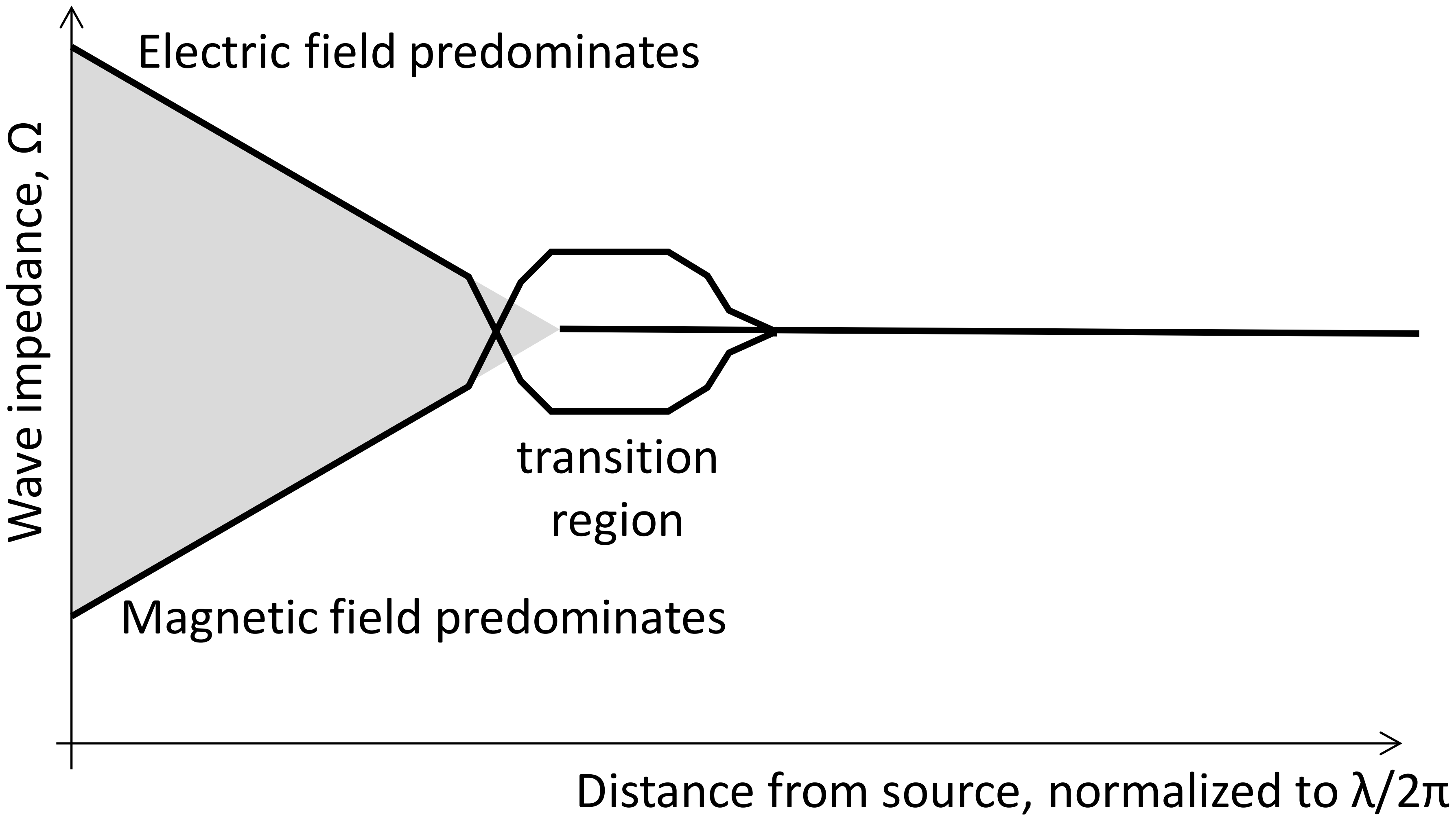


Radiated Coupling

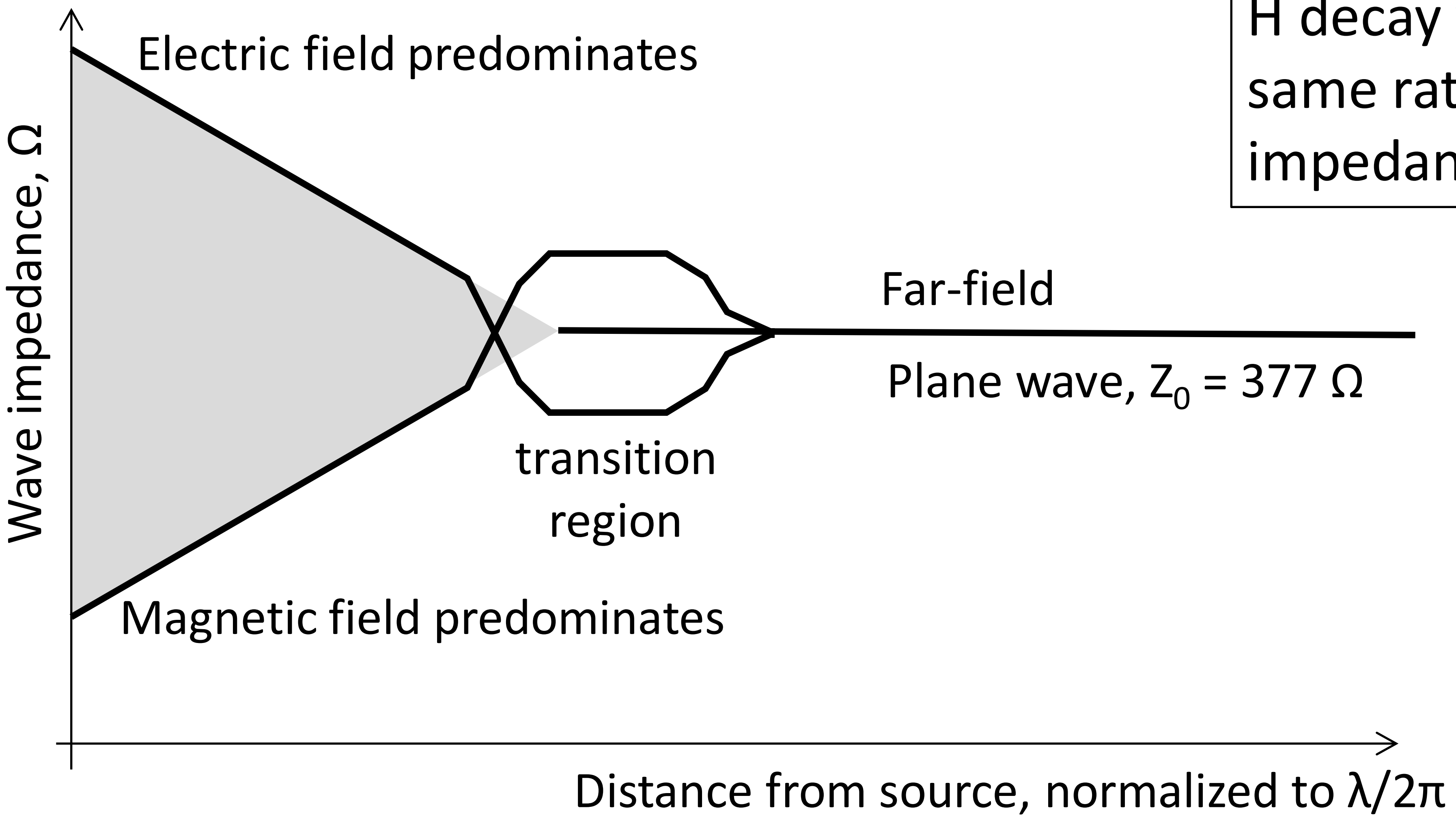
Near field; wave impedance determined by Maxwell's equations



