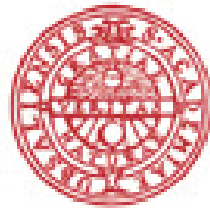

Protection of Civilian Systems against Intentional EMI



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IEMI

“Intentional malicious generation of electromagnetic energy introducing noise or signals into electrical and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes”

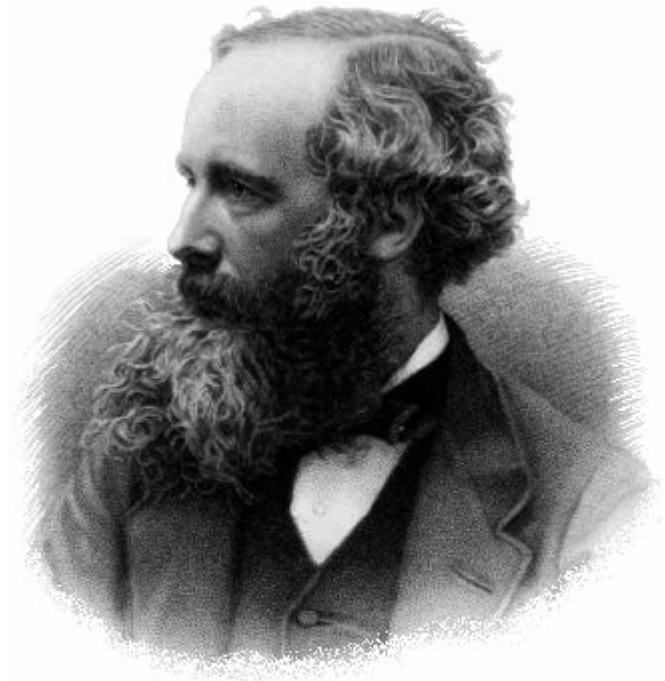
IEC Standard, **61000-2-13**, “Electromagnetic compatibility (EMC) - Part 2-13: Environment - High-power electromagnetic (HPEM) environments - Radiated and conducted”

Intentional Electromagnetic Interference, IEMI...”electromagnetic terrorism”

Nothing new !?

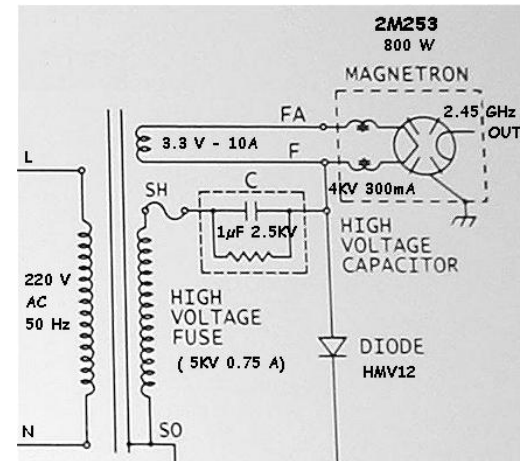
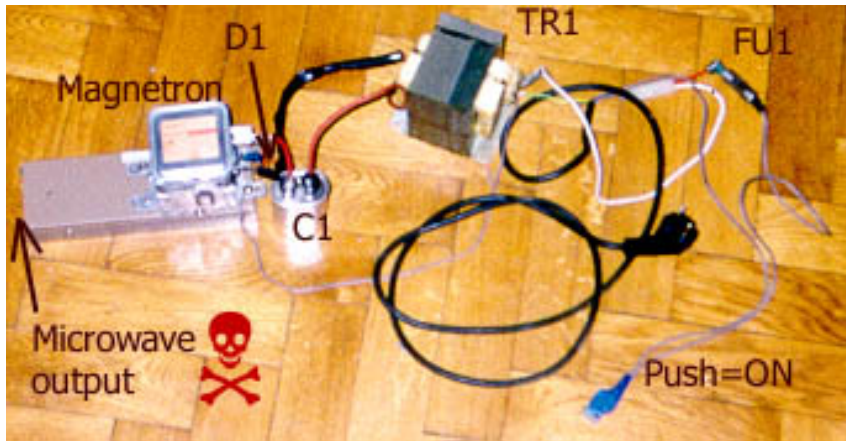
It all still applies !

