Seminar in delavnica
Načrtovanje elektronike za EMC

Elektromagnetna združljivost (EMC)

M. Jankovec

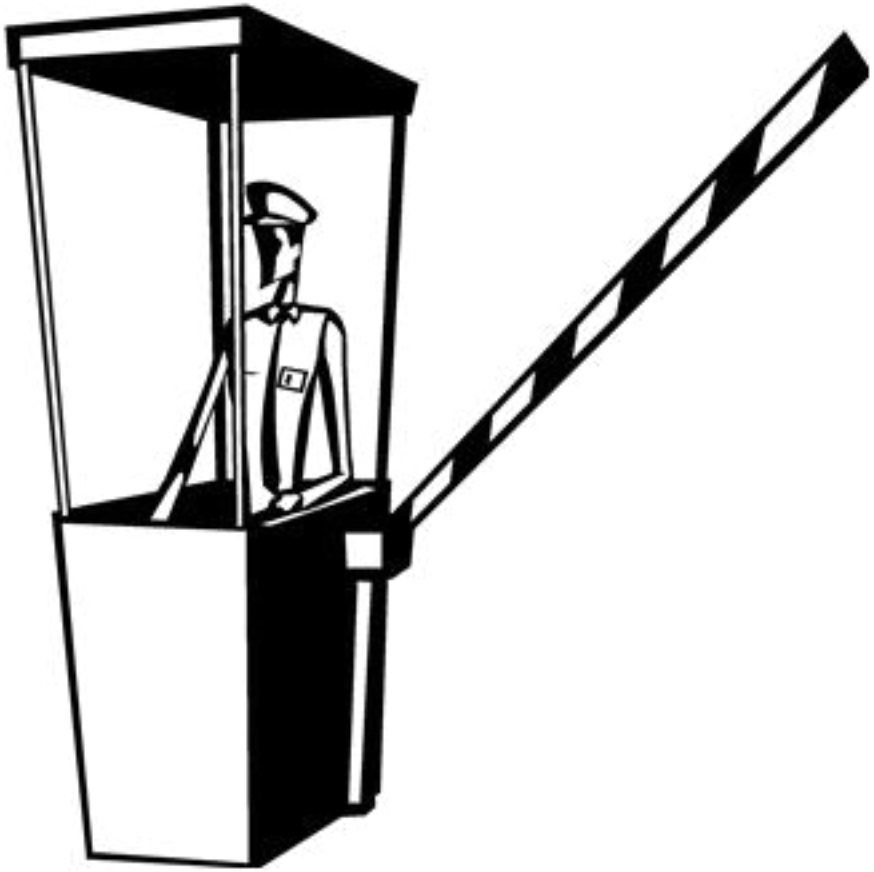
Zakaj EMC?

http://www.compliance-club.com/archive/old_archive/Bananaskins.htm

Banana skin #1

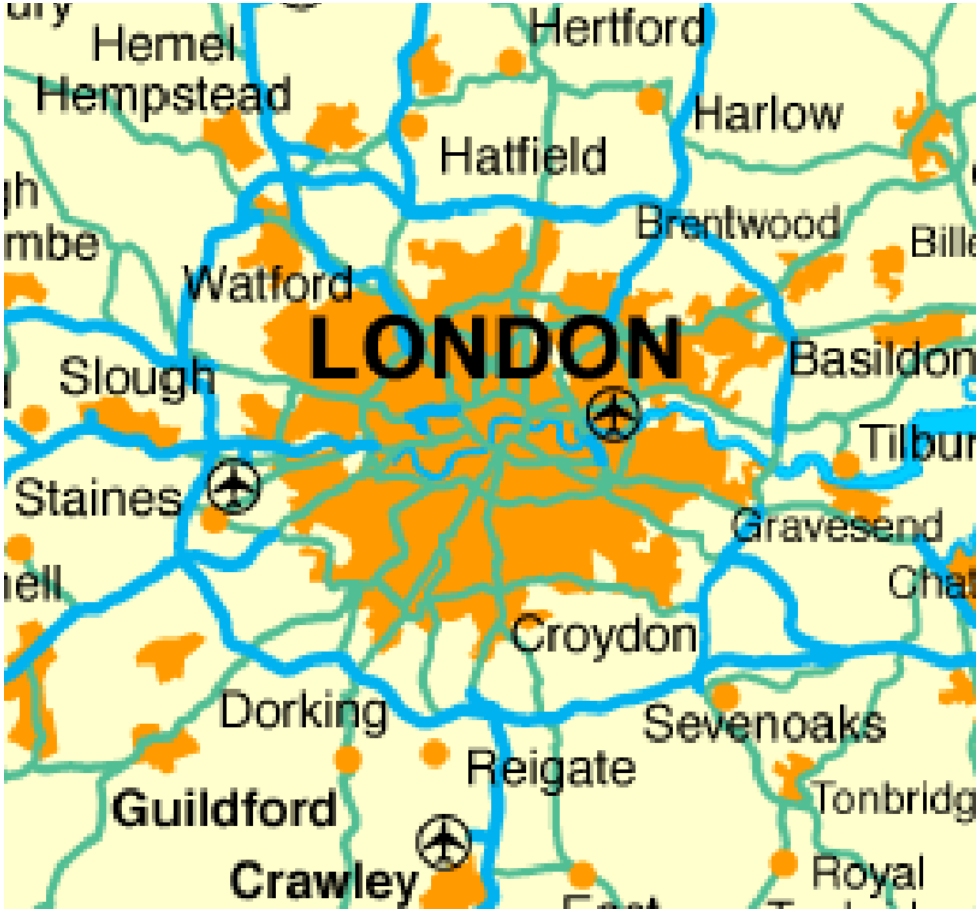
A (CE marked) portable PC carried up the stairs in a domestic household whilst operating, reliably caused the "power shower" in the bathroom to turn itself off if it was in use at the time. (Personal communication in 1997)

Banana skin #2



When a piezo-electric cigarette lighter was lit near the cabinet of a car park barrier control box, the radiated pulse caused the barrier to open and drivers were able to park free of charge.

Banana skin #3



Excessive mains harmonics in the London area, due mainly to the rapidly increasing use of personal computers, are causing overheating problem in AC power cables (including those that run under the Thames). In the offices where the computers are, it is increasingly common for the power-factor correction capacitors normally fitted to fluorescent lamps to blow (the electricians usually just remove the blown capacitors). Damaged and overheated neutrals, and damaged electrical switchgear is increasingly seen as a result of harmonic mains pollution. In the US, fire insurance companies are being urged not to take on any new policies unless they have had the size of the neutral cables in the company concerned checked for their adequacy for the heating effects of harmonic currents. *(Personal communications, January 1998)*

Banana skin #4

Catastrophe with H.M.S. Sheffield during the Falkland crisis. An Exocet missile hit this frigate because its search radar was switched off (so its anti-missile guns couldn't be used – Editor) It was switched off because it was known that the satellite communication system was interfered with by this radar.

Osnovna delitev EMC področja

Motnja/ emisija
- Prevodna (Conducted)
- Sevalna (Radiated)

Odpornost/ imunost
- Prevodna (Conducted)
- Sevalna (Radiated)

Standardi s področja EMC

- Osnovni standardi
  - IEC 61000-1-1: Definicije izrazov
  - IEC 61000-2-x: Definicije okolij
  - IEC 61000-3-x: Omejitve emisij
  - IEC 61000-4-x: Imunost na sevanja in razelektritve
  - IEC 61000-5-x: Priporočila za povezovanje in ozemljevanje
- Generični standardi za posamezna okolja uporabe
  - Imunost
    - IEC 61000-6-1 (domača, komercialna, lažja industrijska)
    - IEC 61000-6-2 (industrijska)
  - Emisije
    - IEC 61000-6-1 (domača, komercialna, lažja industrijska)
    - IEC 61000-6-2 (industrijska)

EMC razredi naprav

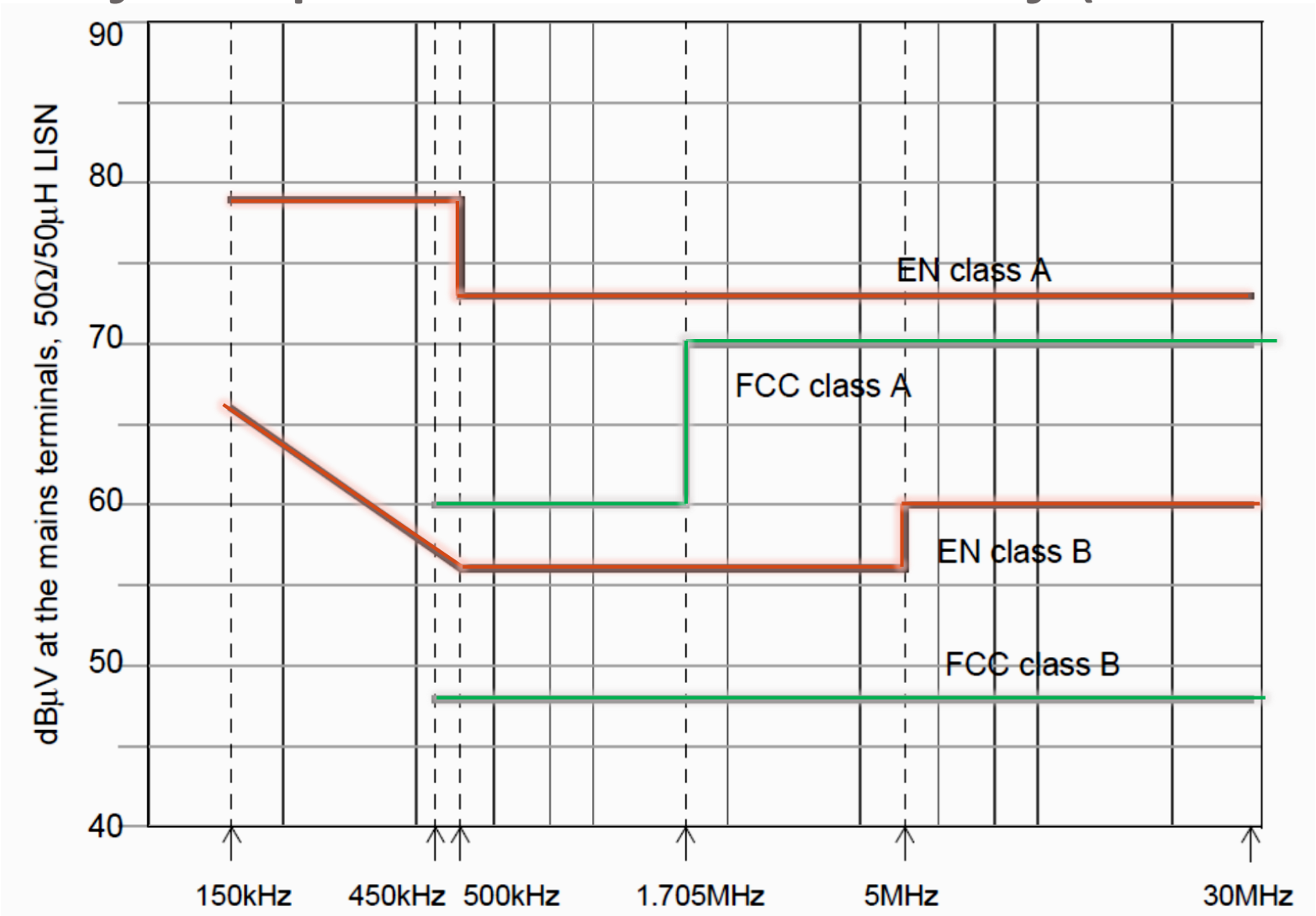
Razred A

- Uporaba
  - industrijsko okolje
- Nadziran dostop
- Časovno omejena izpostavljenost uporabnikom
- Kvalificirani uporabniki
- Večje razdalje med napravami
- Dopustno sevanje je večje
  - + 10 dB glede na razred B

Razred B

- Uporaba
  - Domače okolje
  - Komercialno okolje
  - Lažja industrija
- Neomejen dostop in uporaba
- Nekvalificirani uporabniki
  - Široka potrošnja
- Ostrejše zahteve za sevanje

Omejitve prevodnih RF motenj (< 30 MHz)



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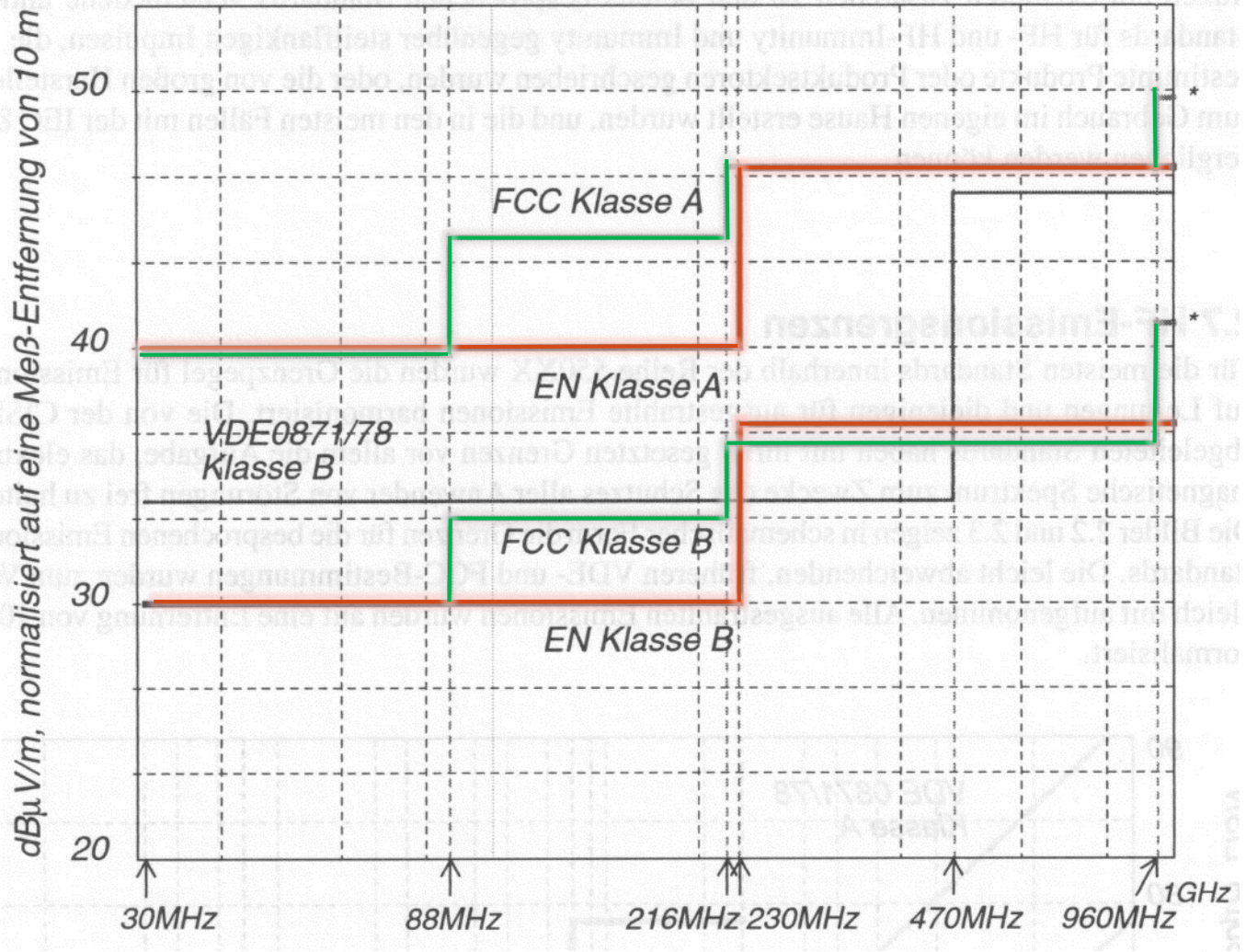
Omejitve sevalnih RF motenj (> 30 MHz)



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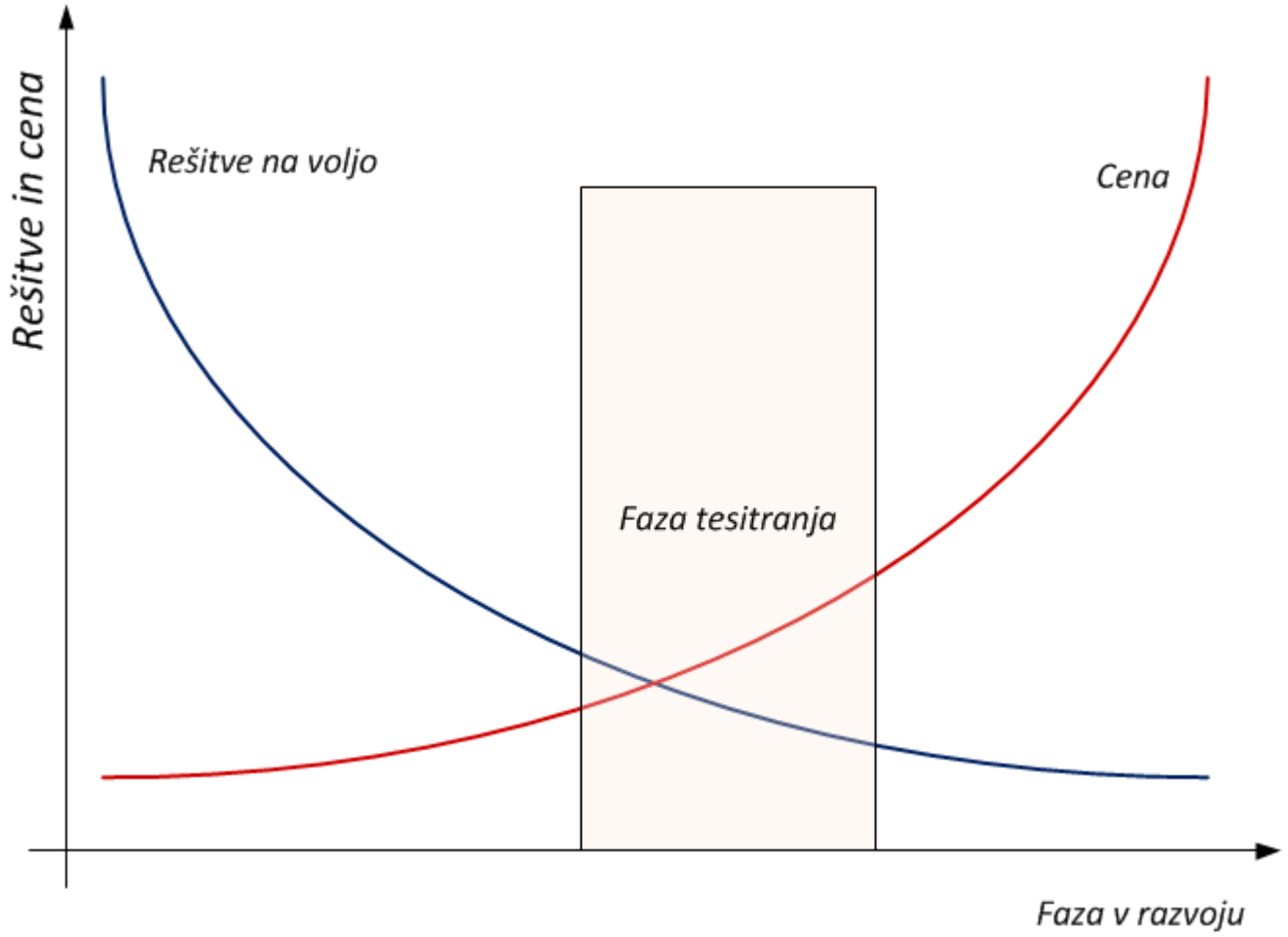
Doseganje EMC



Model EMC

- Model, s katerim se prikaže elektromagnetne motnje, ima tri osnovne gradnike:
  - **izvor** sevanja (motenj),
  - **sprejemnik**,
  - **povezava** med izvorom in sprejemnikom.