Radiated Coupling

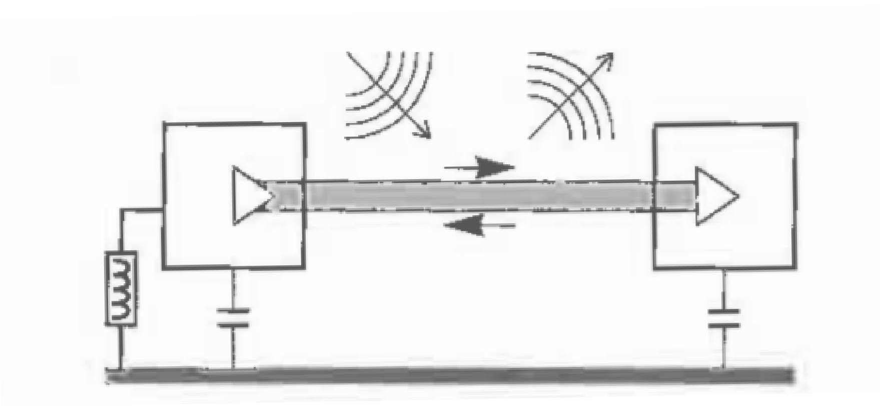


Radiated Coupling



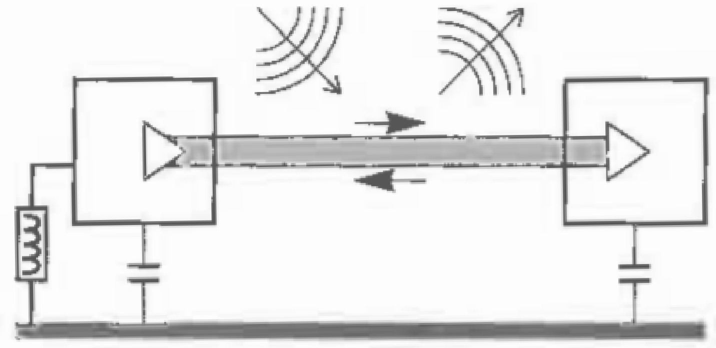
Far field; plane wave. E and H decay with distance at the same rate, therefore the impedance is constant.

Radiated Coupling modes

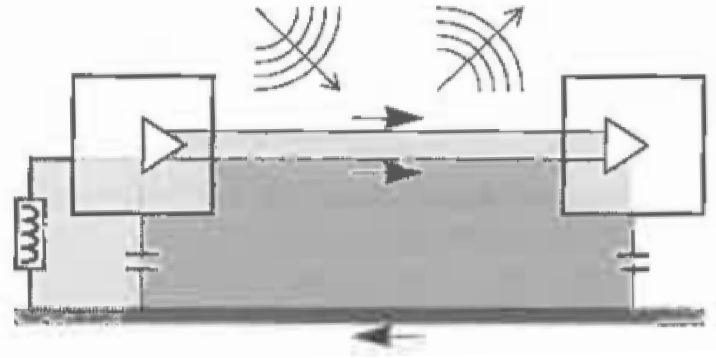


Differential mode

Radiated Coupling modes



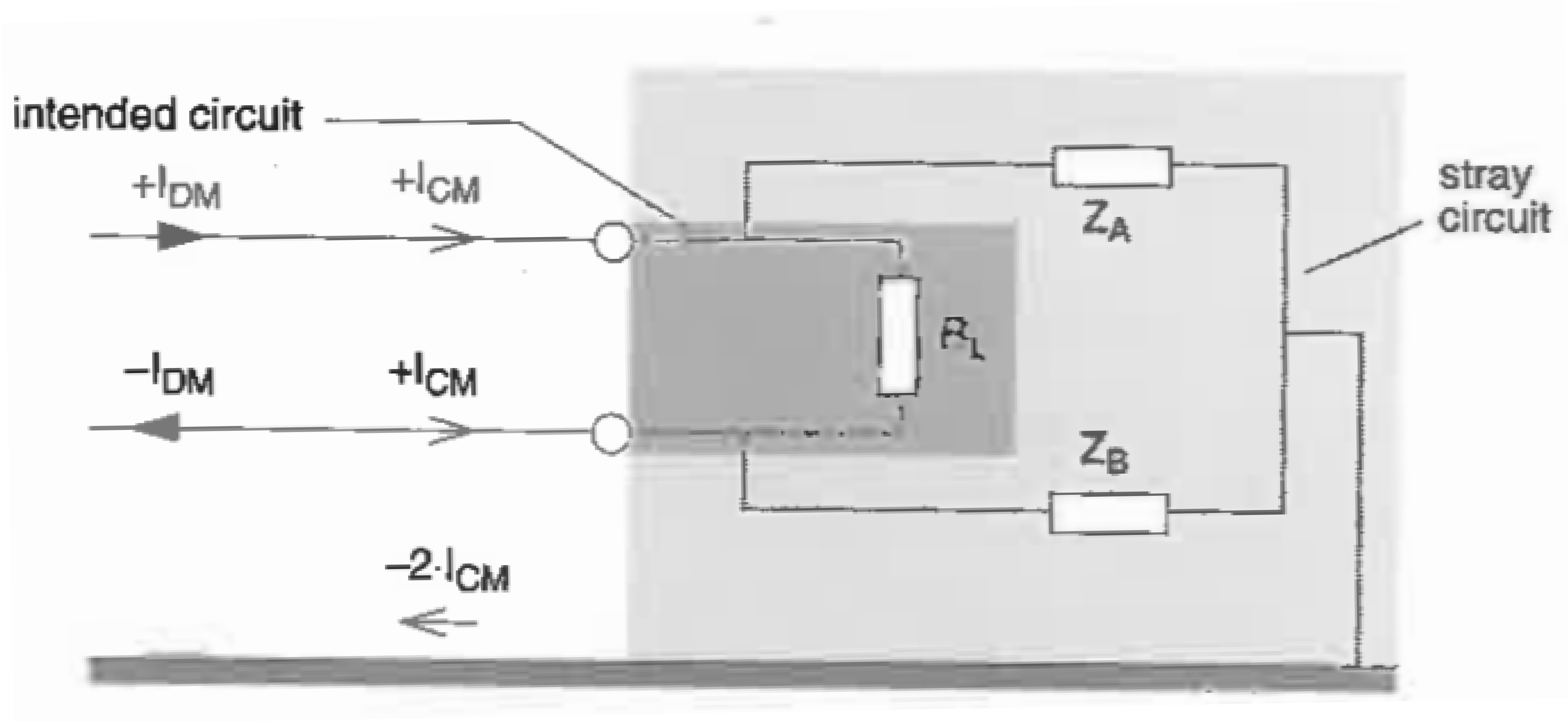
Differential mode



Common mode

(Shaded areas indicate part of circuit that couples with external fields)