$$\begin{aligned}\nabla \cdot \mathbf{E} &= \rho \\ \nabla \times \mathbf{B} - \frac{\partial \mathbf{E}}{\partial t} &= \mathbf{j} \\ \nabla \cdot \mathbf{B} &= 0 \\ \nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} &= 0\end{aligned}$$

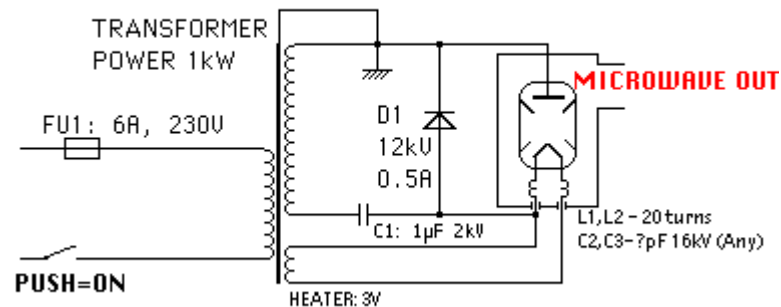


James Clerk Maxwell.

via Google...



ATTENTION! MICROWAVE RADIATION! HIGH VOLTAGE!

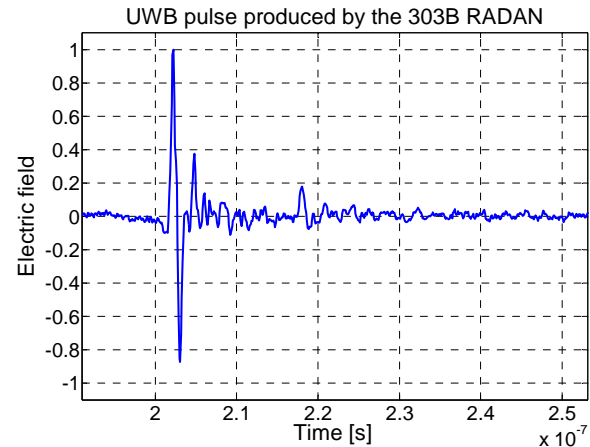
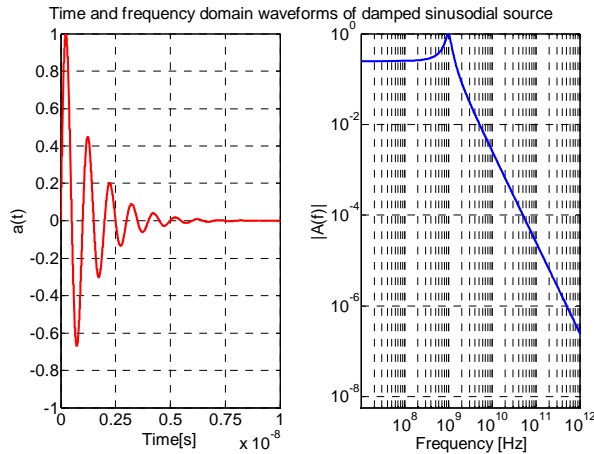
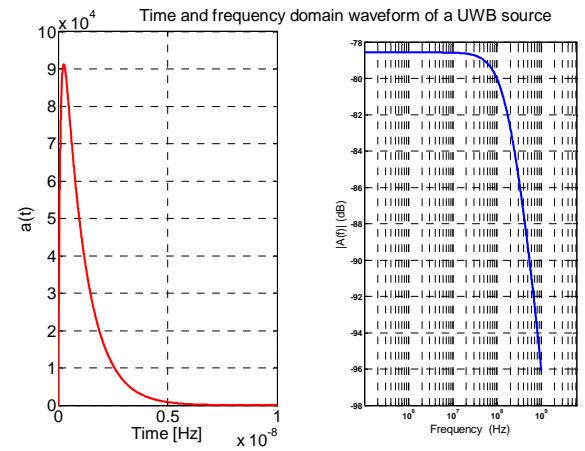
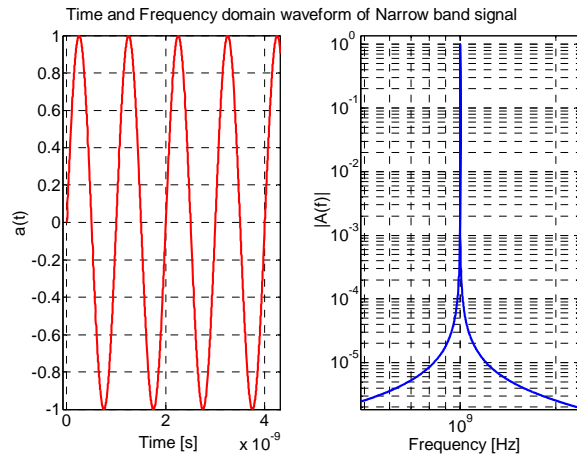


But also...