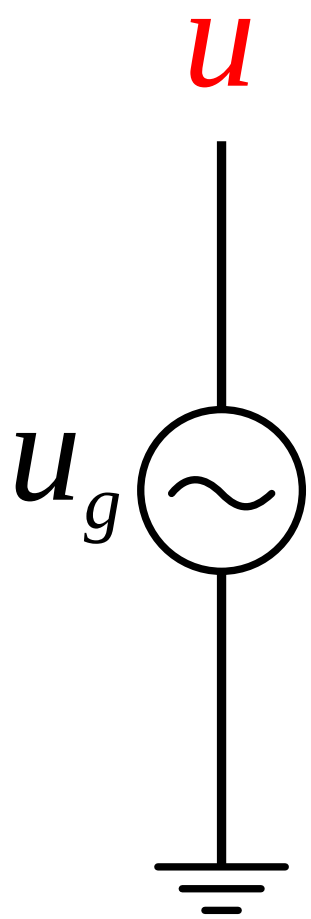
- Naravni
- Umetni
  - Namerni
  - Nenamerni

- Prevodne
- Električno polje
- Magnetno polje
- Elektromagnetno polje

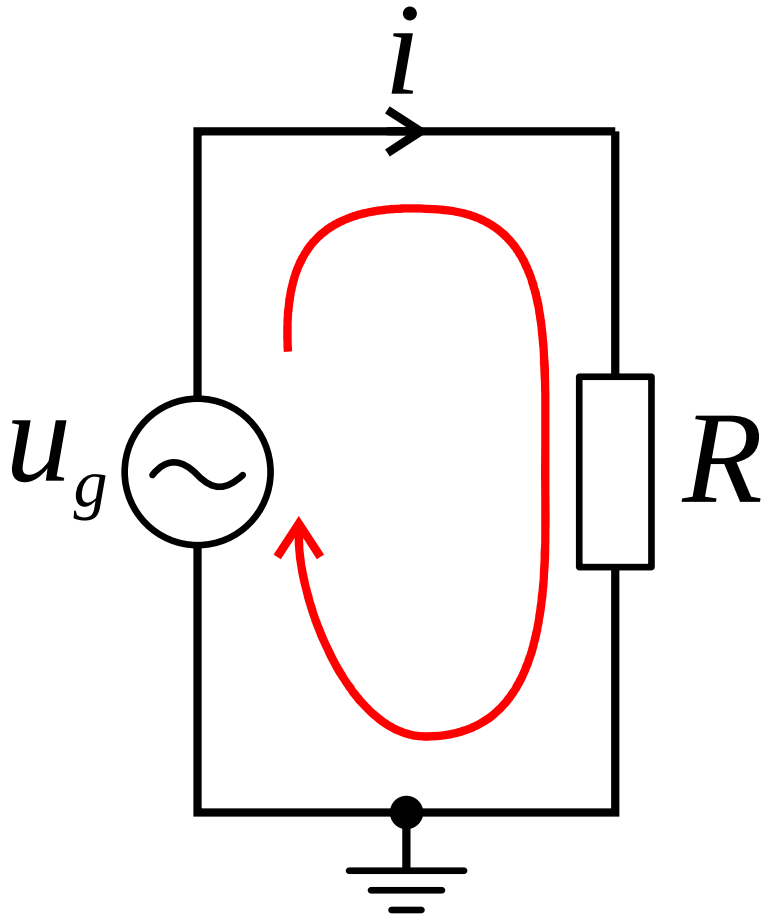
- Biološke
- Umetne

Izvori motenj

VF potenciali

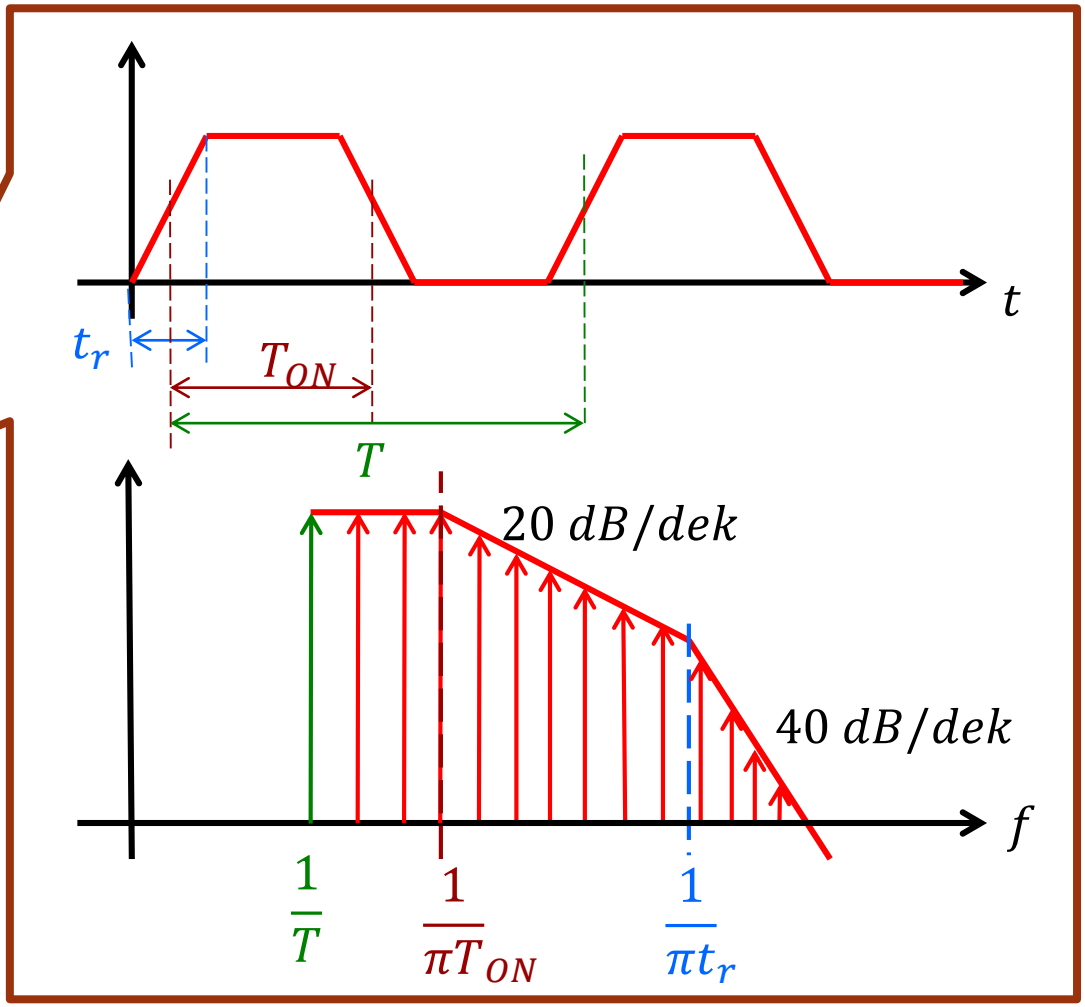


VF tokovne zanke

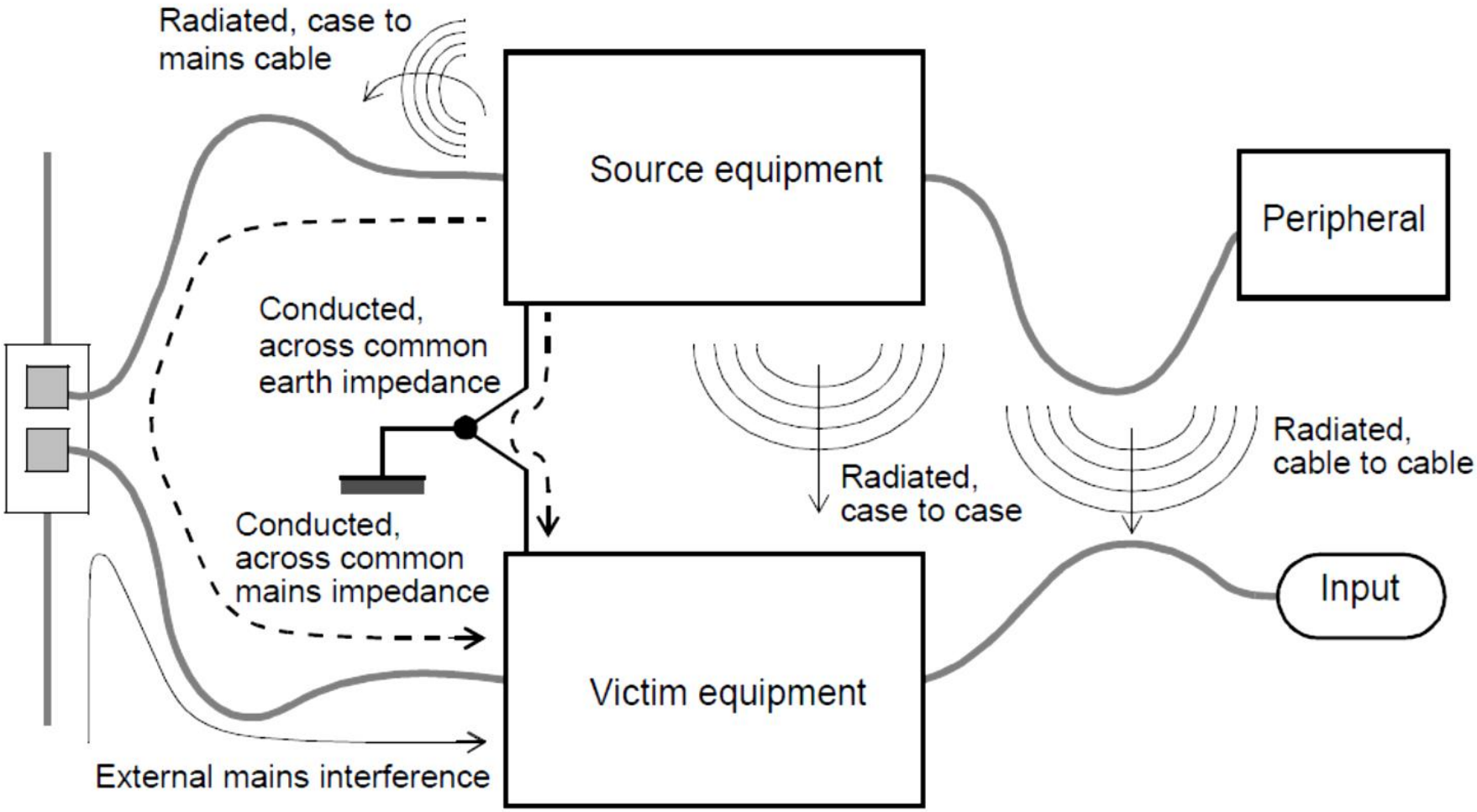


Izvori motenj

- Vprašanja:
  - Kje teče tok?
  - Kje so napetostna nihanja?
  - Kakšna je frekvenčna vsebina toka, napetosti?



Povezava - mehanizmi sklapljanja motenj



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EMC razdelitev glede na vire in sklope

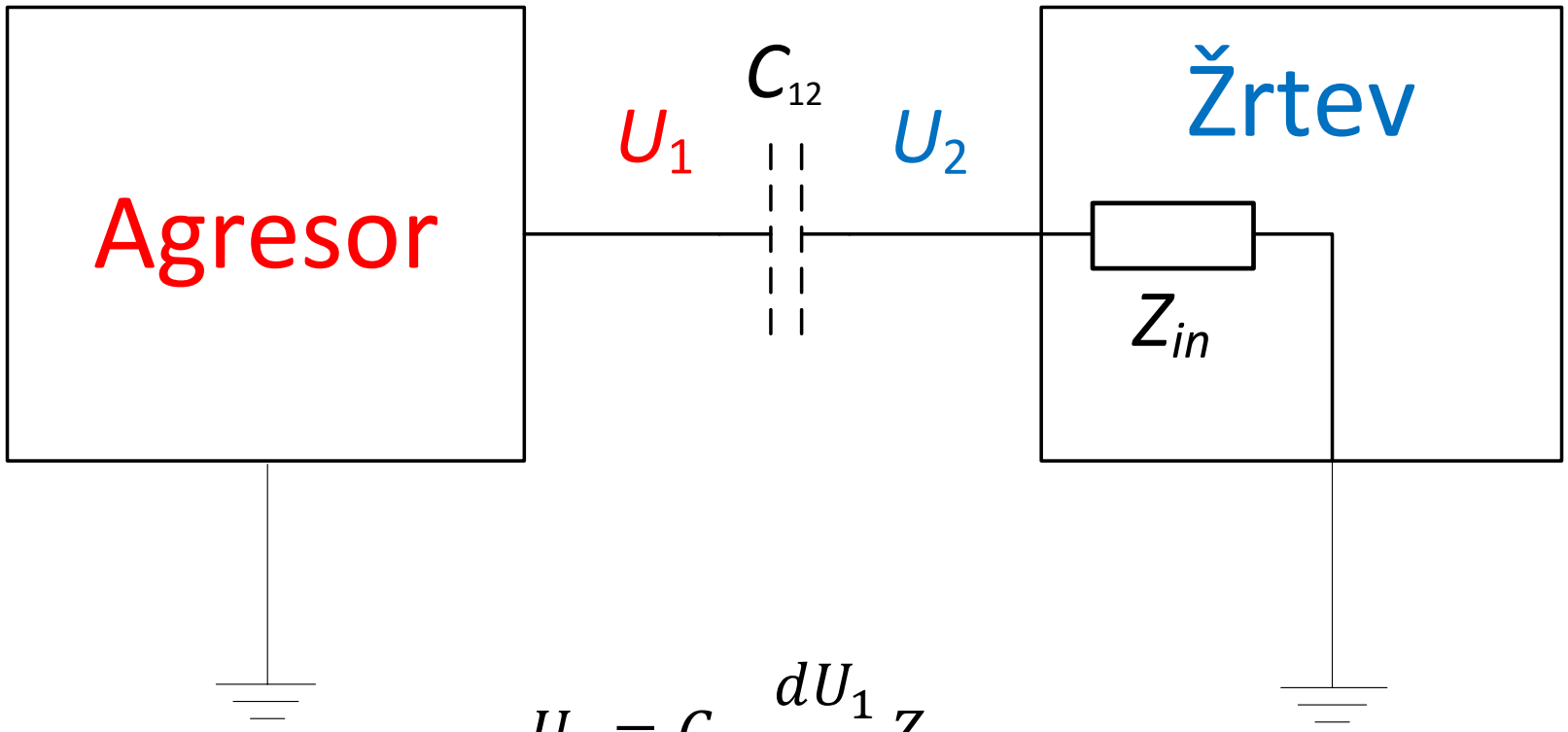
Emisije

- Sevalne
- Prevodne
- NF magnetna polja

Imunost

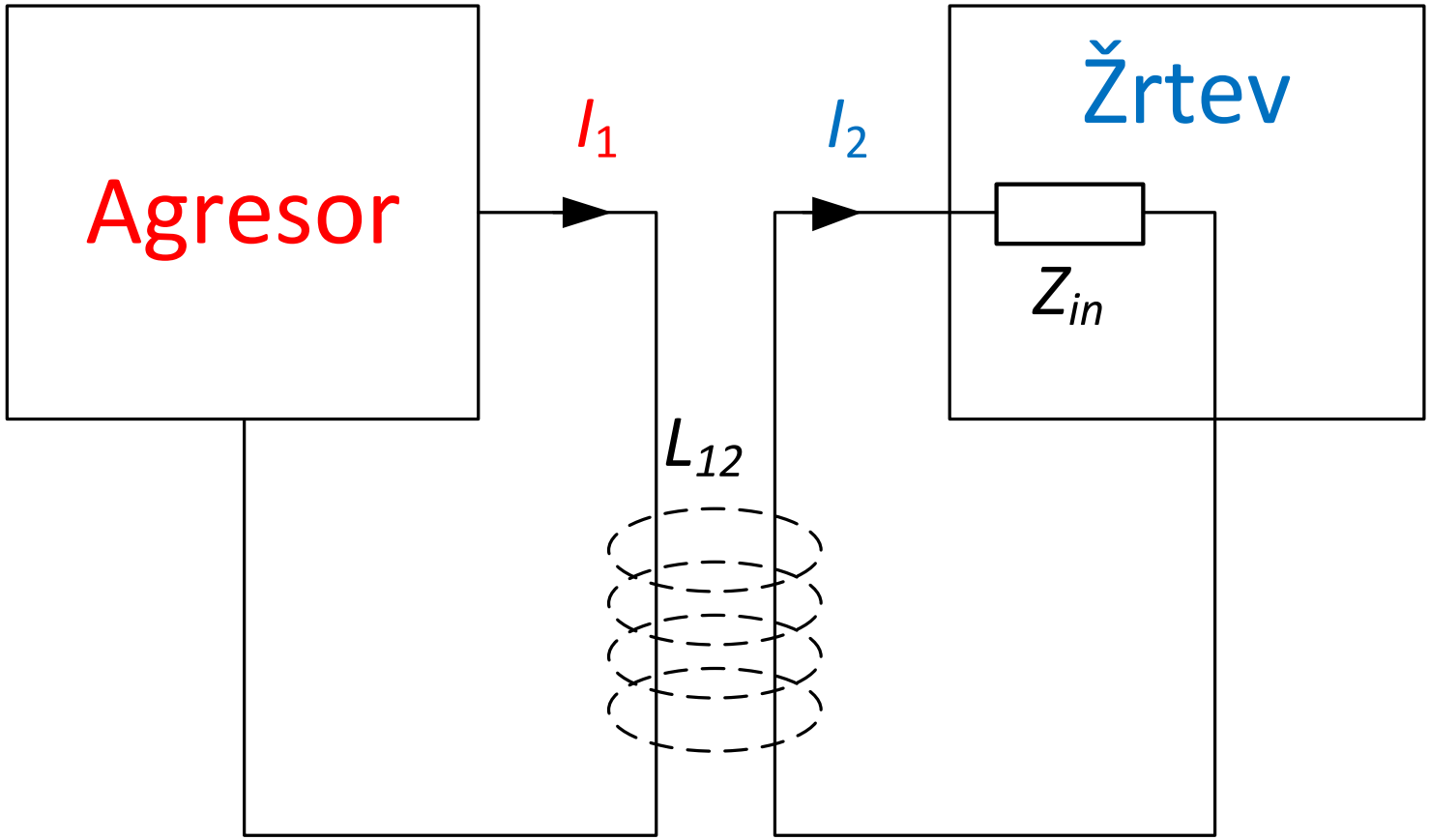
- Hitri prehodni pojavi (FTB)
- Prenapetosti (Surge)
- Elektrostatične izpraznitve (ESD)
- Sevalne motnje
- Prevodne motnje
- NF magnetna polja

Kapacitivni prenos motenj (prek *E* polja)



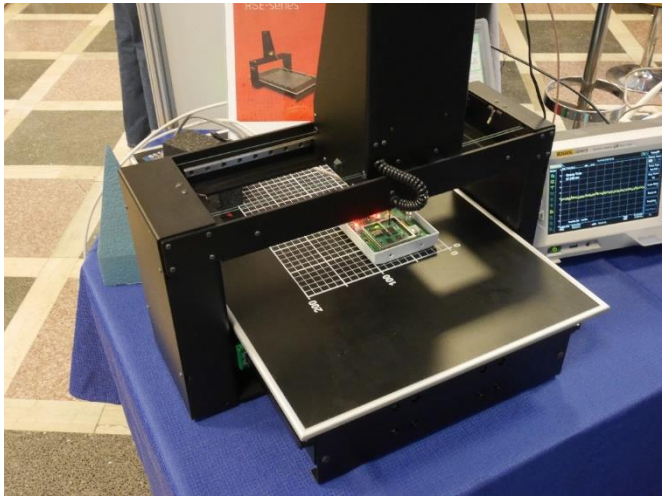
$$U_2 = C_{12}\frac{dU_1}{dt}Z_{in}$$

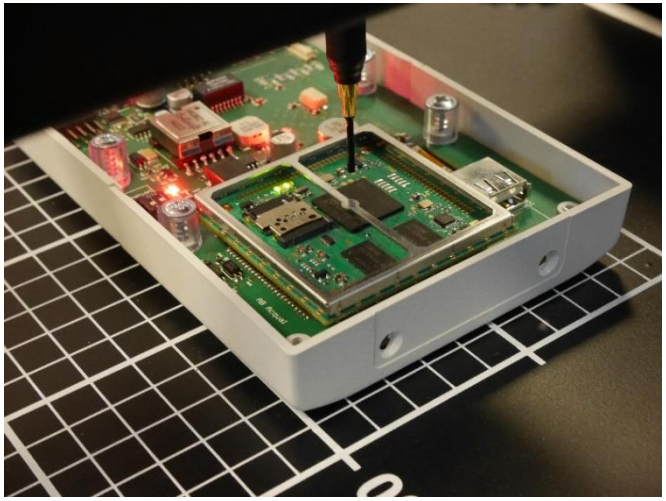
Induktivni prenos motenj (prek *H* polja)