Radiated Coupling modes



Radiated Coupling modes

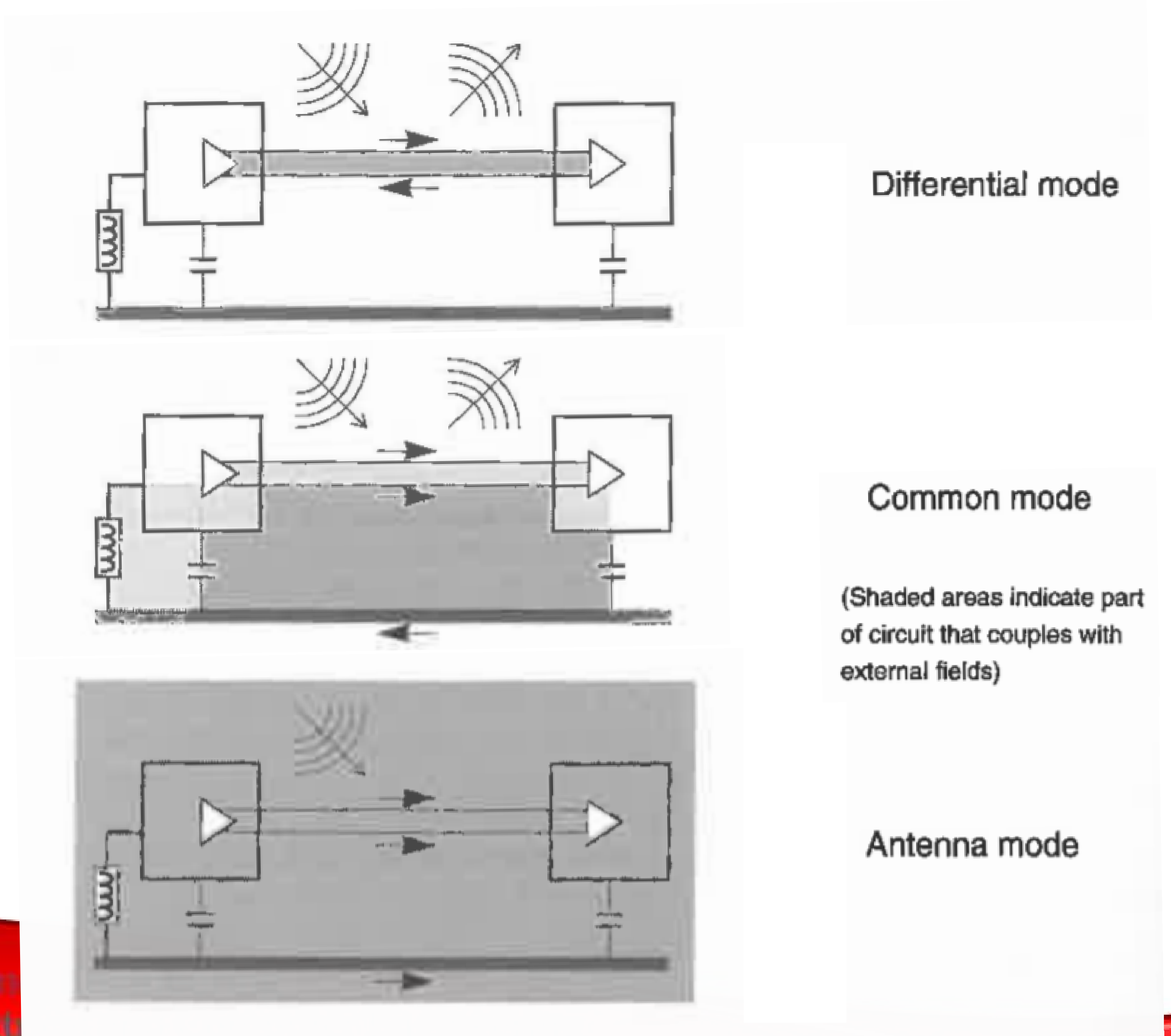


Figure 5.10 Radiated coupling modes

Emissions

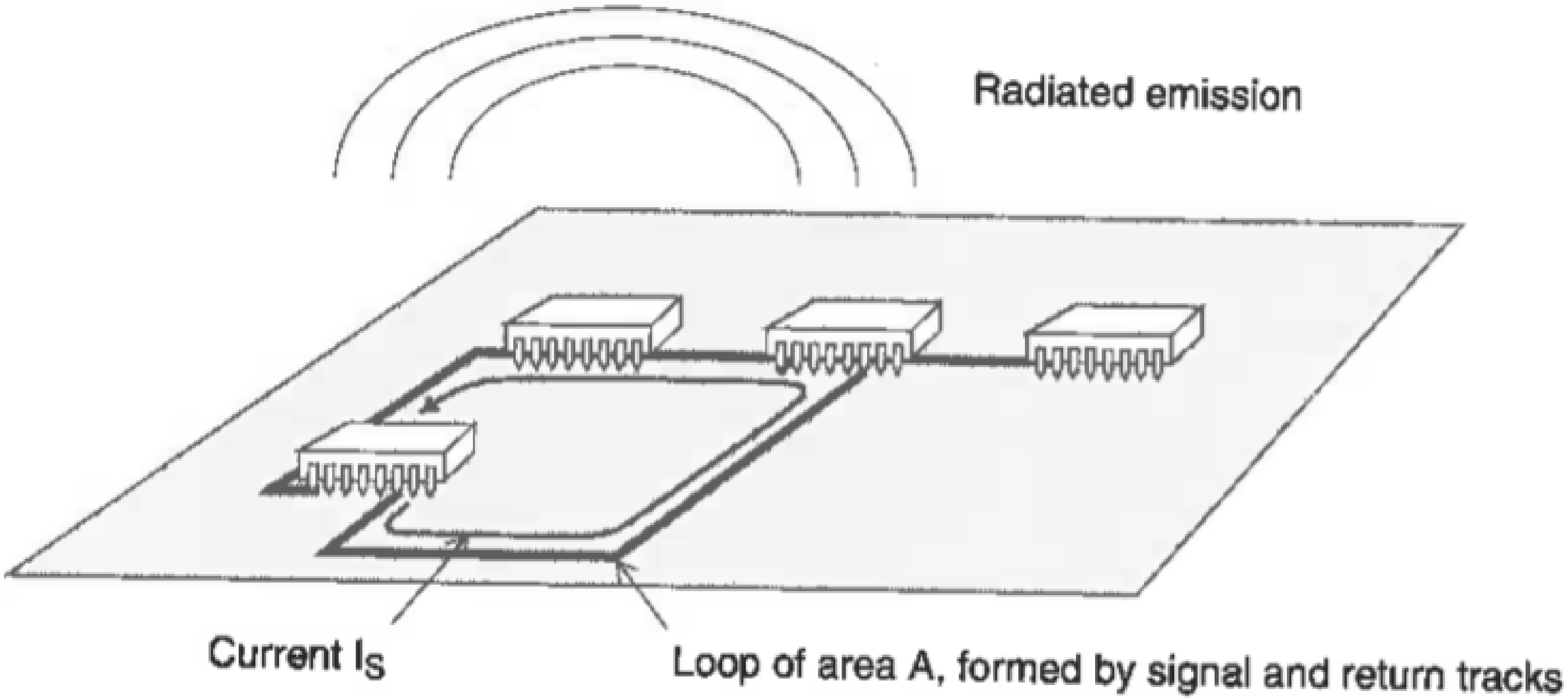


Figure 5.12 PCB radiated emissions

Emissions

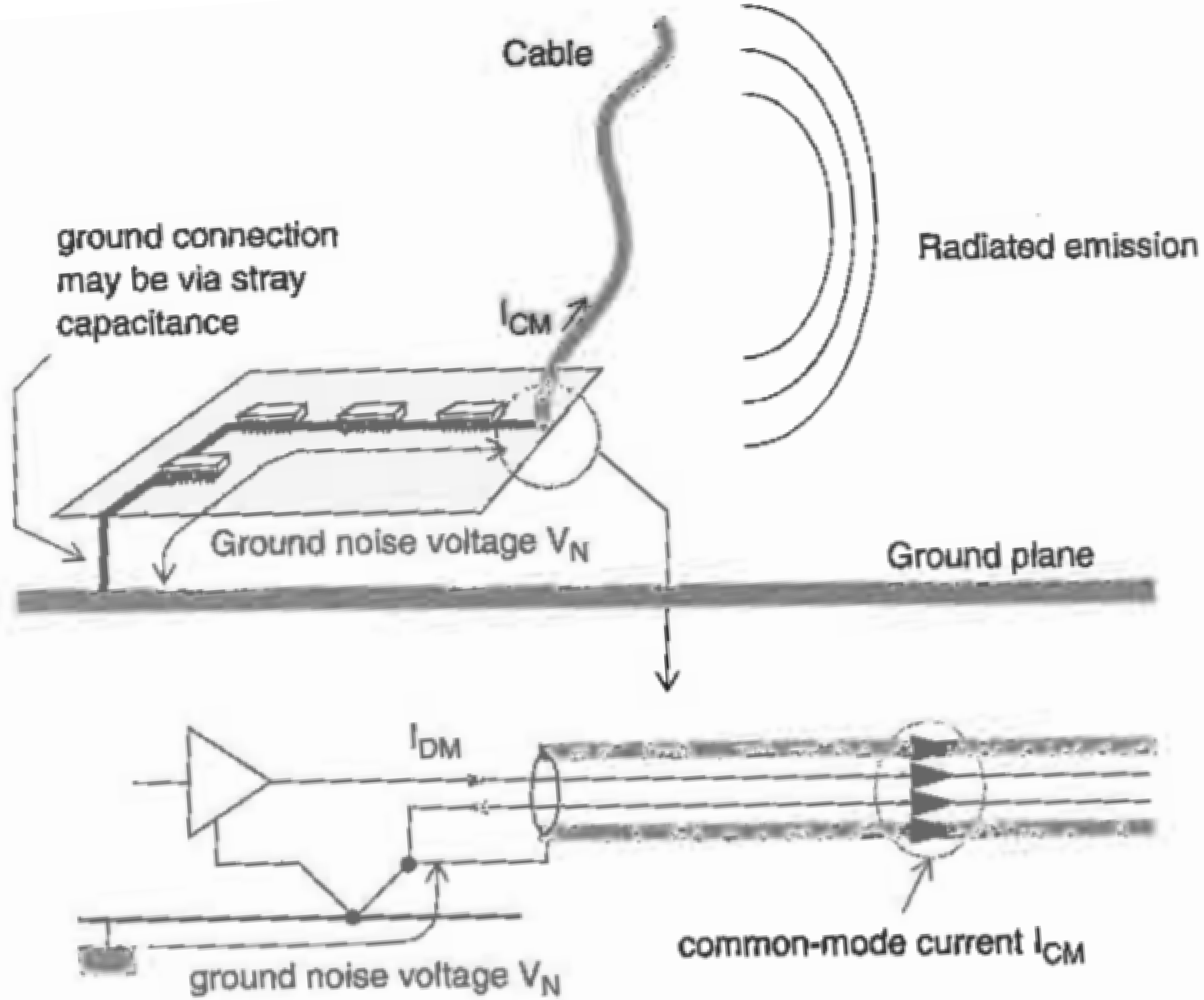


Figure 5.13 Cable radiated emissions

Electrostatic Discharge

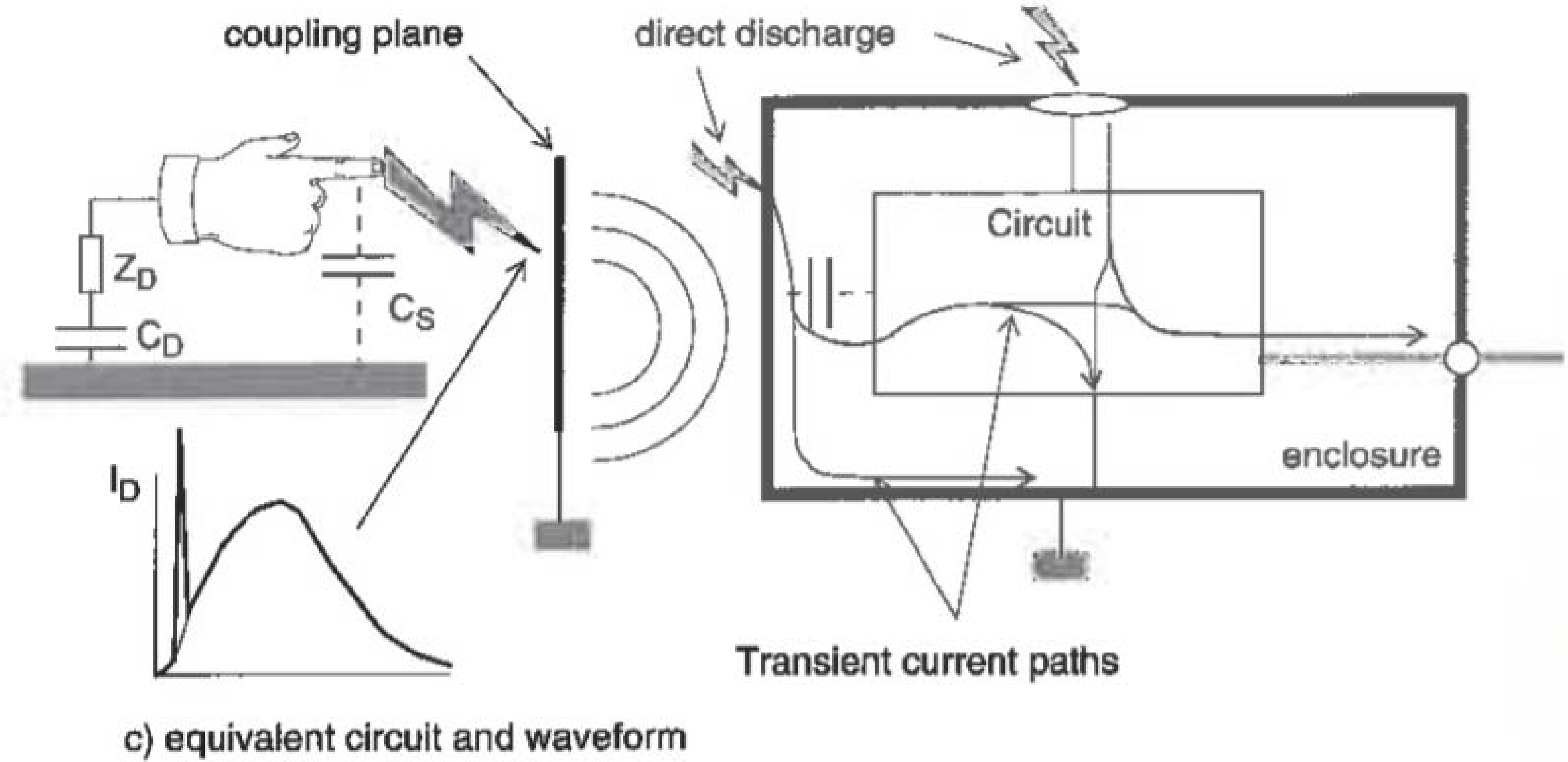
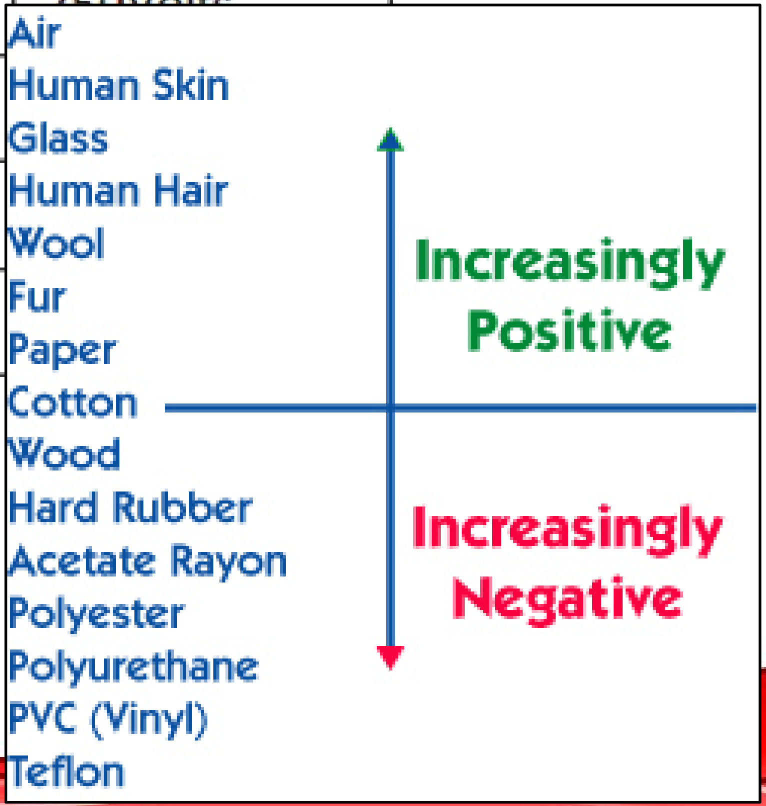


Figure 5.23 The electrostatic discharge

Electrostatic Discharge

Static Voltage Generation at different Relative Humidity (RH) levels		
Generation Method	10-25% RH	60-90% RH
Walking across a carpet	35,000Volts	1,500Volts
Walking across vinyl tiles	12,000Volts	250Volts
Worker at a workbench	6,000Volts	[illegible]
Poly bag picked up from workbench	20,000Volts	[illegible]
Sitting on chair with urethane foam	18,000Volts	[illegible]