Nothing new ?



example of waveforms...



Incidents due to HPEM...

In 1967 a US Navy jet fighter landed at Forrestal and due to degraded shielding and a frequency cable the radar frequency interfered with the weapons system. The plane was hit by a discharged weapon and exploded.

Several fighter planes and army helicopters have been known to be susceptible to EMI when flying too close to radio transmitters. Several cases of crashes due to this are known.

During the early years of the German Autobahn many cars experienced radio interference from a radio transmitter.

In 1999 the San Diego County Water Authority and the San Diego Gas and Electric companies were unable to remotely activate critical valve systems in the Supervisory Control and Data Acquisition system. Technicians were sent to manually open and close water and gas valves.

Sensitive medical equipment with due to the radio interference resulting in one case of death.

The cause was US Navy exercises of the Sand Diego

In 1992 a US naval ship entered the Panama Canal without turning off its radar systems. The Canal Zone computer systems were damaged due to the illumination of HPM and had to be replaced.

“Incidents” due to IEMI...

In 1998 two members of the Japanese criminal organization named Yakuza were arrested for manipulating a “pachinko machine” (a type of gambling machine) with a high energy radio frequency (HERF) generator. The HERF generator was hidden on the waist and the criminal was holding the antenna in the hand. They were successful in earning 30,000 yen (200 €).

A Russian criminal was alleged sentenced in 1996 for disabling the alarm system of a Jewel store with a home made COTS RF generator. Also Chechen commander Salman Radueyev used jammers during a raid on the city of Kizlyar to disable police radio communications.

Is protection considered:

- Sensitive electronic equipment used by military is designed to work in a different environment, both Electromagnetic and otherwise.
- For the civilian counterpart, these issues (of IEMI and HPEM) is only mildly (if all) considered.

The railway network

... is special in the sense of

- Distributed
- Uses a mix of sensitive electronics and old technologies
- Easily accessible...
- Critical infrastructure component (personal and cargo transport)

... still how sensitive is it?

What is the effect of a major disruption in the normal routine?

Nothing New ?

Do you have locks on your power-sockets ?