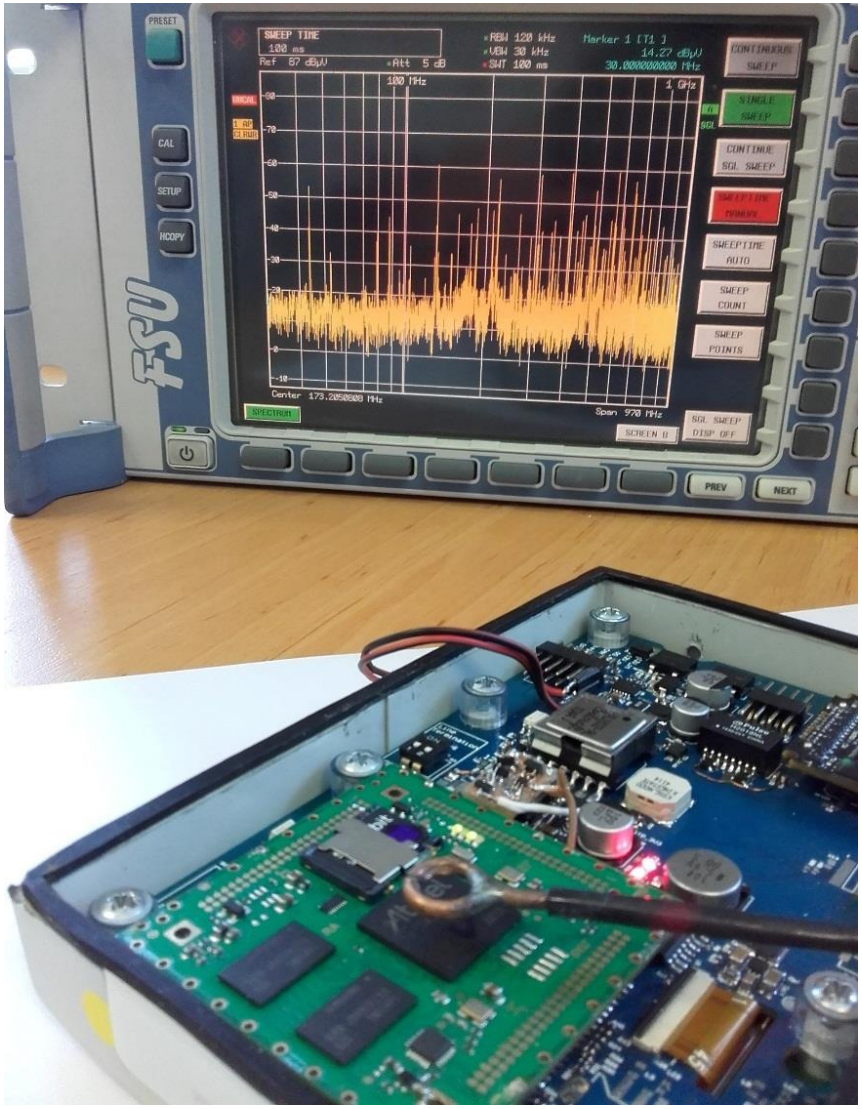


$$I_2 = -L_{12}\frac{dI_1}{dt}\frac{1}{Z_{in}}$$

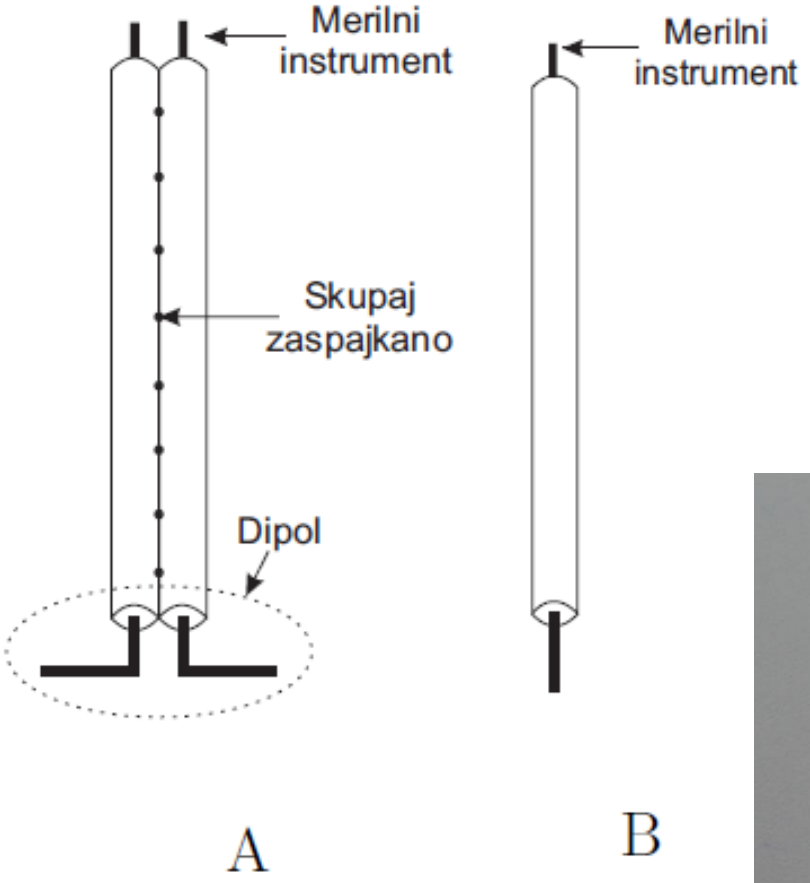
EMC meritve sevalnih emisij v bližnjem polju

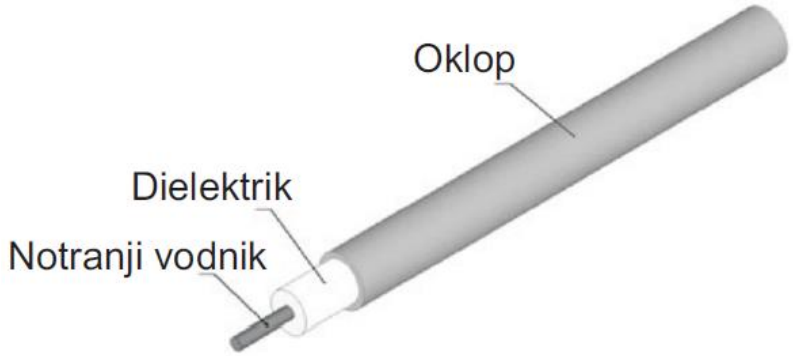


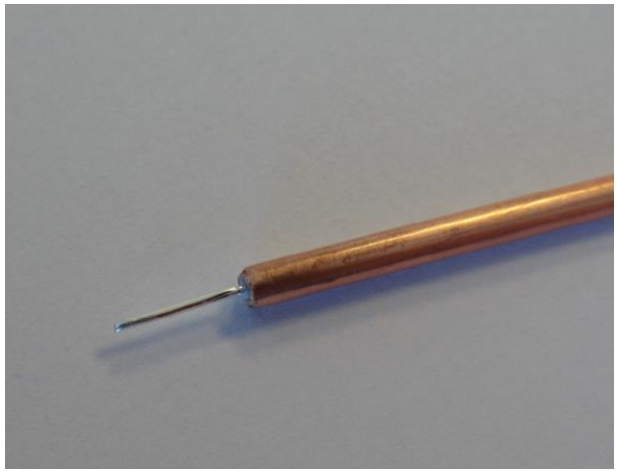


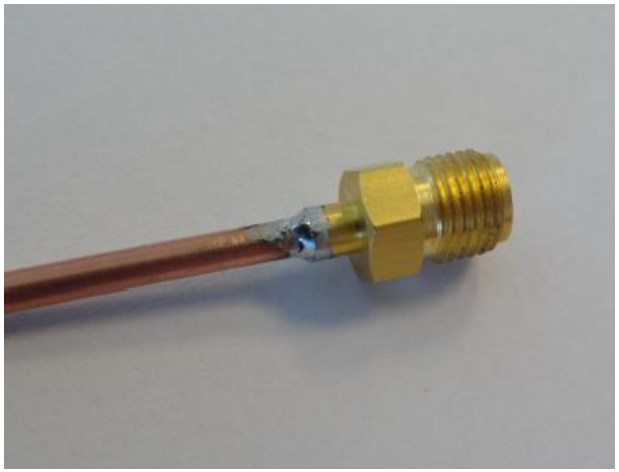


Antene za bližnje E polje (precompliance)



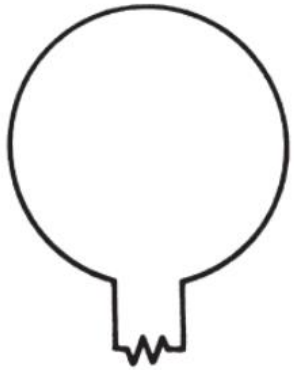






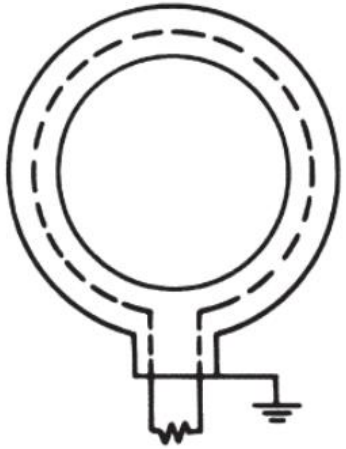
Gjorgji Nusev, Diplomsko delo, 2014

Antene za bližnje H polje (precompliance)