Electrostatic Discharge

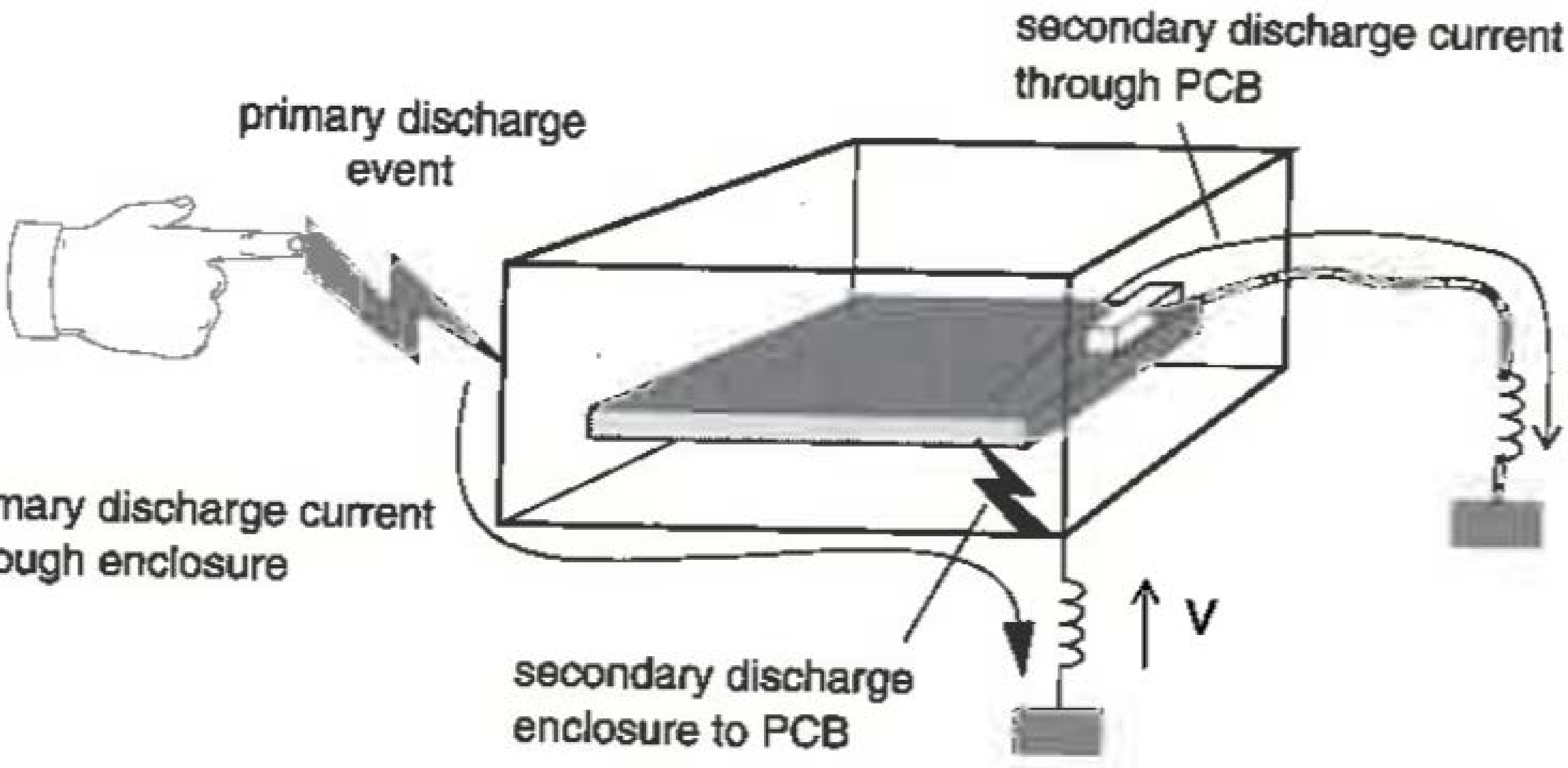


Figure 5.24 The cause of secondary discharge

PCB Layout and Grounding

"Ground is a low-impedance path by which current can return to its source"