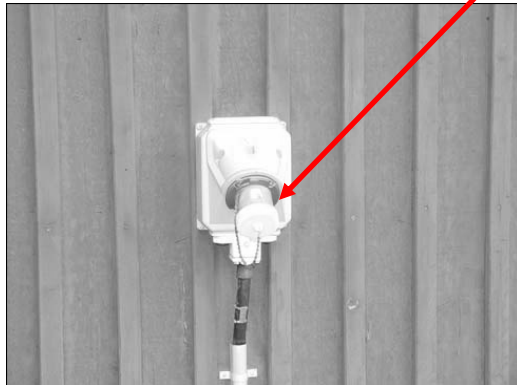


...unusual entry ports



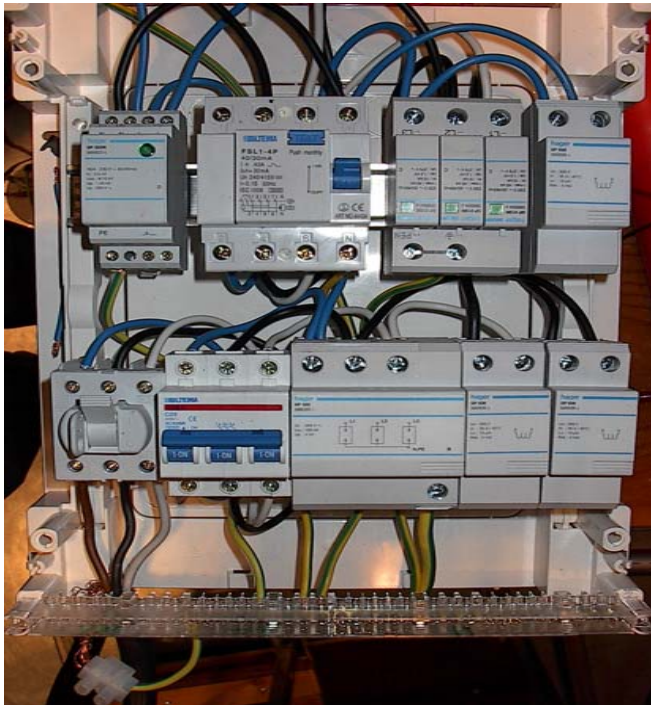
“Front door” coupled

Somewhere in
Sweden (railway
system relay-hut)



NOT uncommon !

...and...

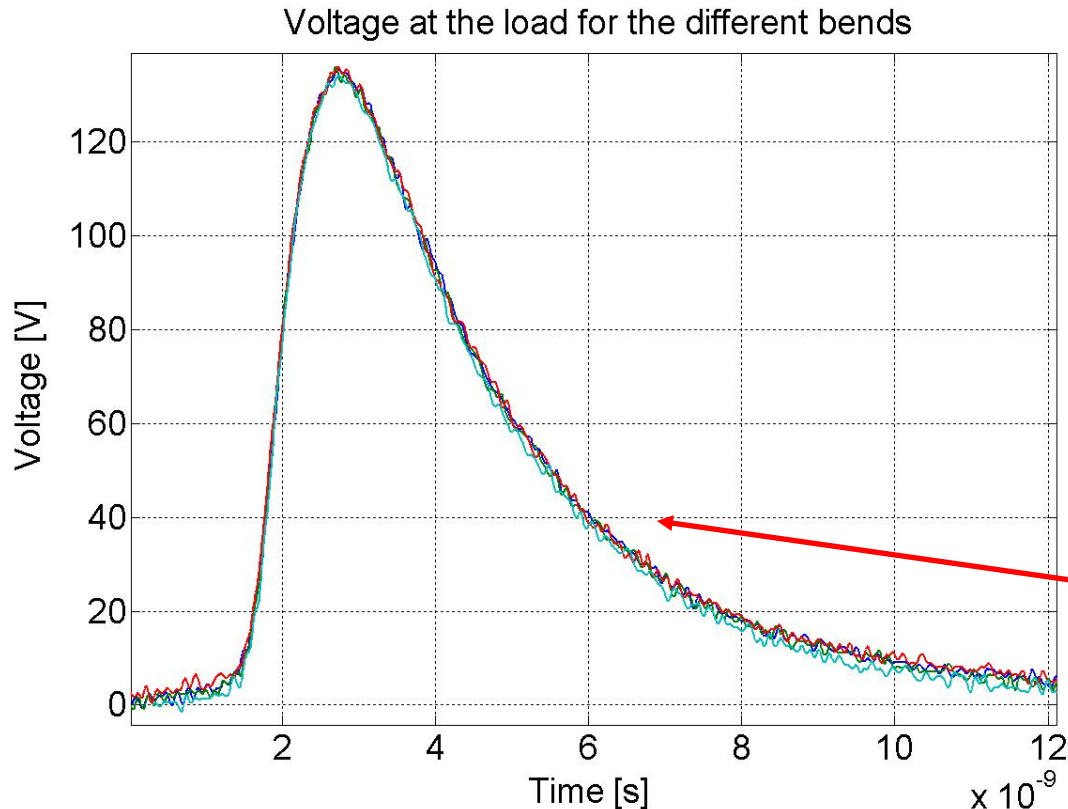


...how do you put
you're cables?

Crosstalk effects...



....and it propagates....



The power of an UWB pulse in a low-voltage power network is mostly attenuated due to mismatches :

source \leftarrow \rightarrow cable

Cable \leftarrow \rightarrow load

E.g. for D.M injection bends have no effect on received power.