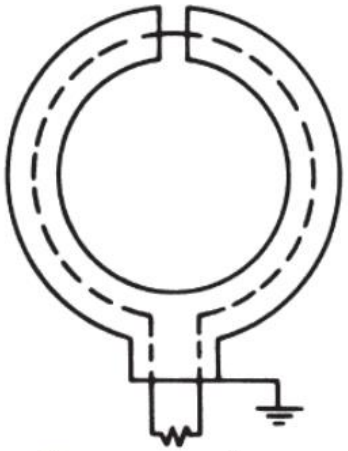
Osnovna zanka

A



Oklopljena zanka

B

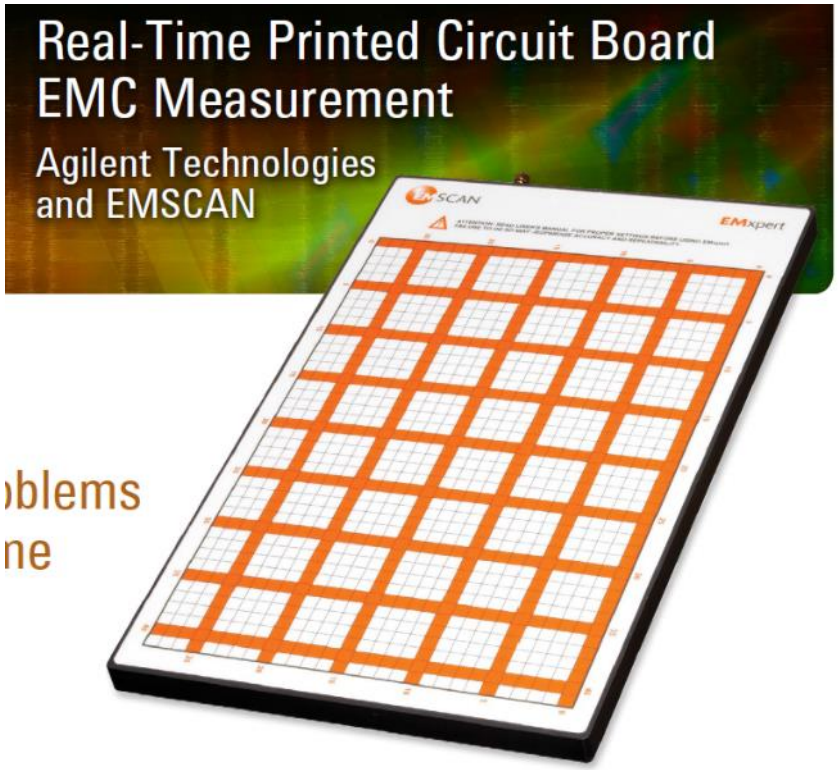


Oklopljena zanka z režo

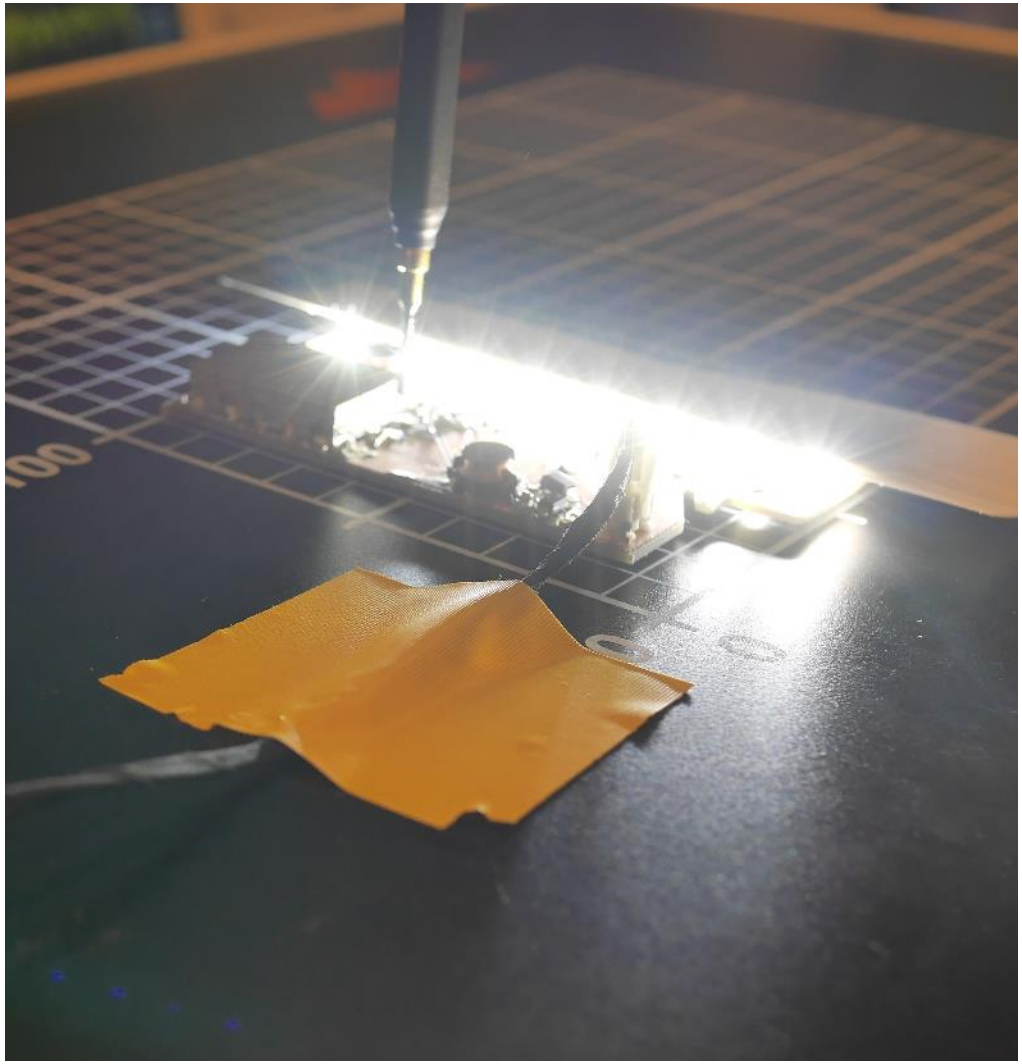
C

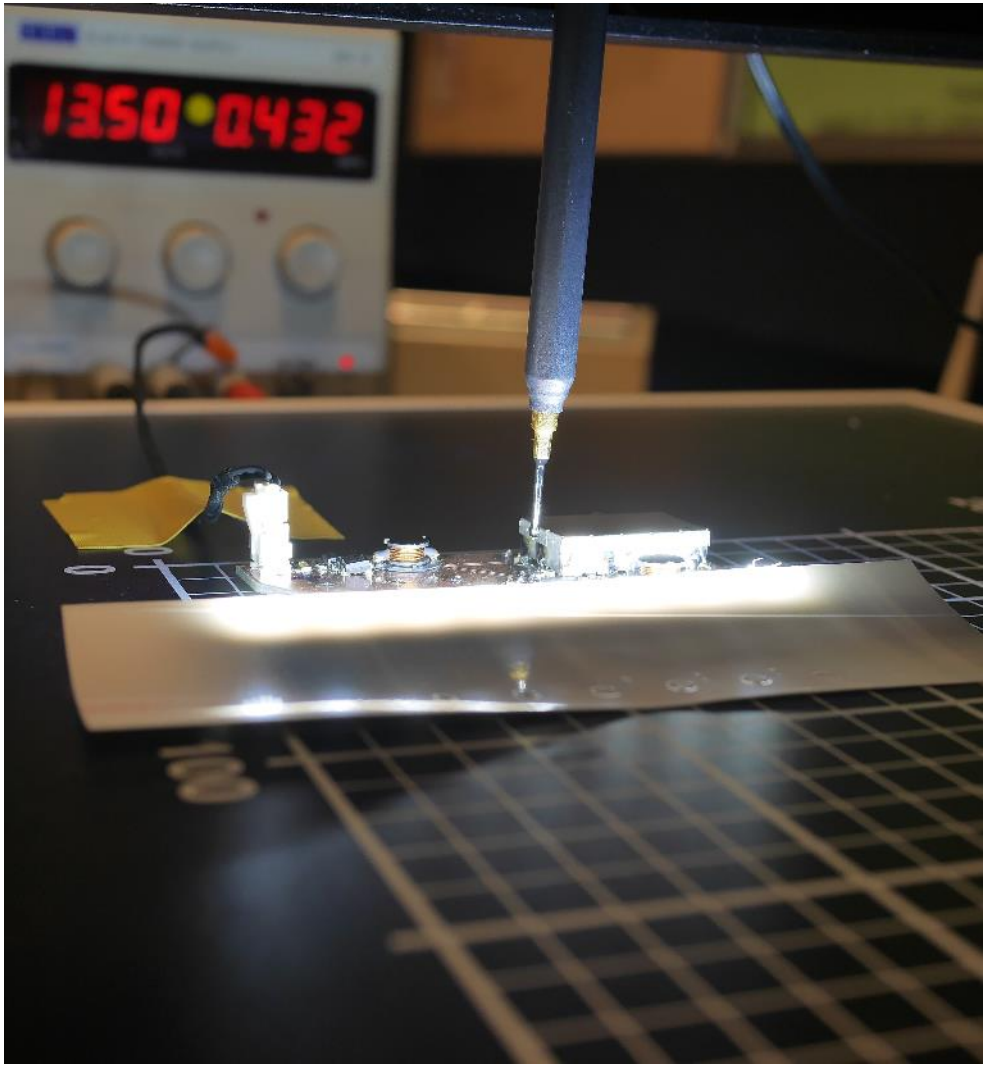
Gjorgji Nusev, Diplomsko delo, 2014

EM scan / Detectus

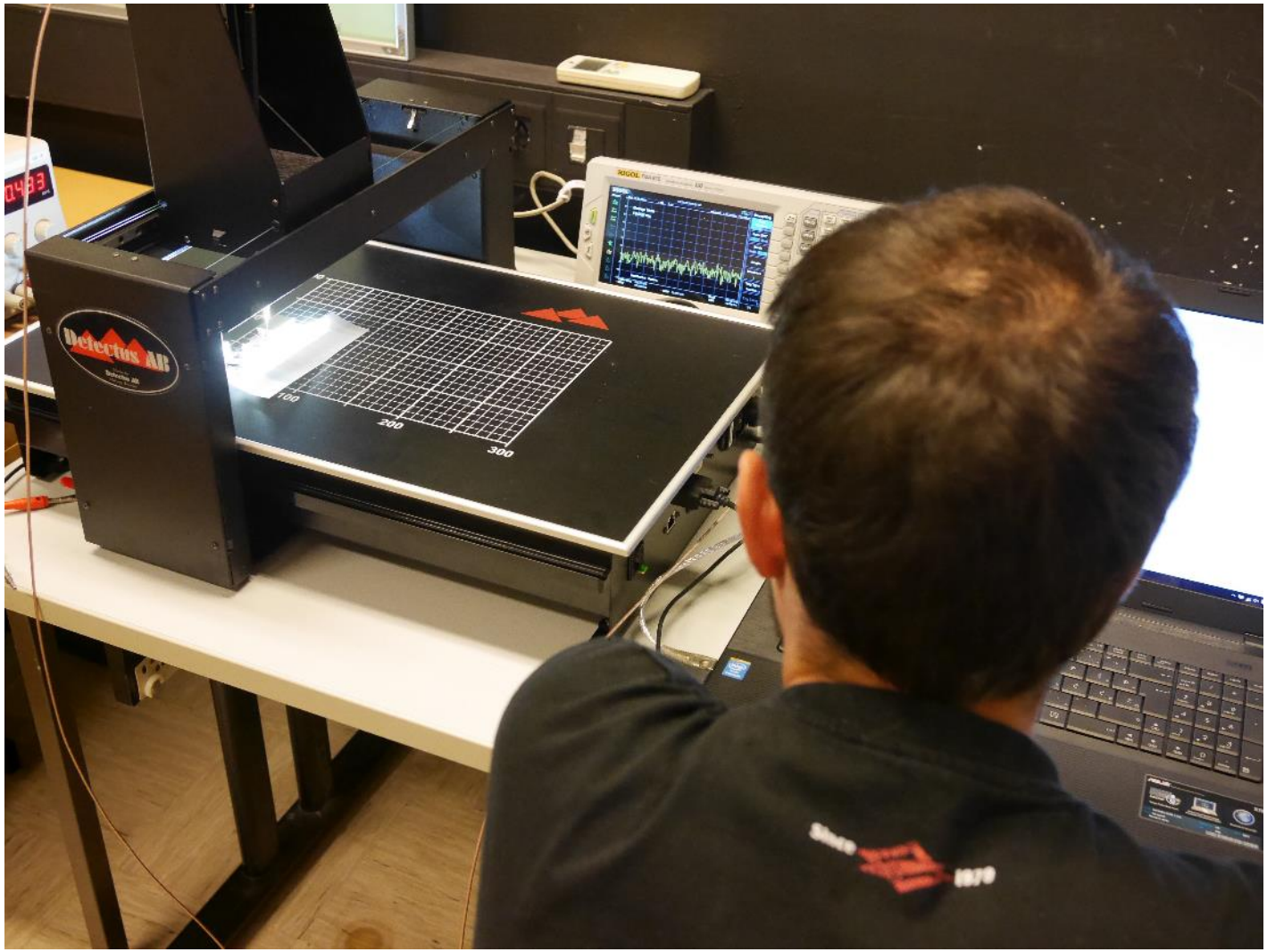


Detectus

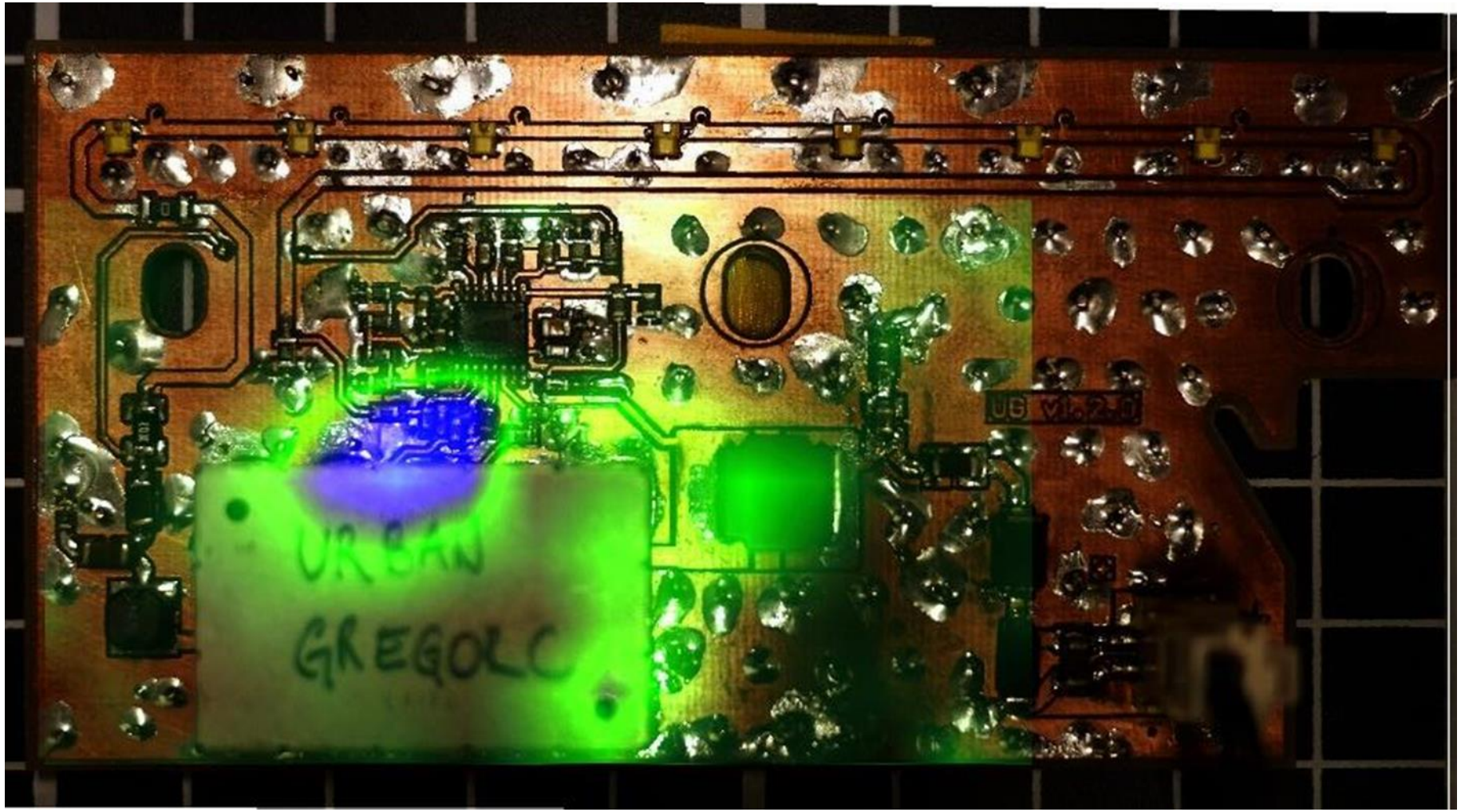




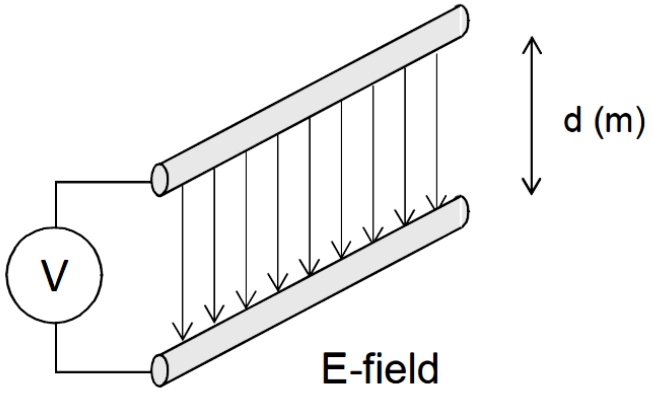
Detectus



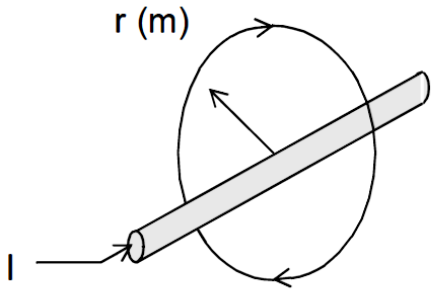
Primer nizkih emisij



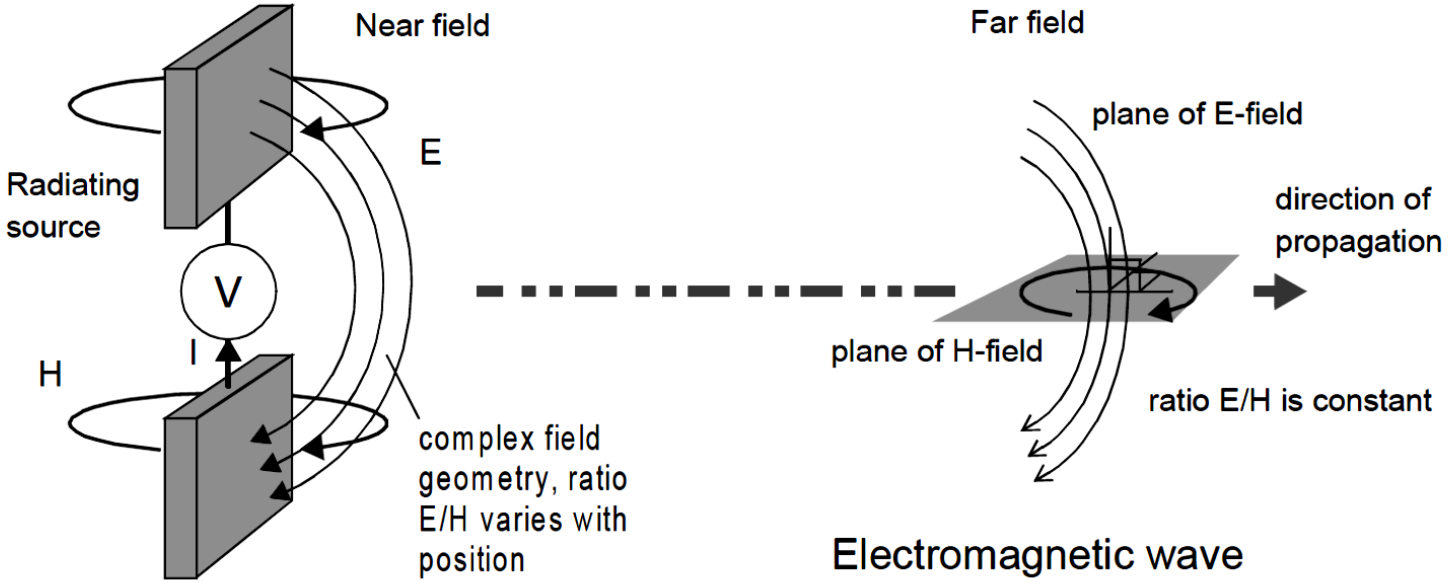
Prenos motnje preko EM polja



E-field



H-field



Electromagnetic wave

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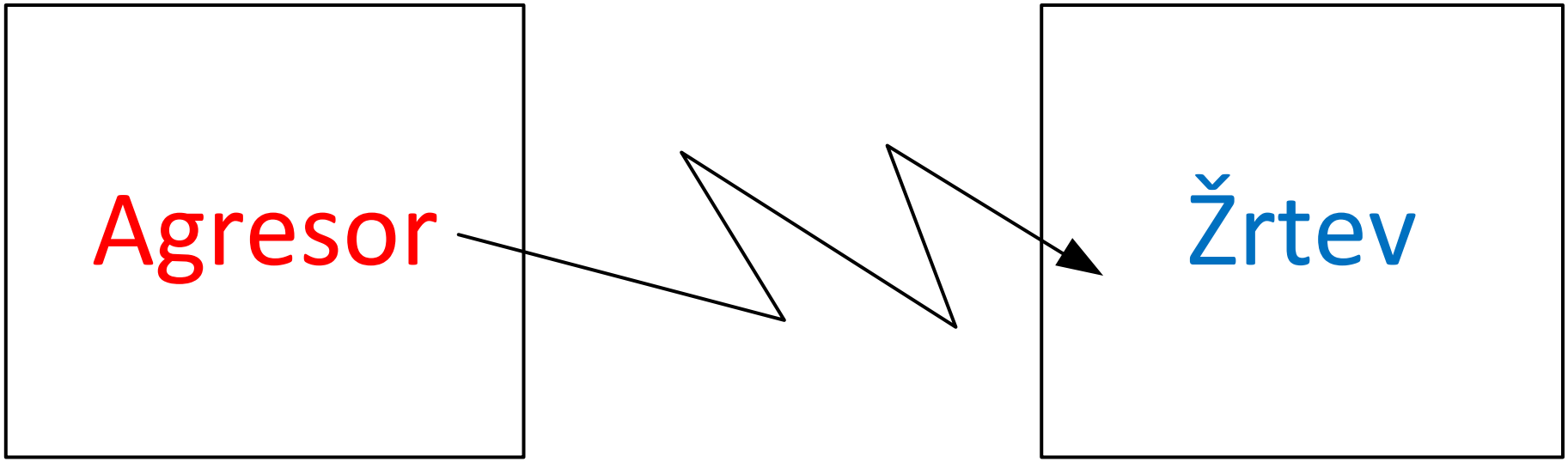
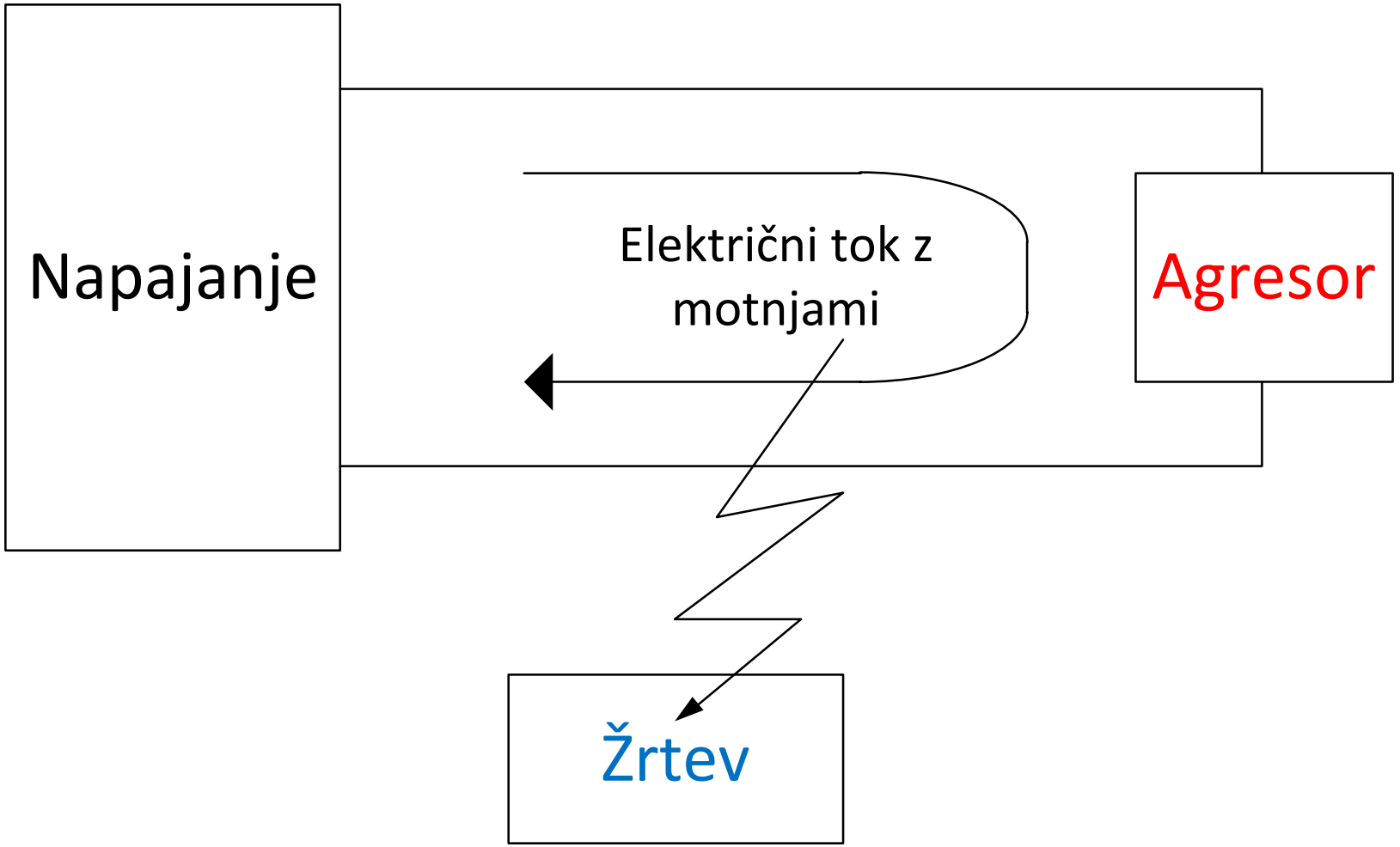
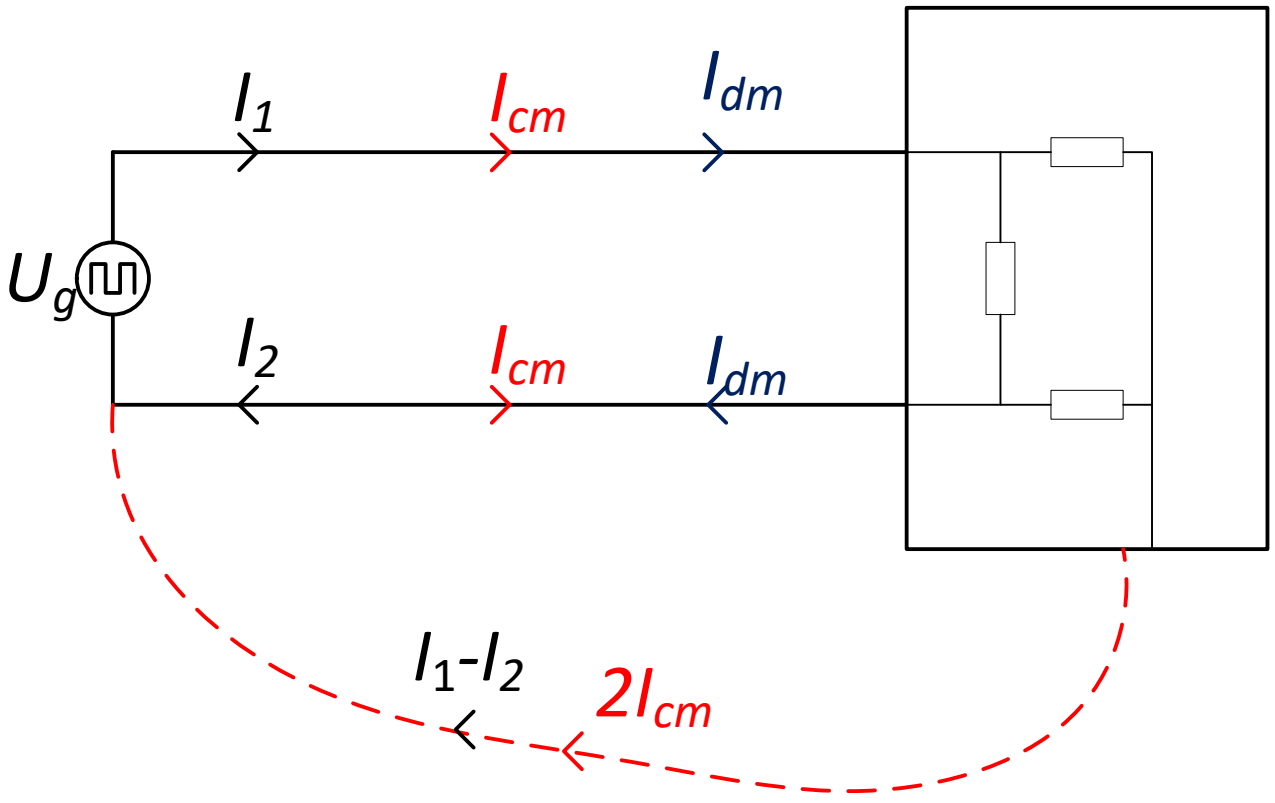
Prenos motnje preko EM polja