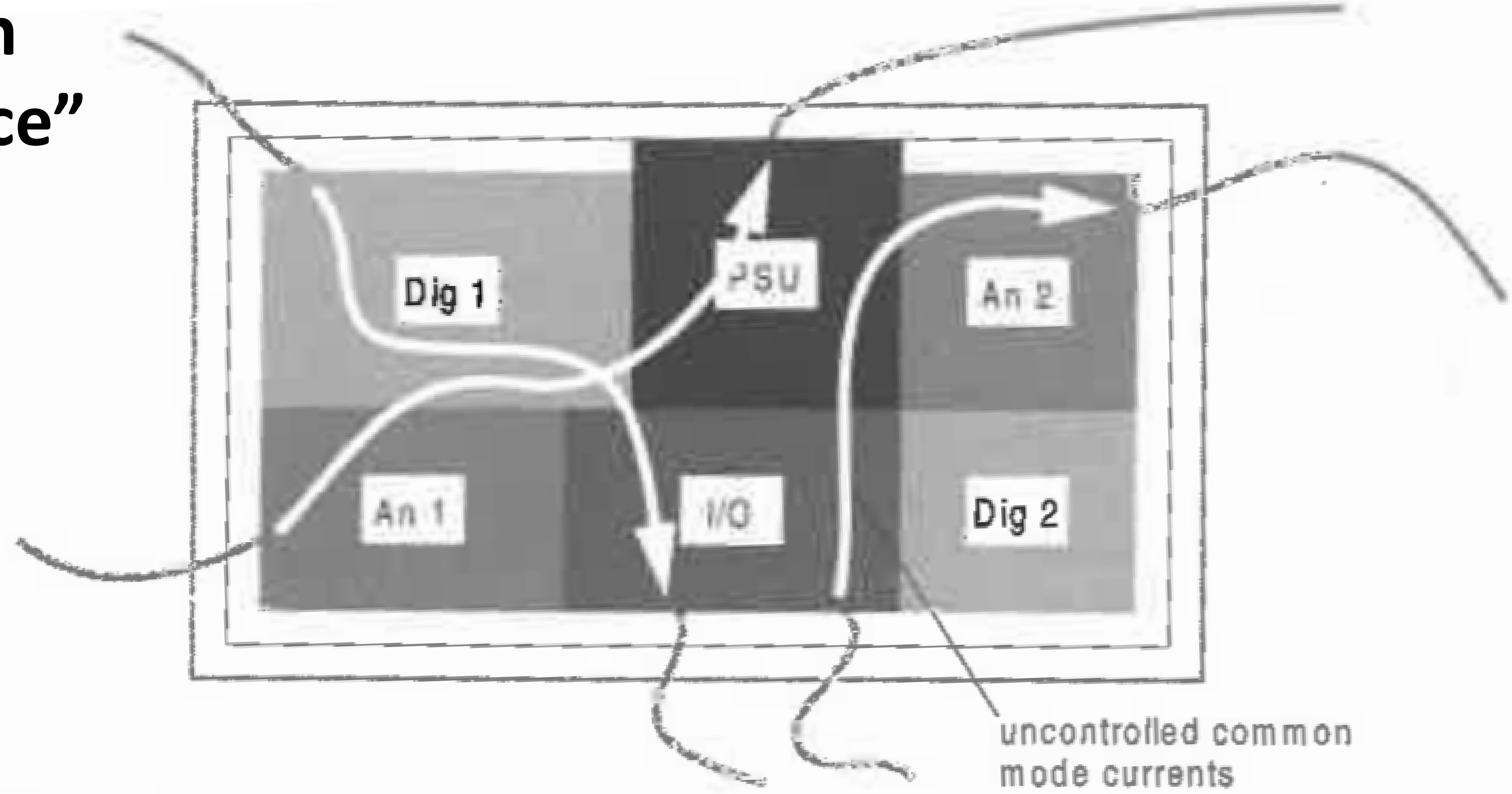
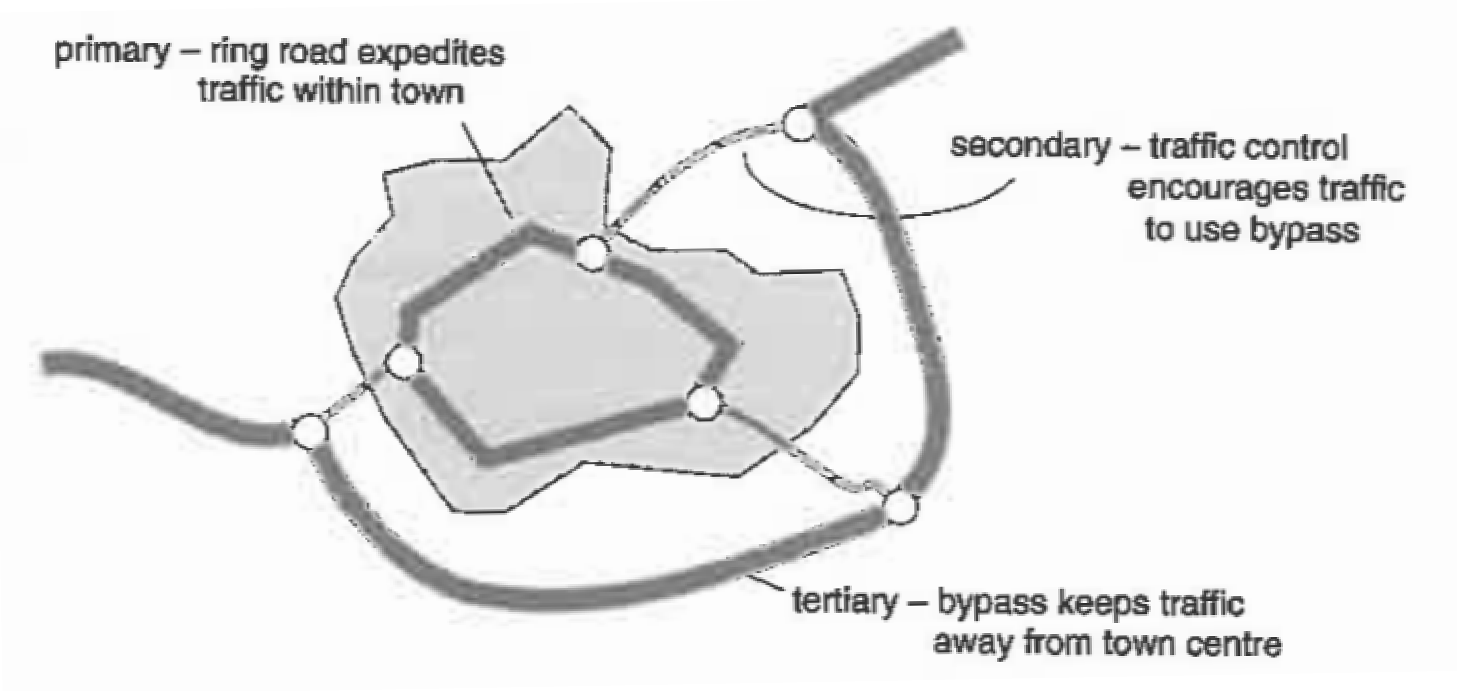
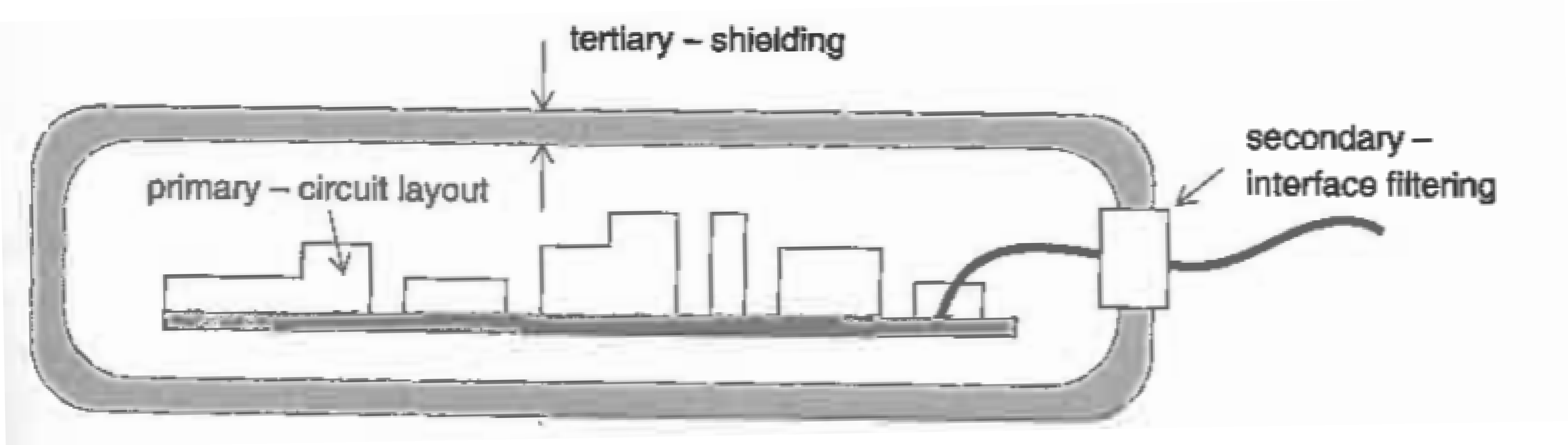


Figure 6.2 The haphazard system

PCB Layout and Grounding

"Ground is a low-impedance path by which current can return to its source"





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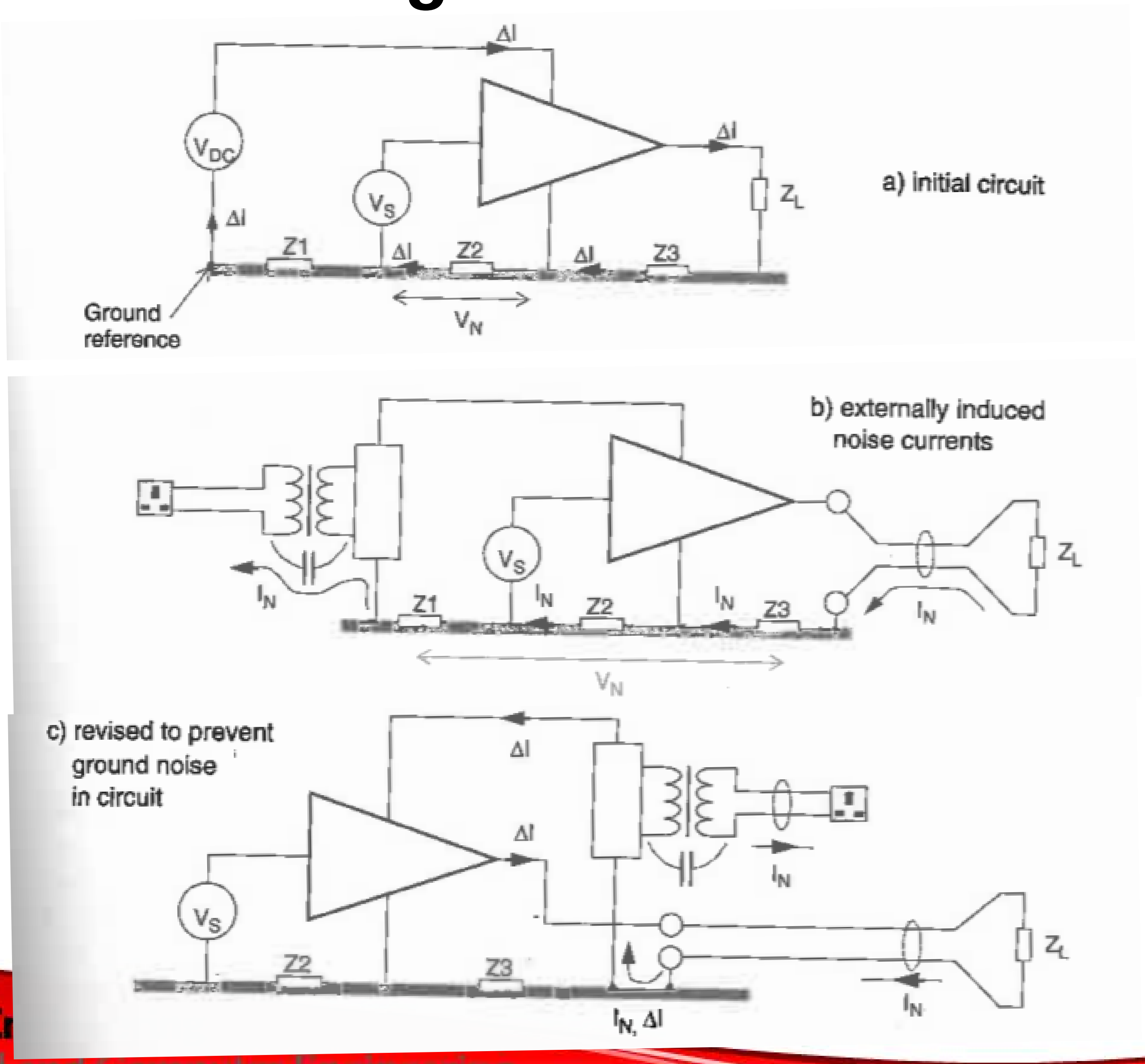