Prevodno-sevalni prenos motenj



Diferencialni in sofazni signali



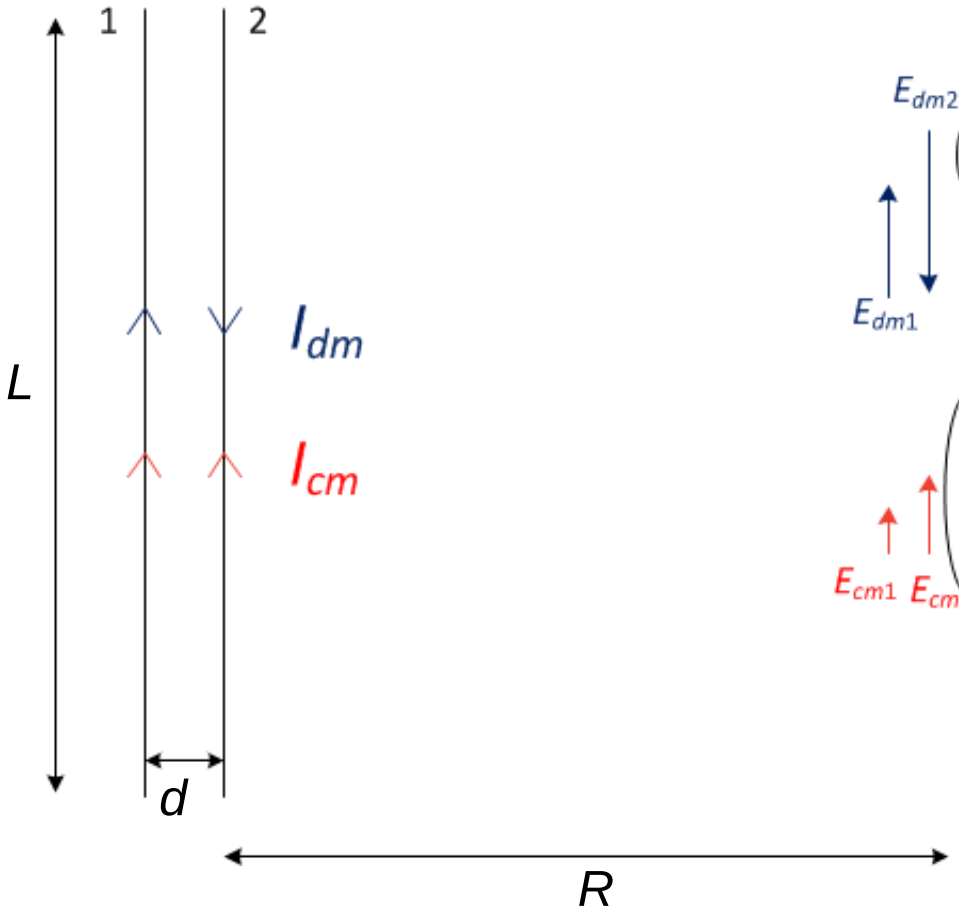
$$I_1 = I_{dm} + I_{cm}$$

$$I_2 = I_{dm} - I_{cm}$$

$$I_{dm} = \frac{I_1 + I_2}{2}$$

$$I_{cm} = \frac{I_1 - I_2}{2}$$

Diferencialne in sofazne motnje



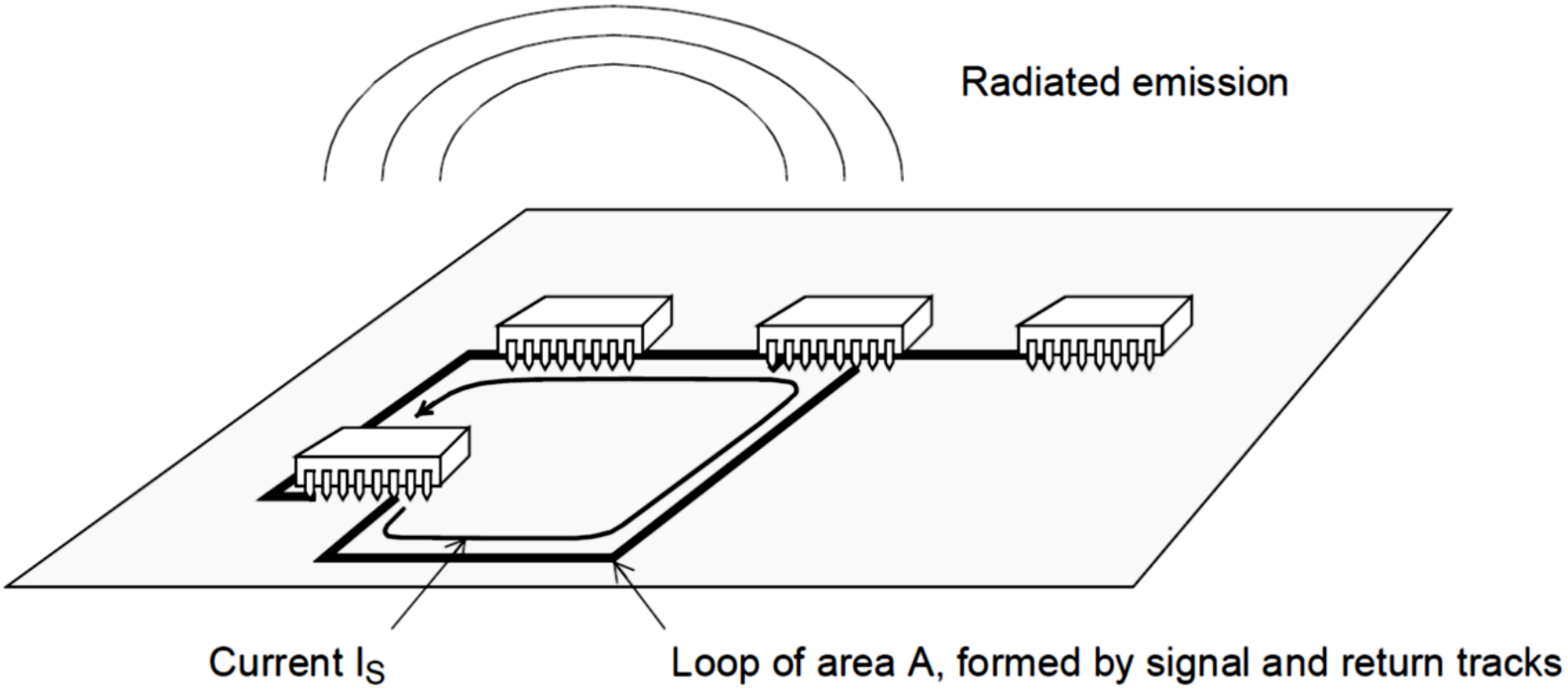
$$E_{dm_{maks}}(f) = 1{,}31 \cdot 10^{-14} \frac{I_{dm}(f) f^2 L d}{R} \text{ V/m}$$

$$E_{dm_{maks}}(f) = 2{,}63 \cdot 10^{-14} \frac{I_{dm}(f) f^2 L d}{R} \text{ V/m}$$

$$E_{cm_{maks}}(f) = \pi \cdot 10^{-7} \frac{I_{cm}(f) f L}{R} \text{ V/m}$$

C. A. Balanis, Antenna theory: analysis and design. John Wiley & Sons, 2012.

Primer vira diferencialne motnje na TIV



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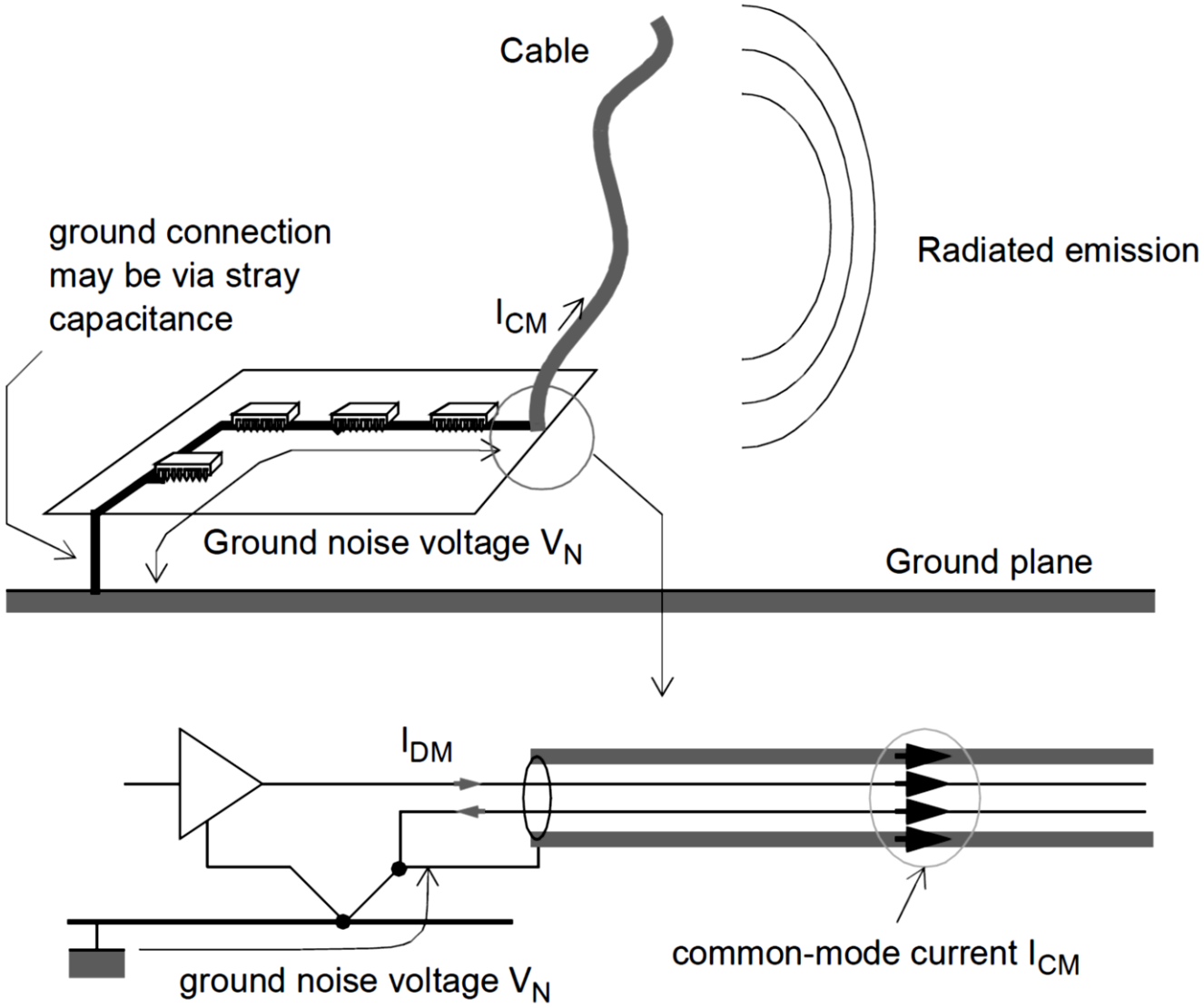
Primer vira sofazne motnje na TIV



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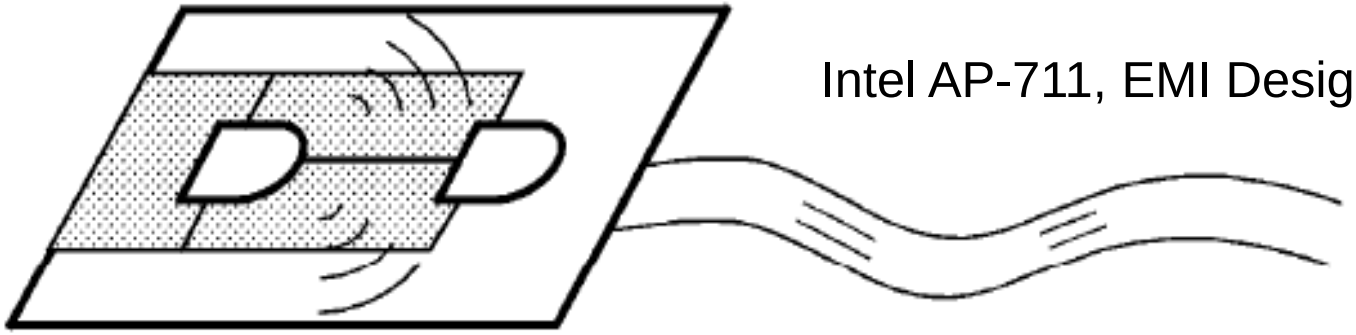
Primeriava diferencialne in sofazne motnie



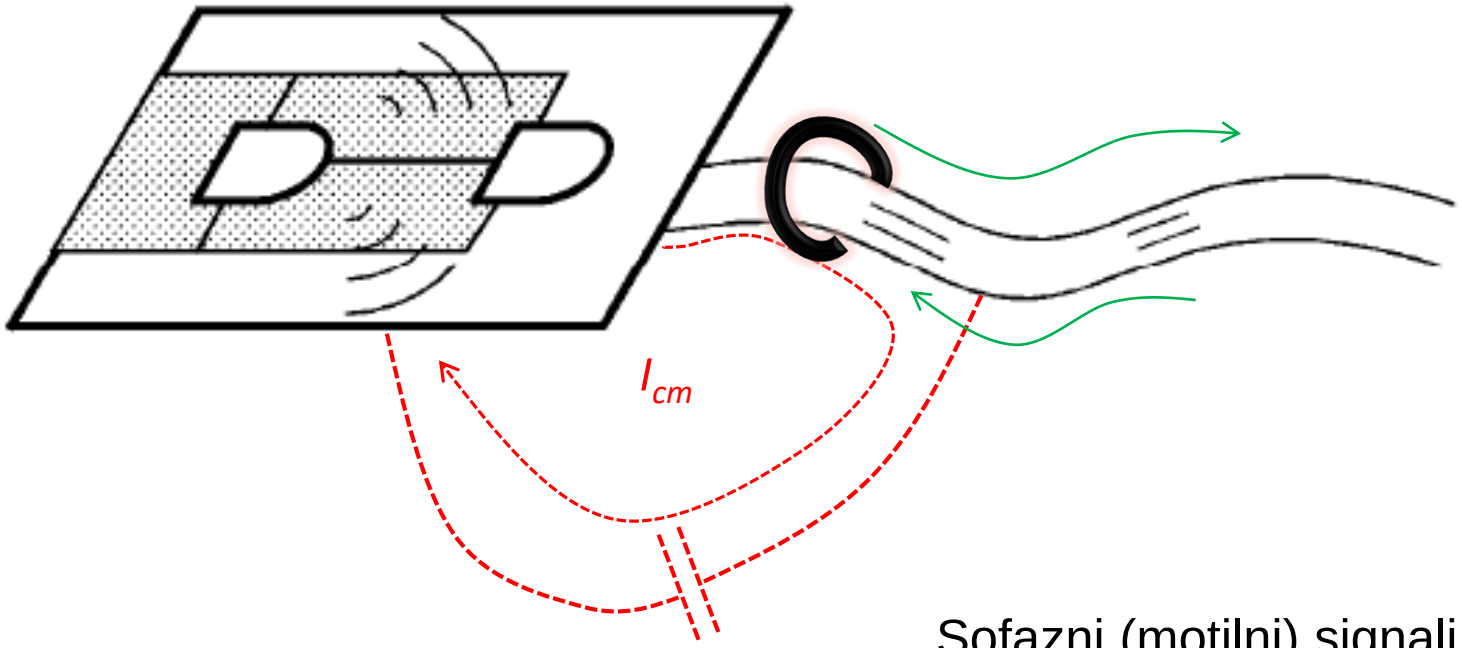
Intel AP-711, EMI Design Techniques

- Signali na PCB
  - Majhne tokovne zanke (A)
  - Protifazni zančni tokovi (I)
  - $E_{dm} = 2{,}63 \cdot 10^{-14} \frac{I_{dm} A f^2}{R}$
- $I = 1\,mA, f = 100\,MHz, A = 1\,cm^2$
- $E = 26 \frac{\mu V}{m} @\ 1\ \mathrm{m}$

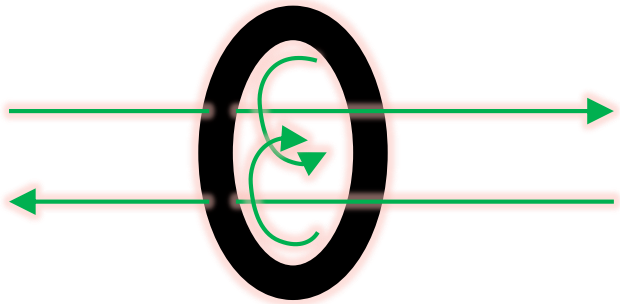
- Signali na povezovalnem kablu
  - Velike dipolne antene (dolžine L)
  - Sofazni tokovi (I)
  - $E_{cm} = \pi \cdot 10^{-7} \frac{I_{cm} f L}{R}$
- $I = 0.8\,\mu A, f = 100MHz, L = 1m$
- $E = 26 \frac{\mu V}{m} @\ 1\ \mathrm{m}$

$$26 \frac{\mu\mathrm{V}}{\mathrm{m}} = 20 \cdot \log\left(\frac{26}{1}\right) = 28\ \mathrm{dB}\mu\mathrm{V/m}$$

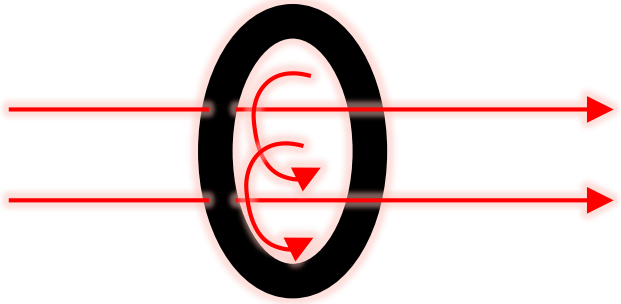
Feritni obroček



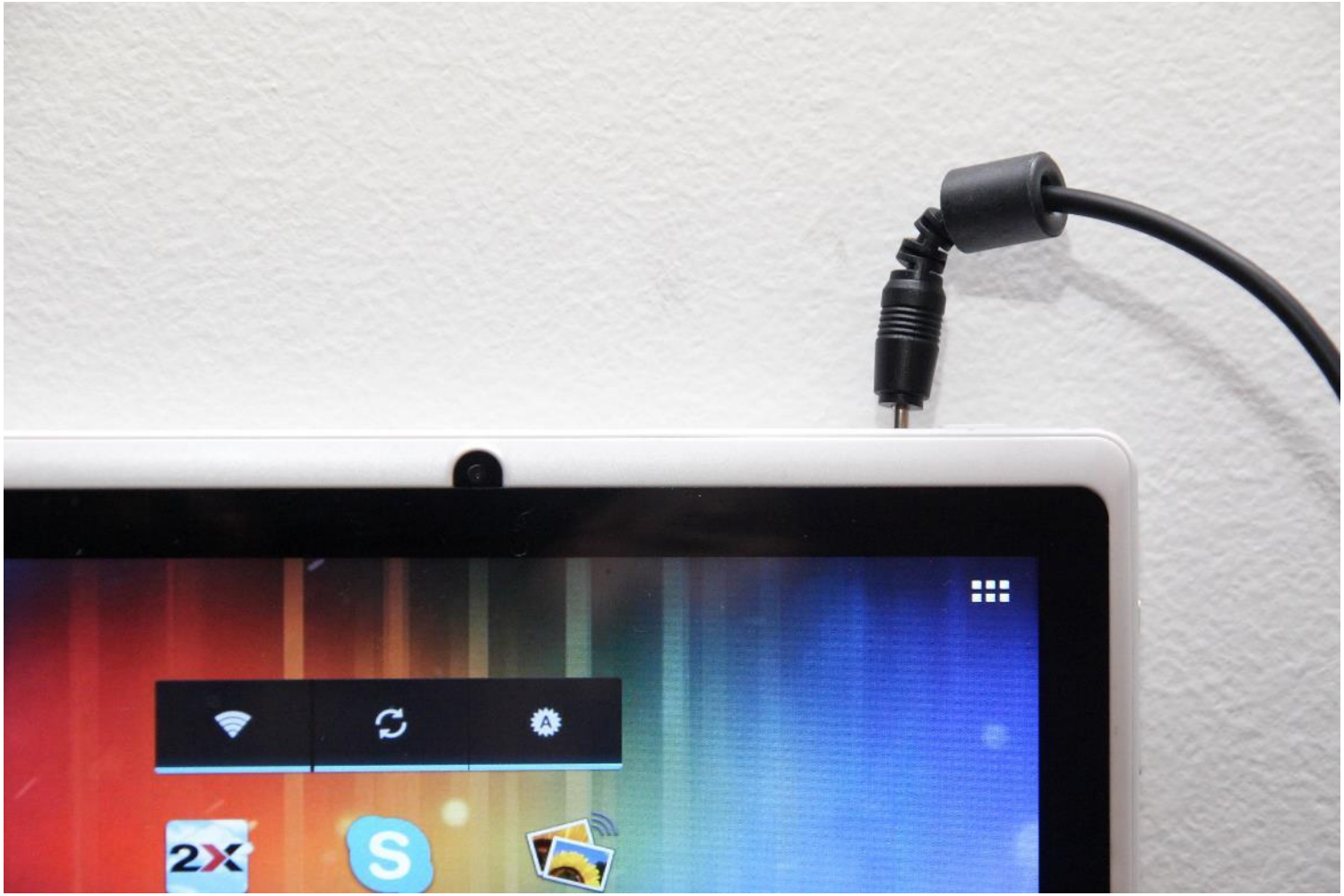
Diferencialni (koristni) signali



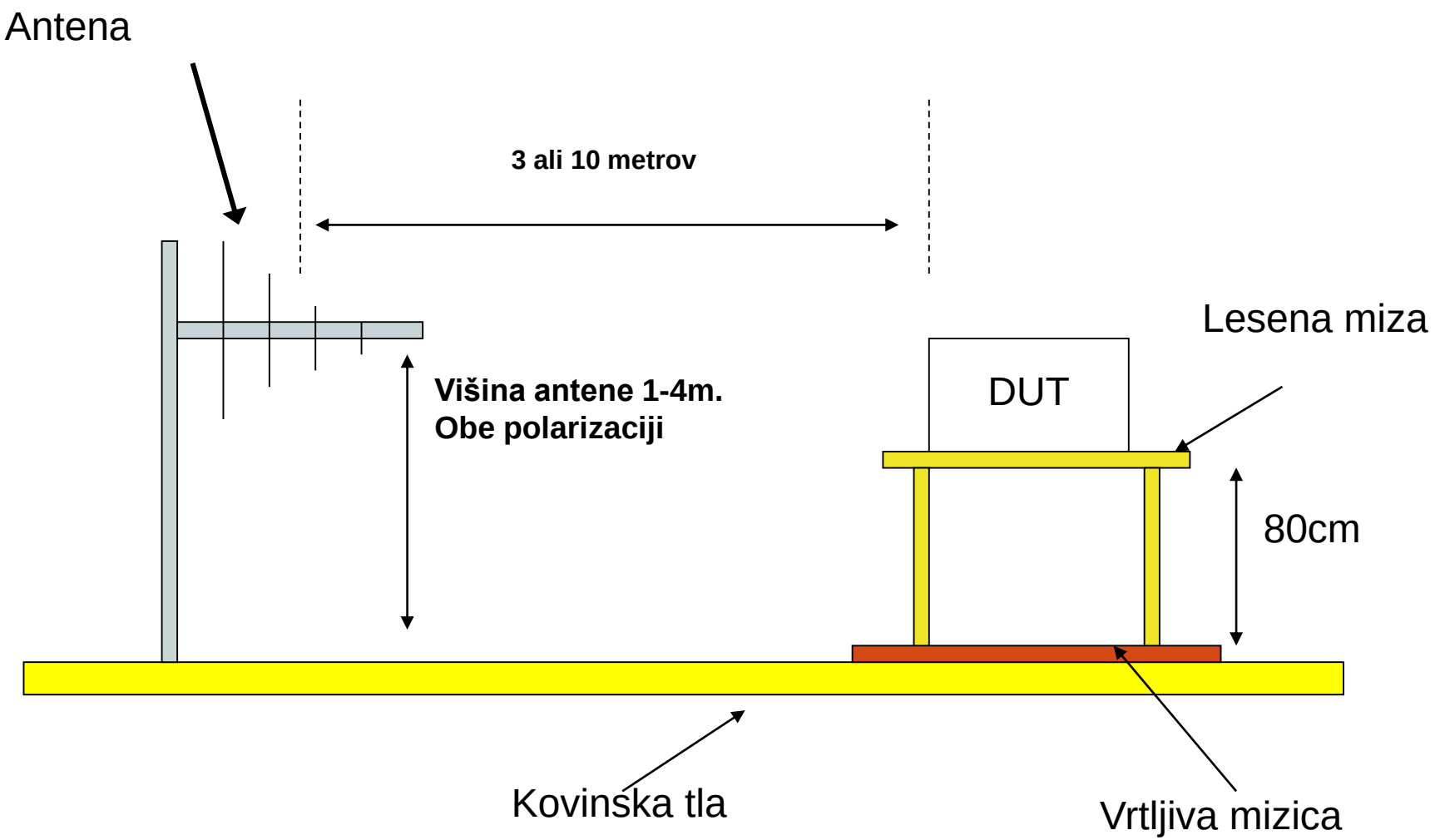
Sofazni (motilni) signali



Kitajska tablica z dvomljivim CE znakom

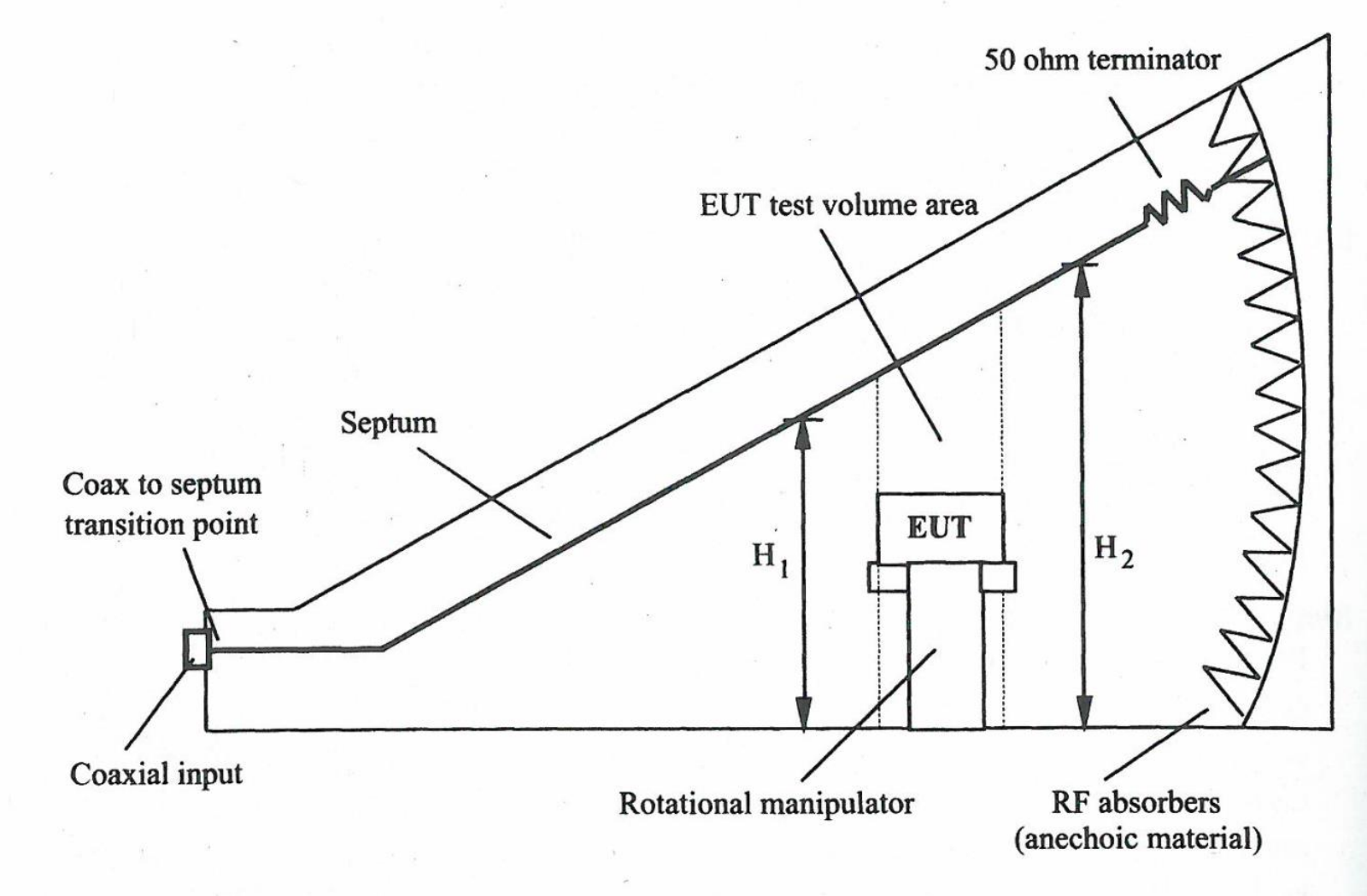


Meritve sevalnih emisij - komora



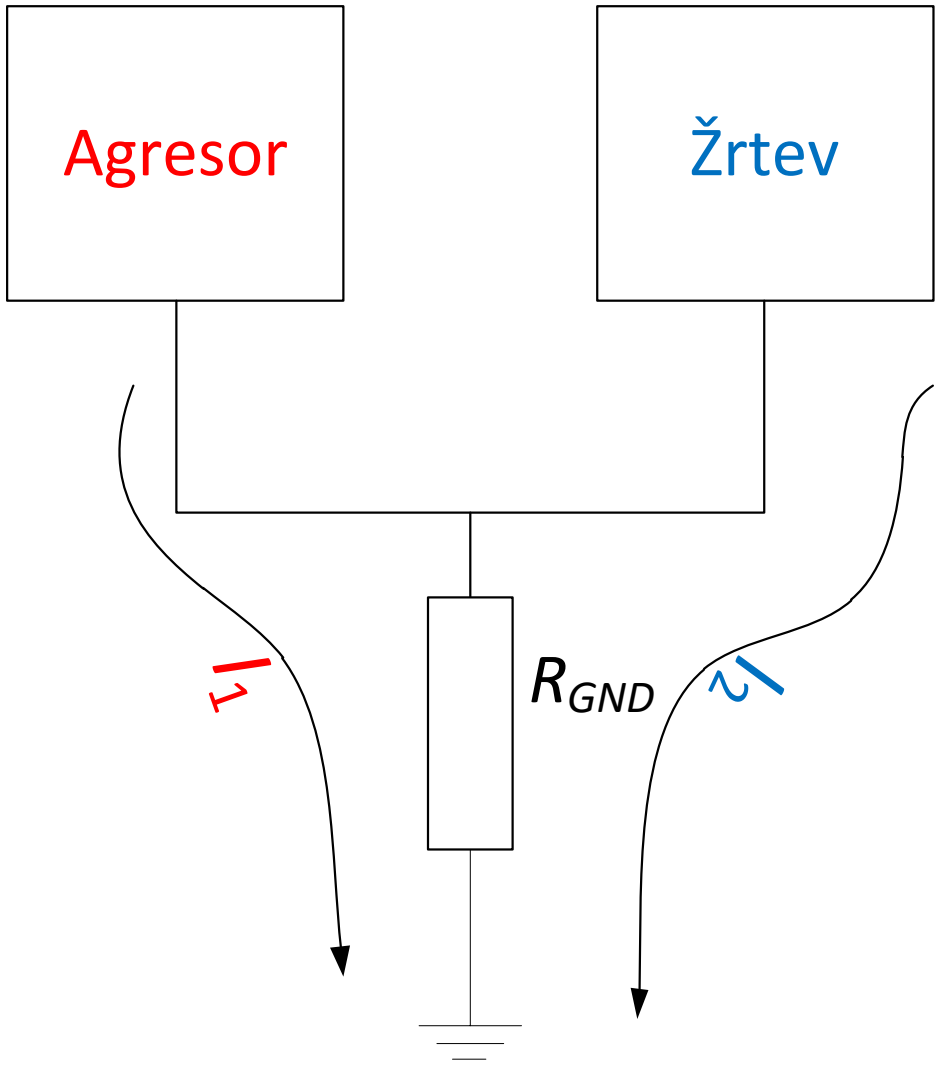
Meritve sevalnih emisij – neodbojna komora

Meritve sevalnih emisij - GTEM celica



Meritve sevalnih emisij - GTEM celica

Prevodni prenos motenj preko skupne mase



\+

$$U_{GND} = R_{GND} * (I_1 + I_2)$$

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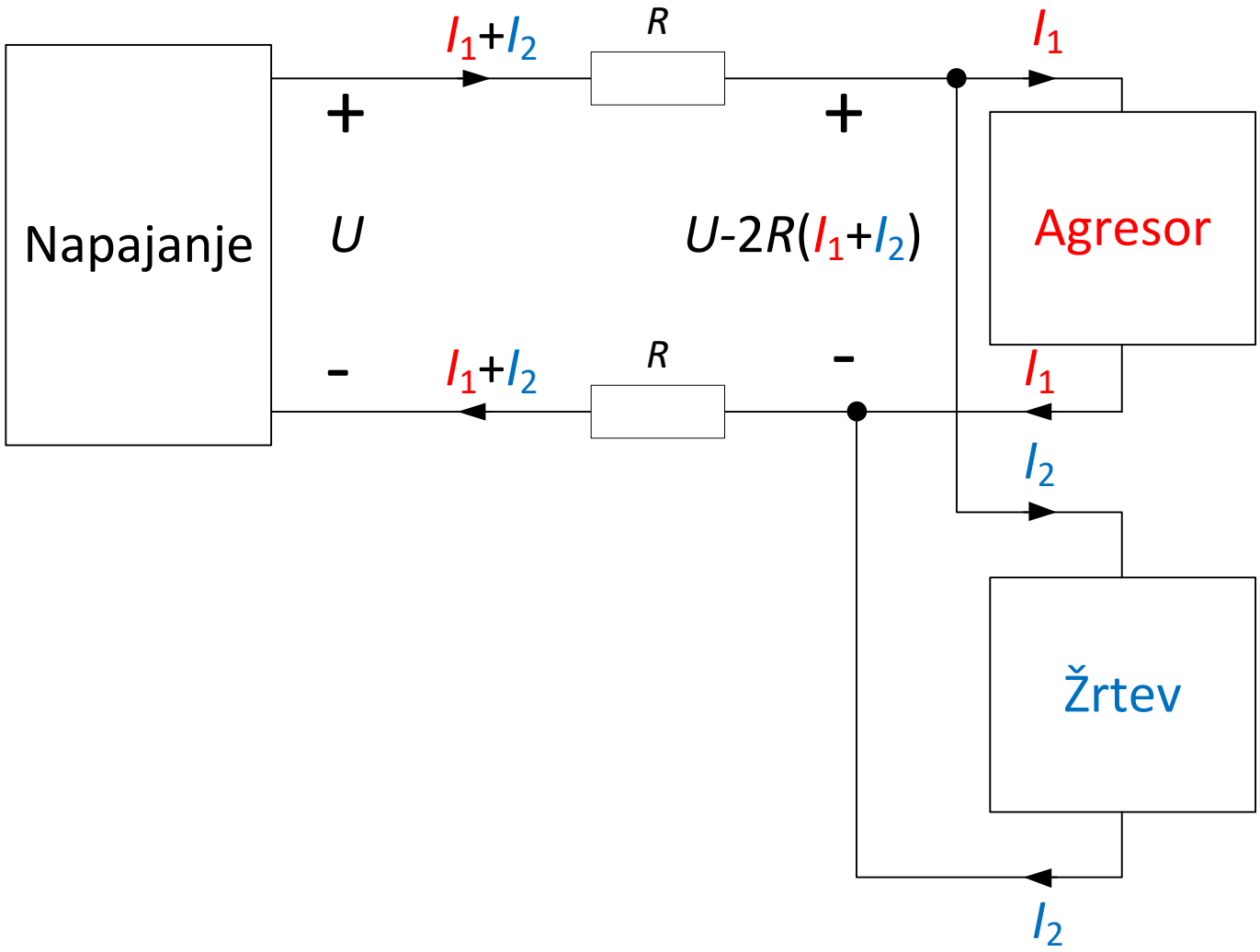
Prevodni prenos motenj iz napajalnih linij