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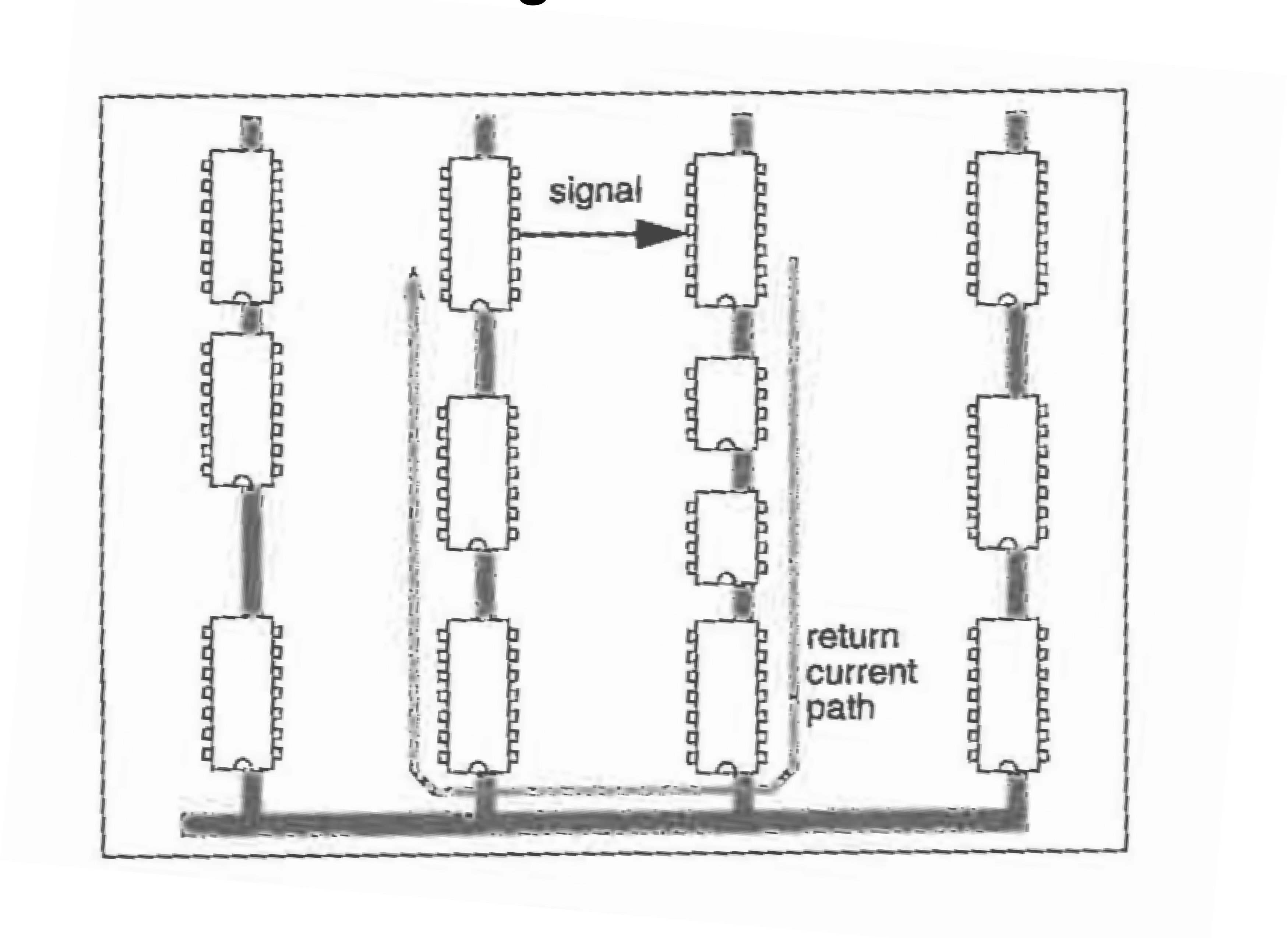
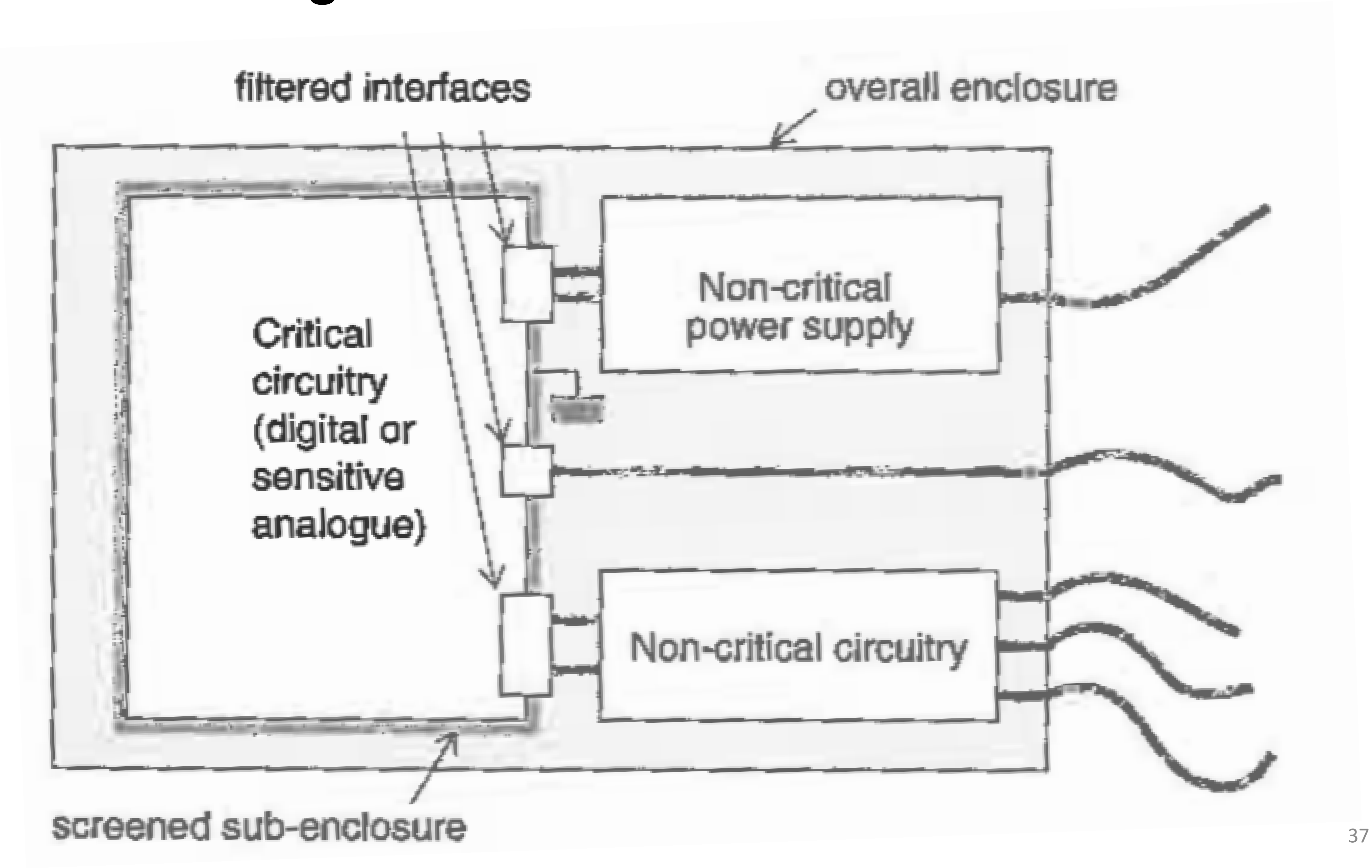