Primer prevodnih motenj

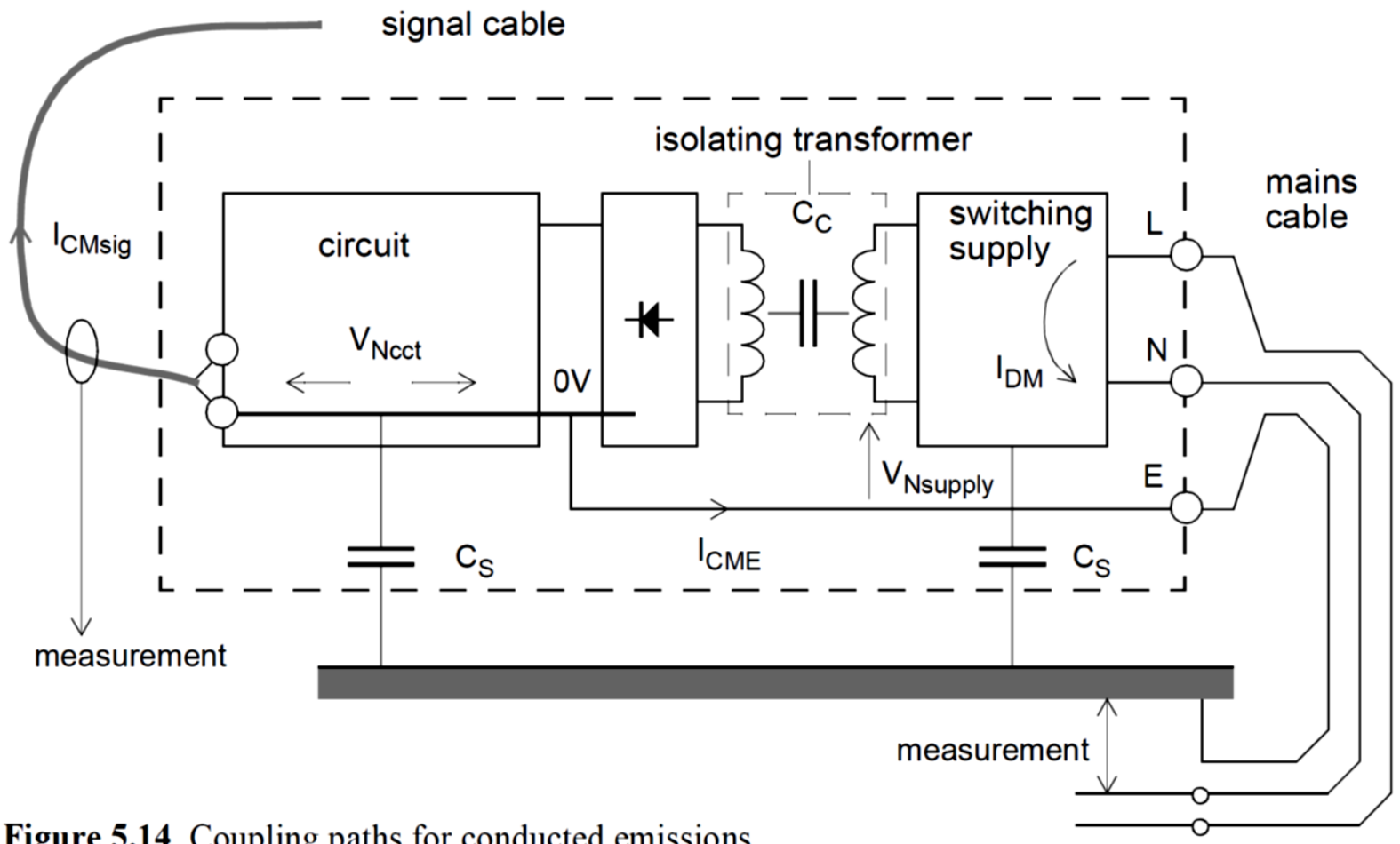


Figure 5.14 Coupling paths for conducted emissions

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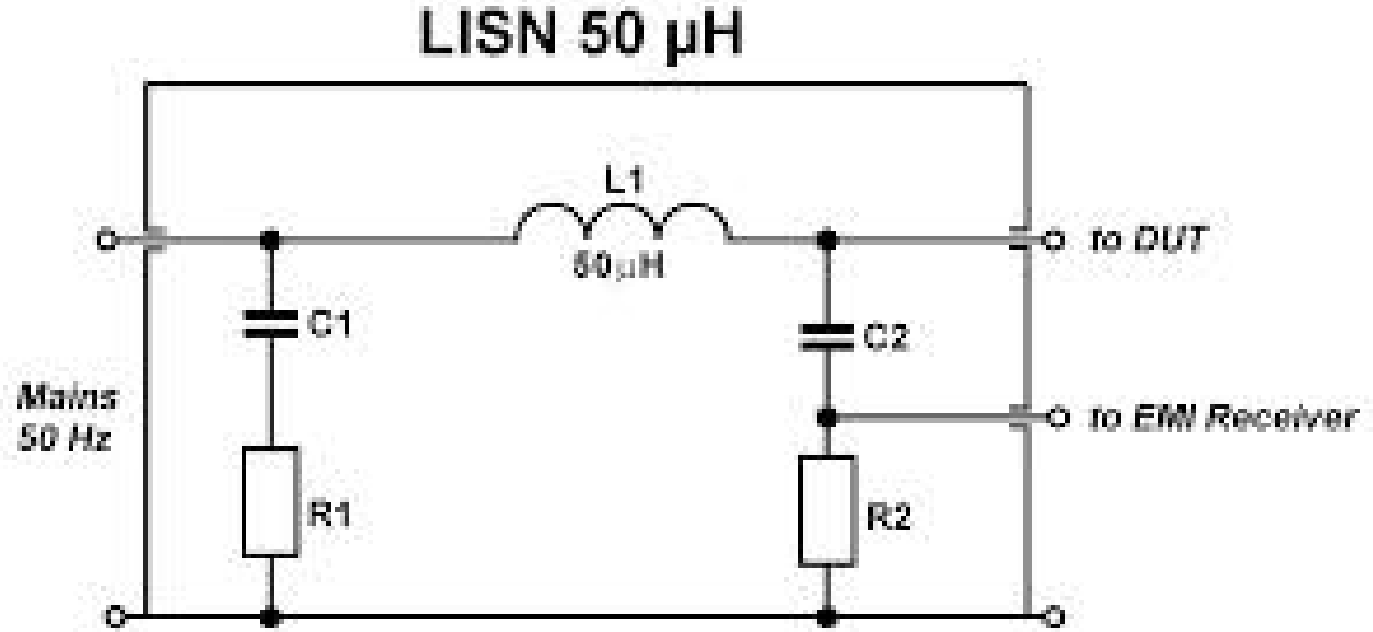
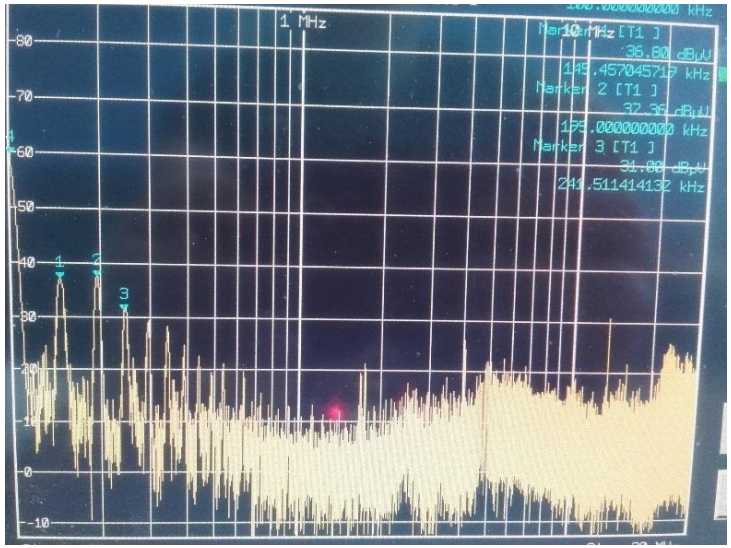
Meritve prevodnih emisij - LISN

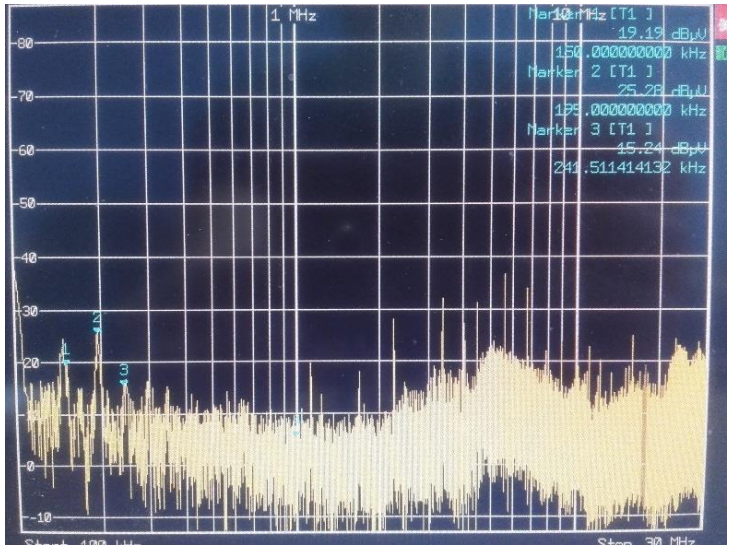


Meritve prevodnih emisij - LISN

Slikano na SIQ pri meritvi emisij vezij iz EMC delavnice

Meritve prevodnih motenj- domača izdelava





Odpornost

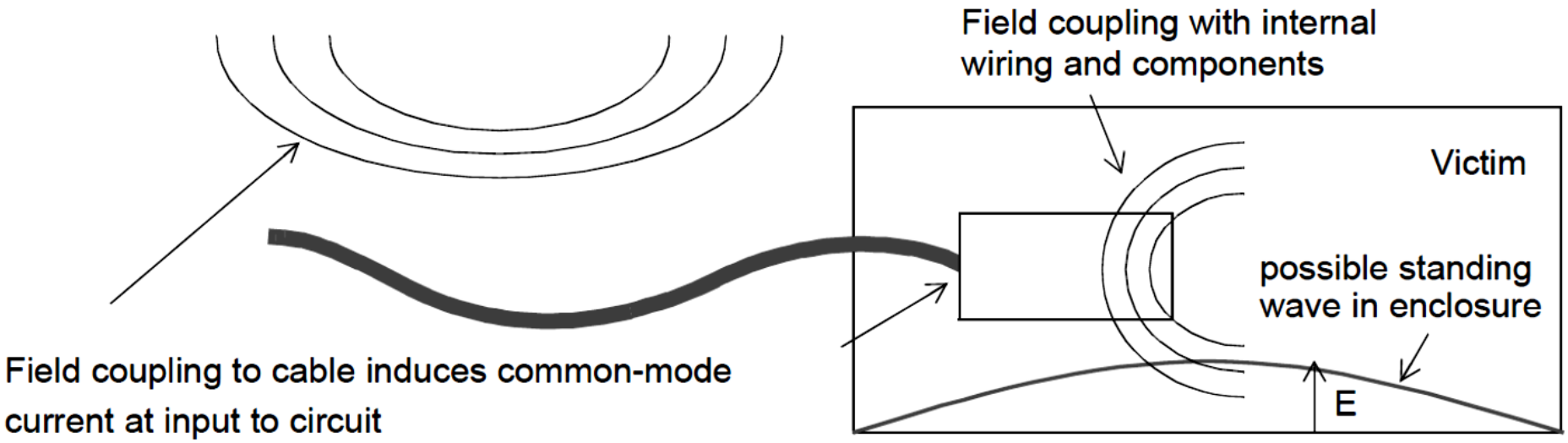
Sevalna

- VF EM polja
- Elektrostatična izpraznitev (ESD)
- NF magnetna polja

Prevodna

- Prehodni pojavi
  - Hitri prehodni pojavi (FTB)
  - Prenapetost (surge)
  - Elektrostatična izpraznitev (ESD)
- Pojavi v omrežni napetosti

Odpornost na sevalne motnje – (recipročnost)



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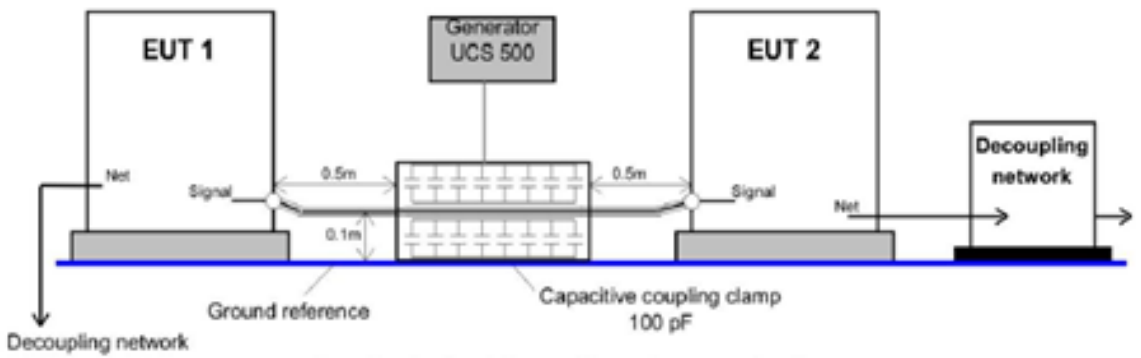
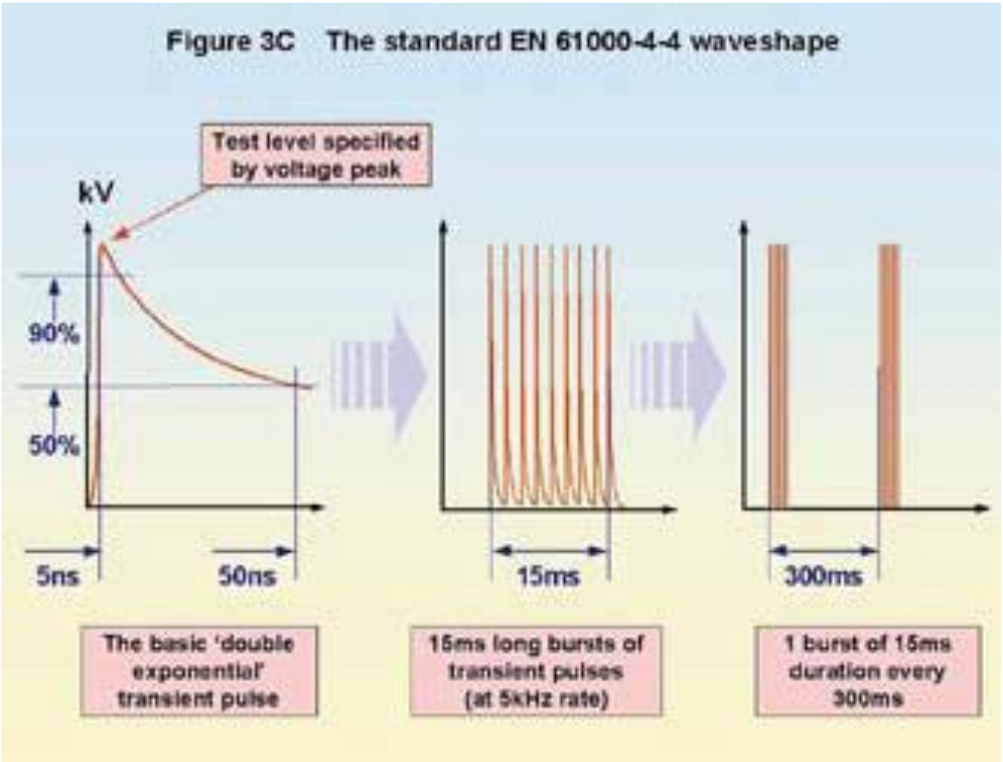
Hitri prehodni pojavi (Fast Transient Bursts FTB)

- Hitri signali, vlaki impulzov
- Vklopi/izklopi
  - Preklapljanje stikal v bližini
- Induktivna bremena
  - Motorji in releji
  - Balasti fluorescenčnih sijalk
- V šopih kablov se ob preklopih motnje kapacitivno prenašajo z vodnikov, ki napajajo močne porabnike na ostale
- Posredni udarci strele, mnogokratni odboji na povezovalnih linijah

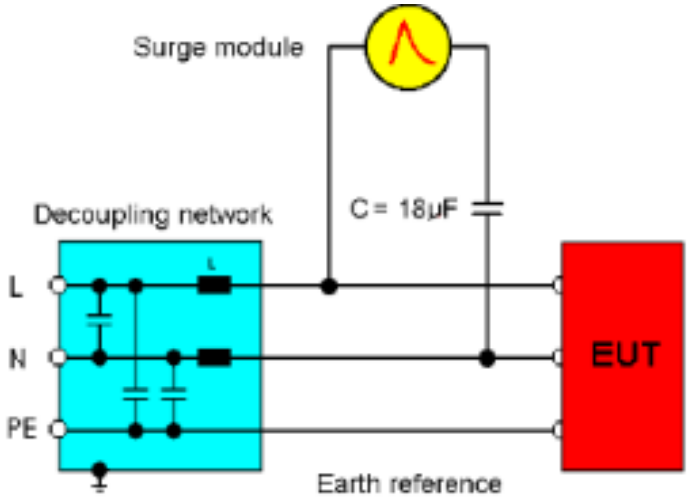




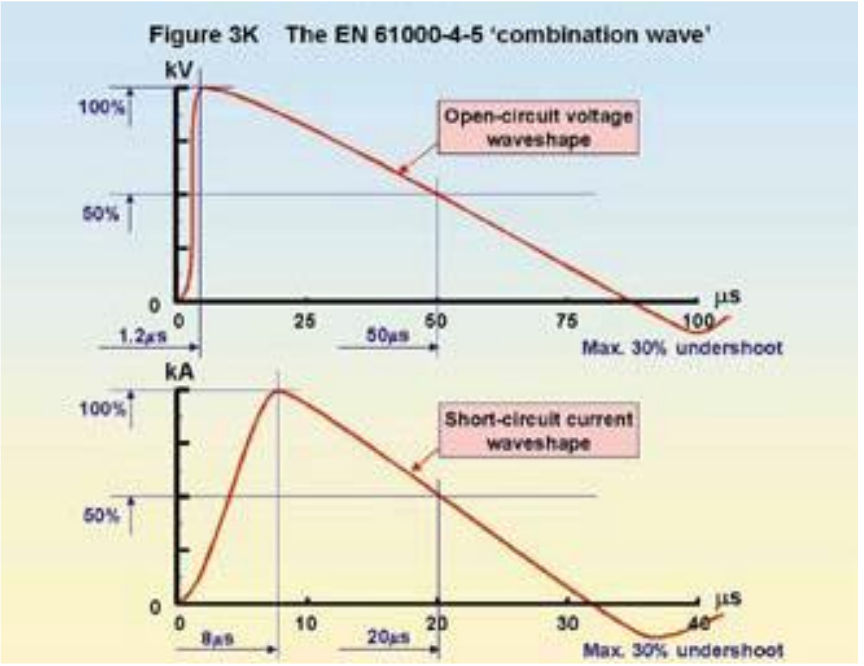
http://www.compliance-club.com/pdf/EMCTestingPart3.pdf

Prenapetost

- Nizkofrekvenčni močnostni impulzi.
  - Preklopi v omrežju
  - Izolacijski problem omrežju
  - Vklopi/izklopi močnih porabnikov
  - Pregorevanje varovalk
  - Udarci strele
- Moč in energija pulzov je dovoljšna, da povzroči eksplozije elementov v napravi
- AC vtičnica v stanovanju
  - 3 x 6kV prenapetostnih pulzov na leto!



Coupling Line to Line



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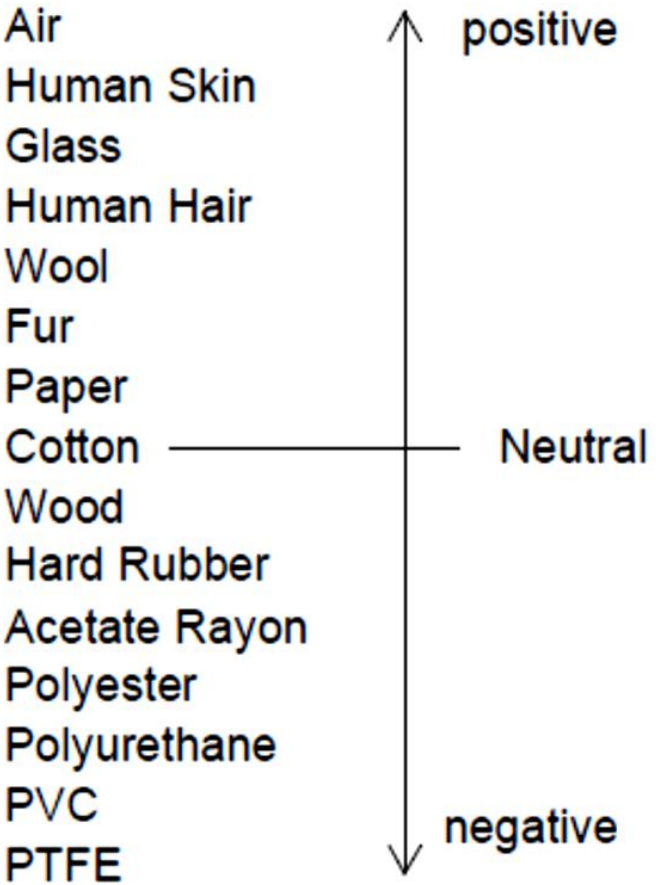
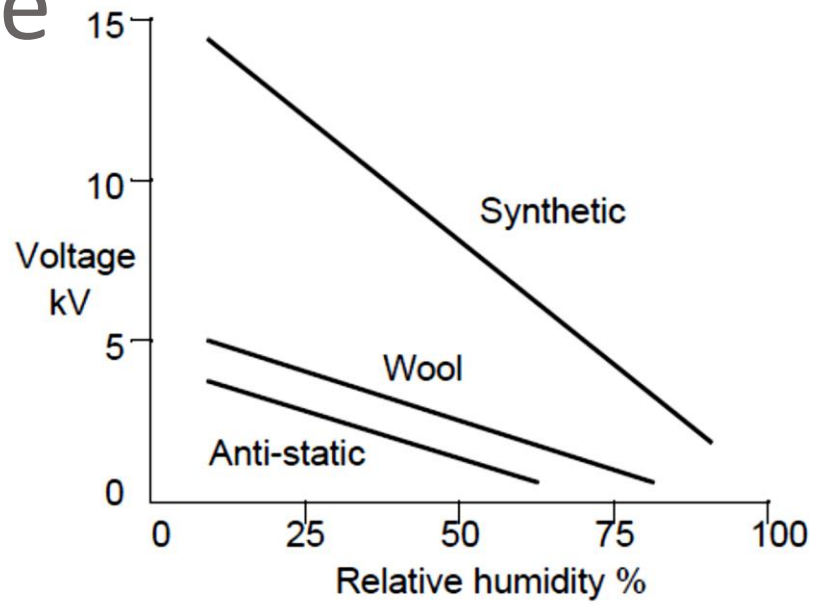
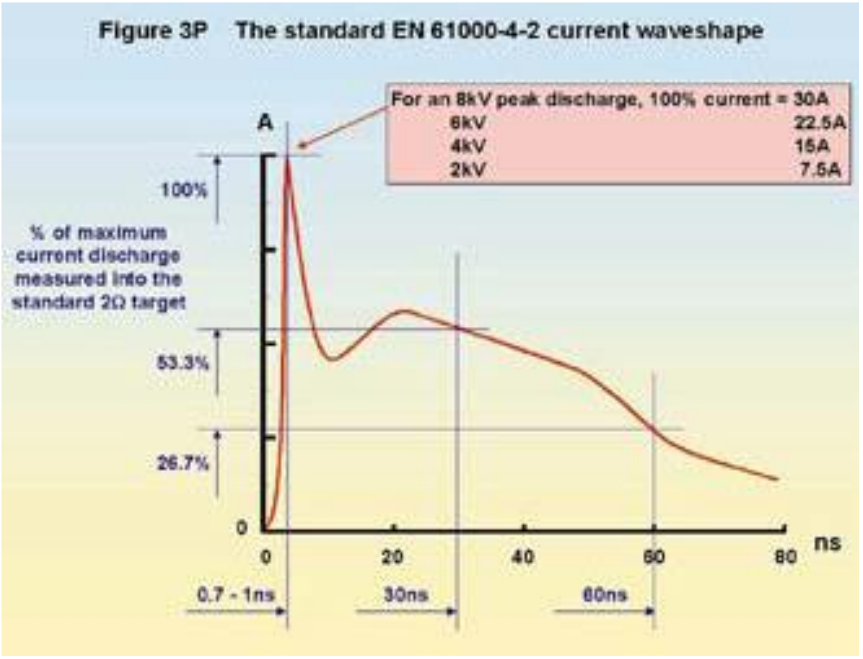
Elektrostatične izpraznitve