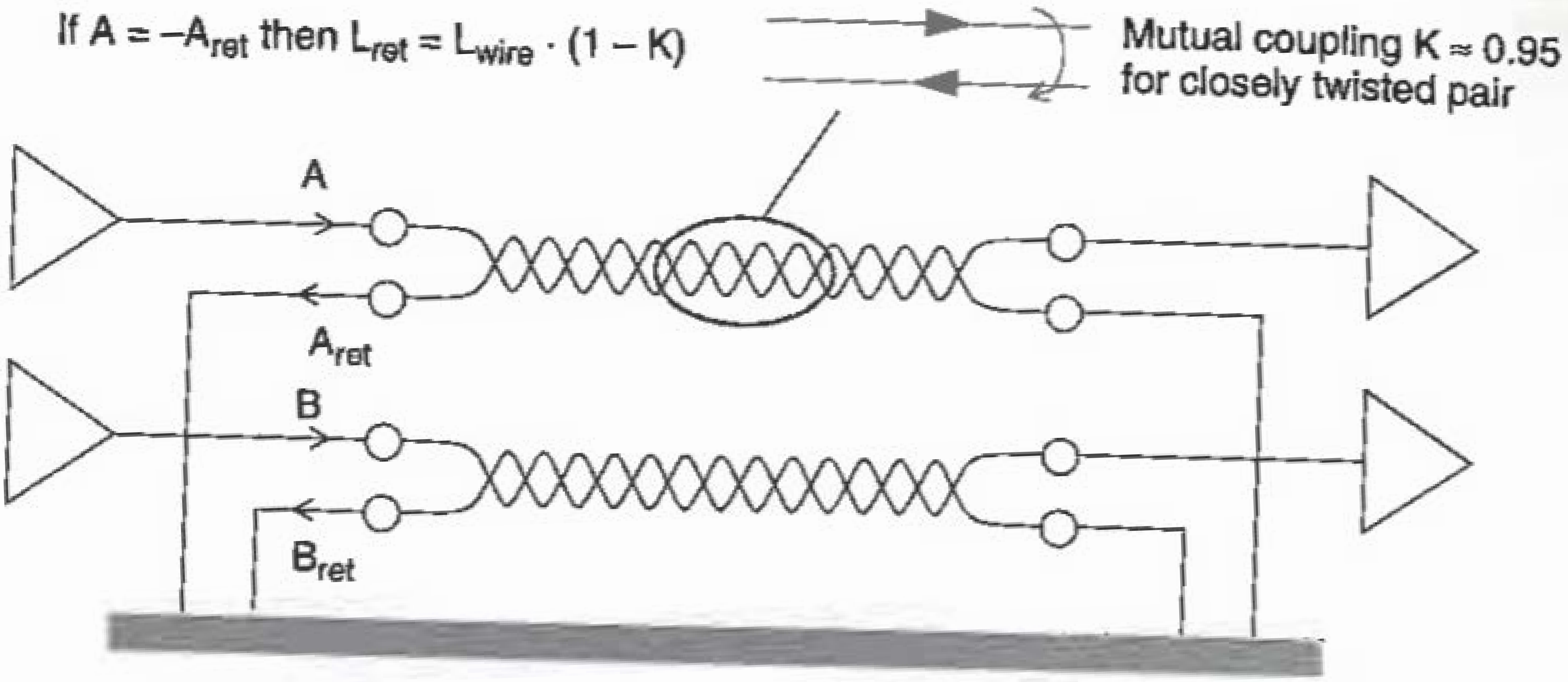
Good Practices for EMI Immunity

- Control the flow of interference into and out of the equipment
  - Keep interference paths away from critical logic circuitry
- Add I/O filters / isolation
- Use high-noise threshold logic (e.g. 74HC)
- Avoid edge triggered inputs if possible
- Use a watchdog

System Partitioning

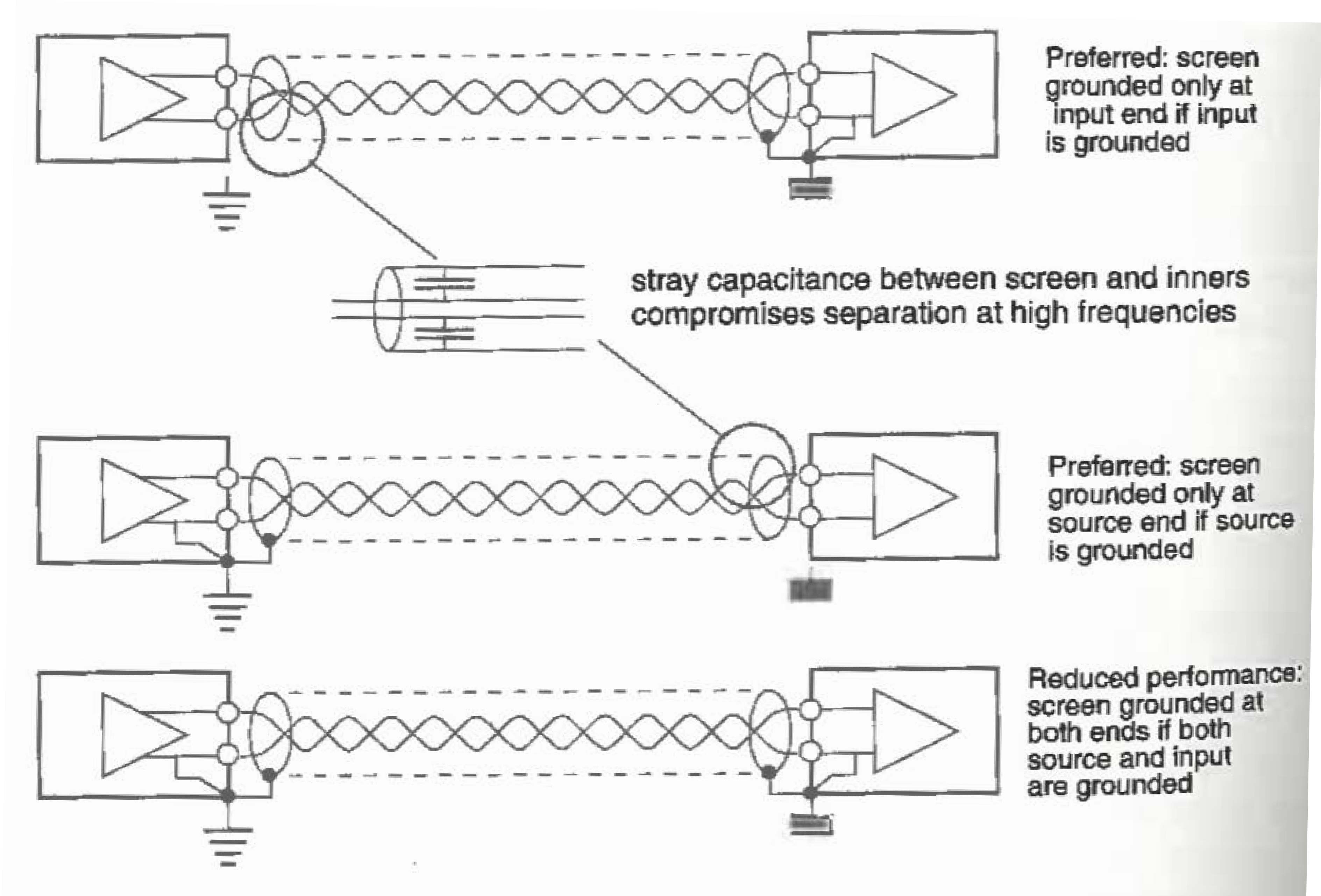


Twisted Wires!



Signal return currents A_{ret} and B_{ret} flow through their local twisted pair return path rather than through ground because this offers the lowest overall path inductance L_{ret}

Shielded wires



Go Wire Robots!