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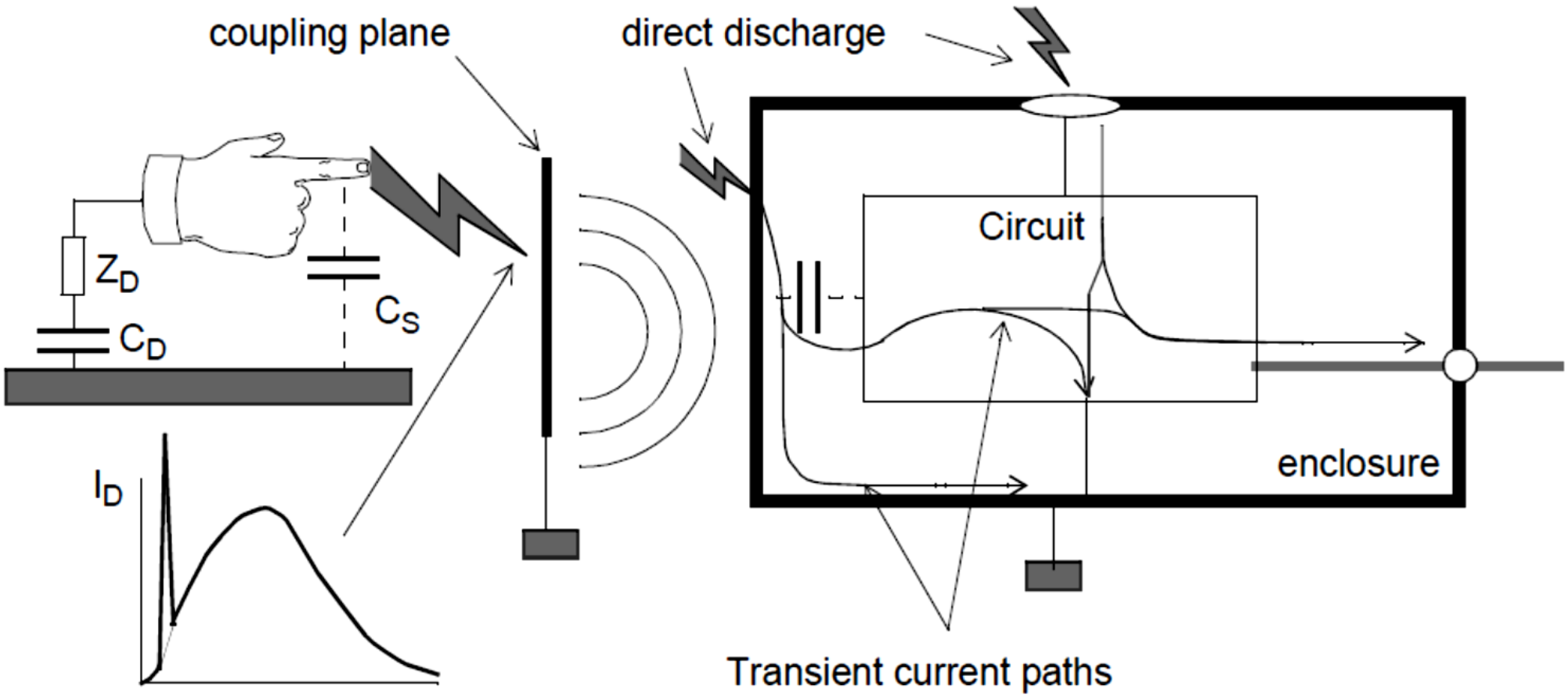
Elektrostatične izpraznitve



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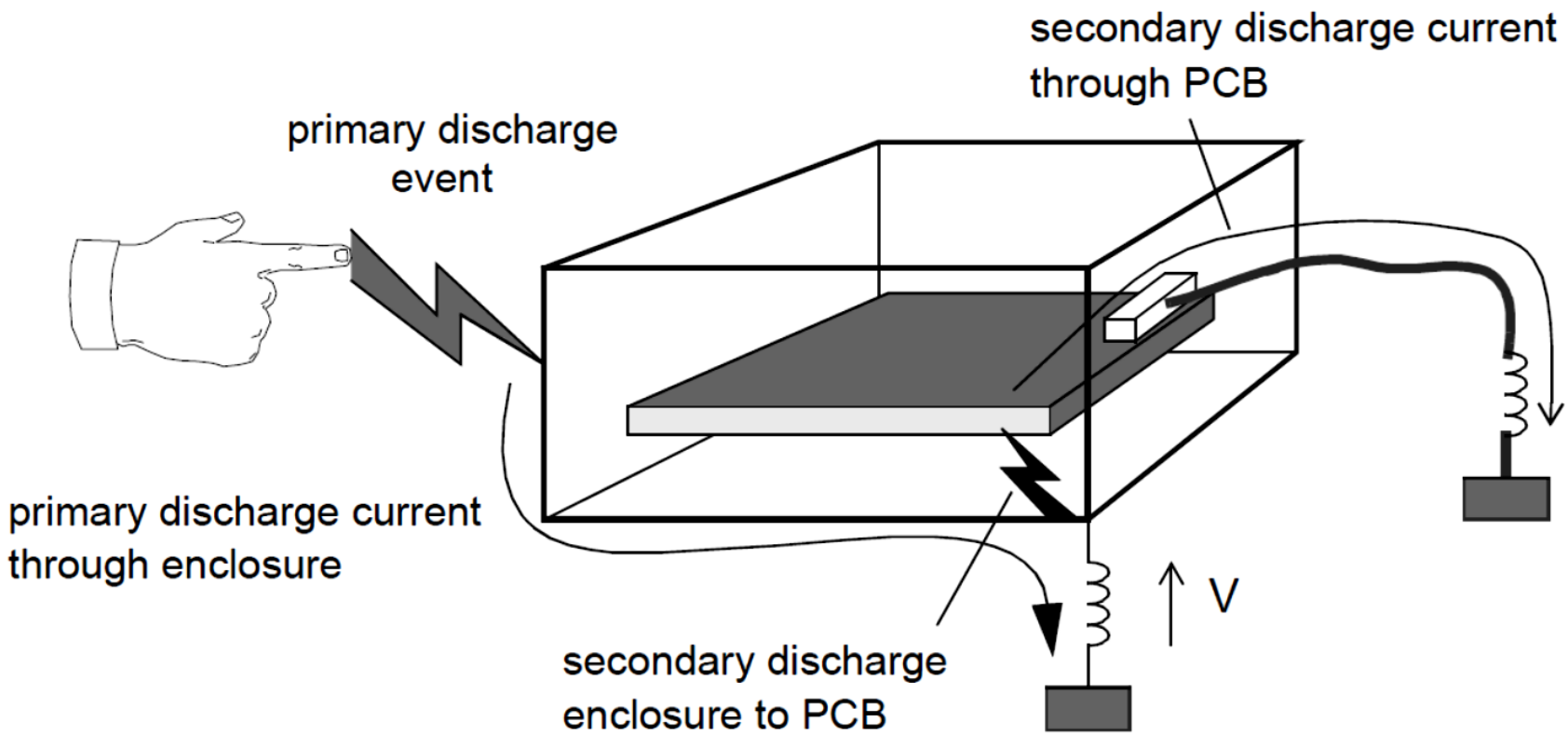
Sekundarne izpraznitvene poti



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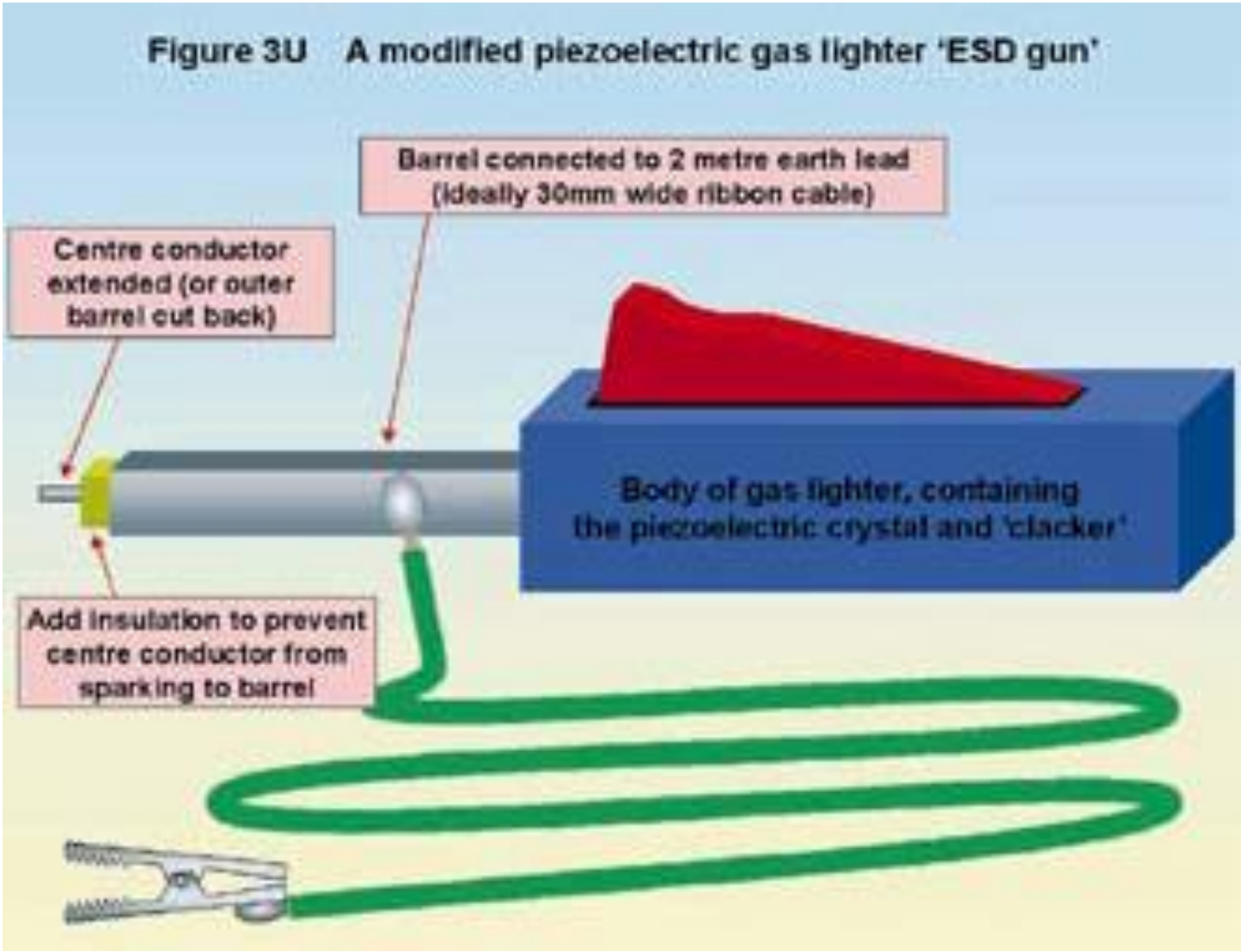
Elektrostatične izpraznitve (ESD)



http://www.compliance-club.com/pdf/EMCTestingPart3.pdf

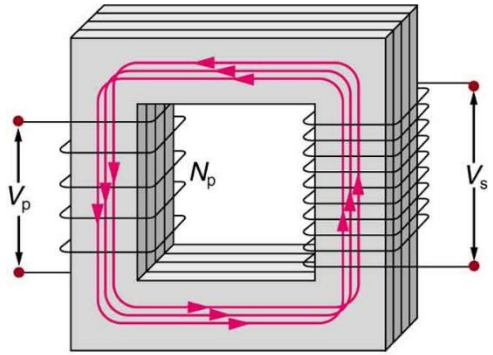
Ostale težave z odpornostjo naprav

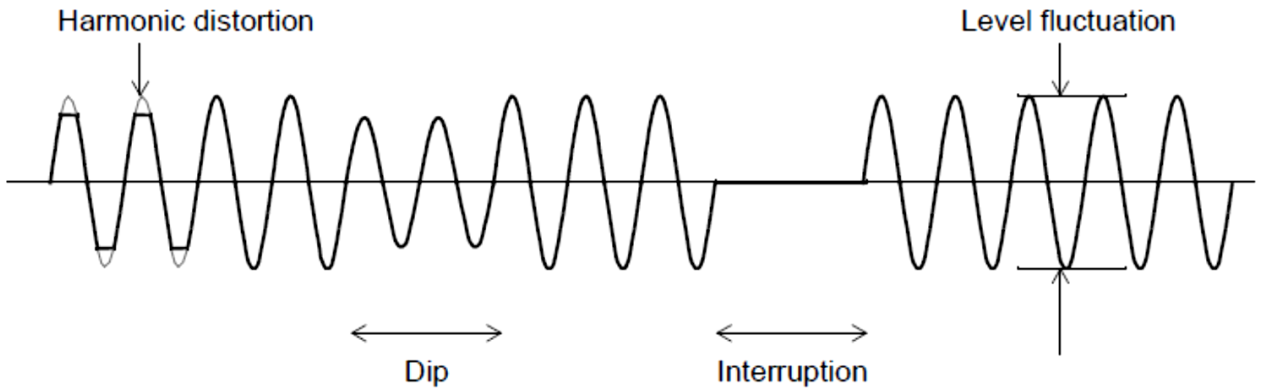
NF magnetna polja

- Indukcija v sklenjenih zankah
  - Transformatorji
  - Stikalni napajalniki (transformatorji)
  - Najpogostejše pri 50 Hz
- Zaščita
  - Oklopi iz visoko permabilnih materialov

Težave v omrežni napetosti

- Višji harmoniki
- Nihanje napetosti, kratki in daljši izpadi in prekinitve napetosti
- Neuravnoteženost trifaznega sistema
- Komunikacije prek napetostnega omrežja
- Spremembe frekvence omrežne napetosti



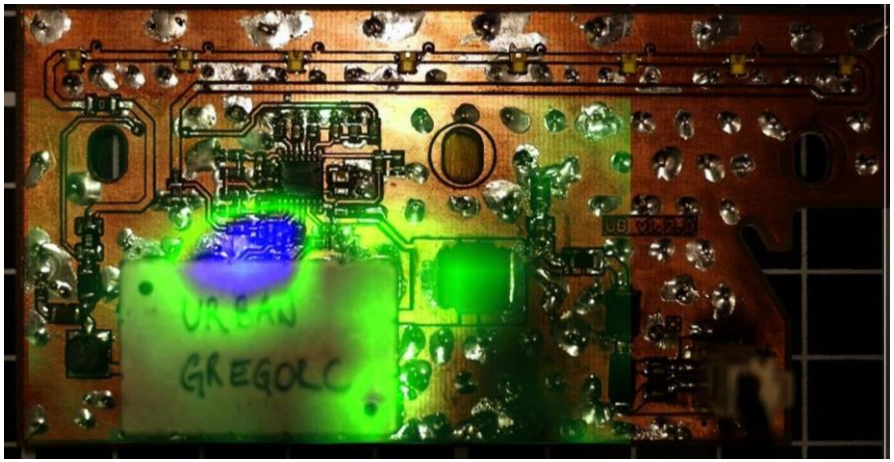


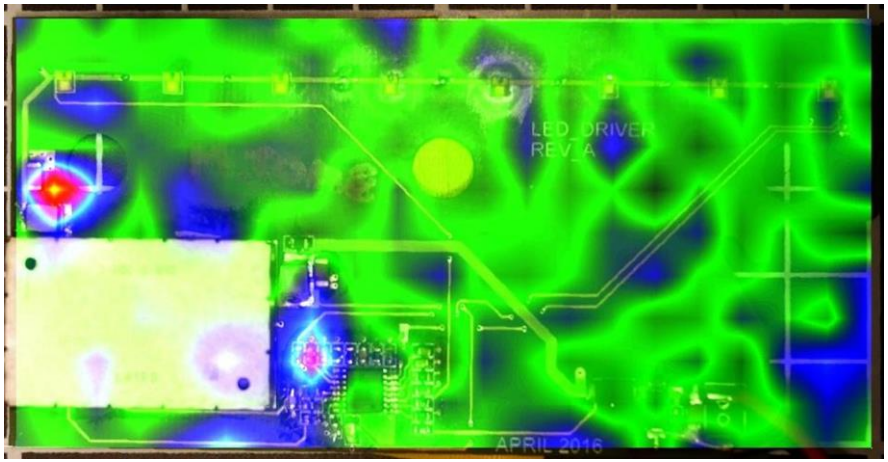
Resnica

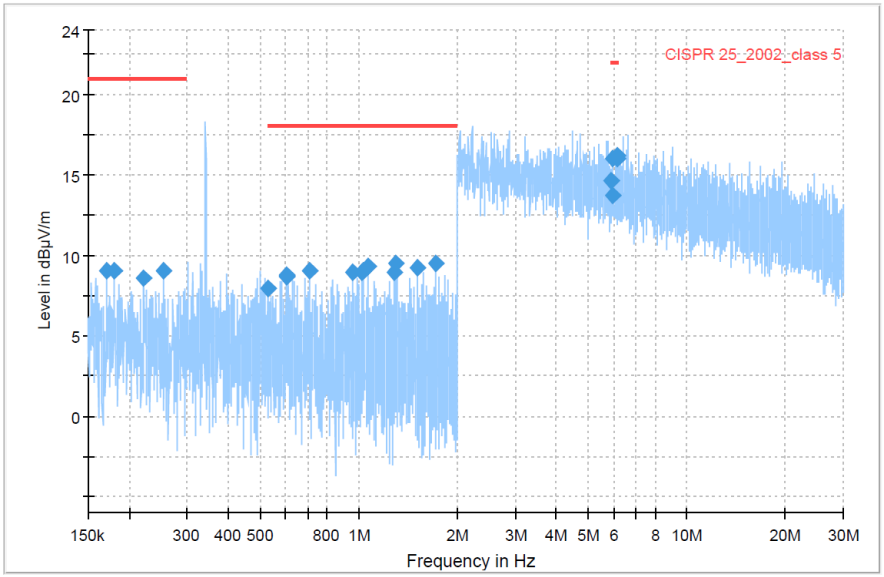
"Some of the worst printed circuit boards we've seen were designed by engineers who were trying to comply with a list of EMC design rules.„

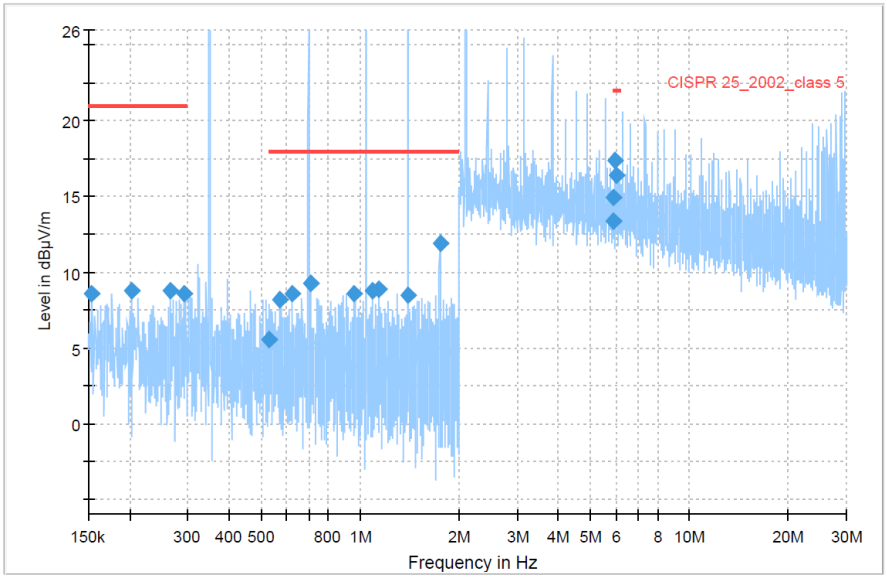
Todd Hubing

Na koncu?









http://lpvo.fe.uni-lj.si/izobrazevanje/seminarji/nacrtovanje-elektronike-za-emc/