By: UU & FOI

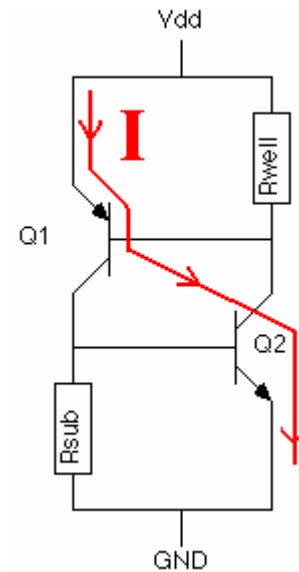
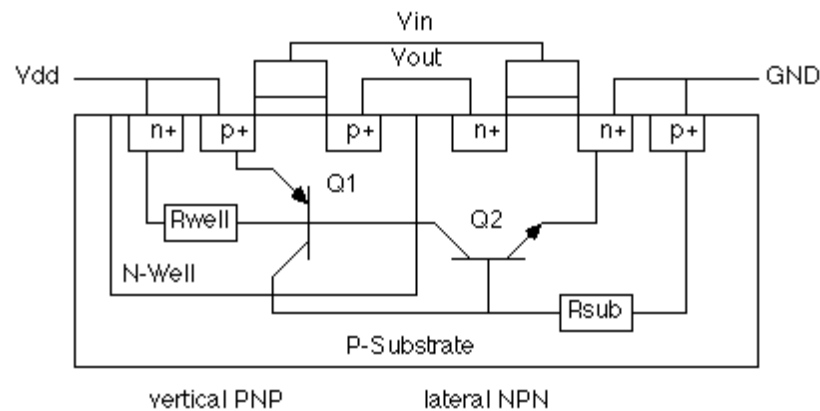
....and then

As we have seen sensitive electronic equipment can be disrupted and damaged by HPEM

Some equipment can even be more susceptible to UWB HPEM due to e.g. *Latch-up* effects in CMOS IC.

$V_{\text{trigger_latchup}} \sim 1 / \text{Pulse-width}$

...reminder of Latch-up...



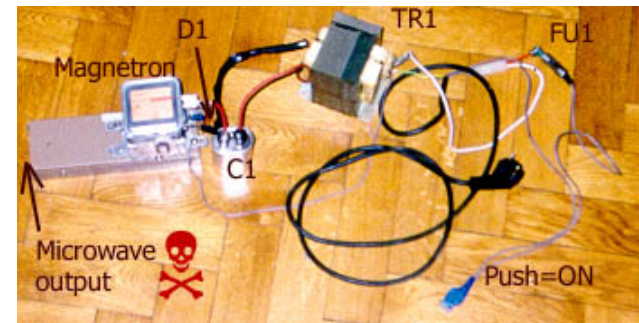
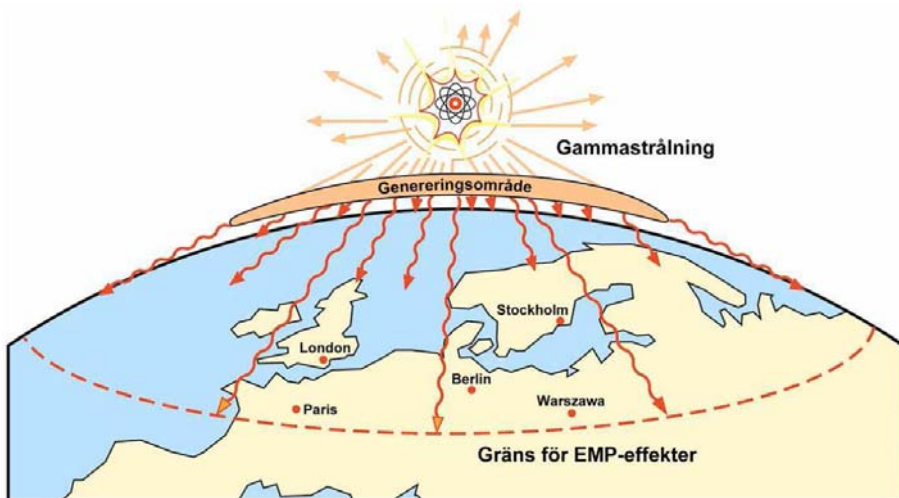
...however sometimes it may be that UWB field cause less disruptions.

1. Backdoor coupling through, e.g. slots increases with freq.
2. ...however coupling onto wires (can) decreases with freq.

Is this why irradiated systems suffer little disruptions above a few GHz (like everything, exceptions exists e.g. resonances, front-door coupling, ...)

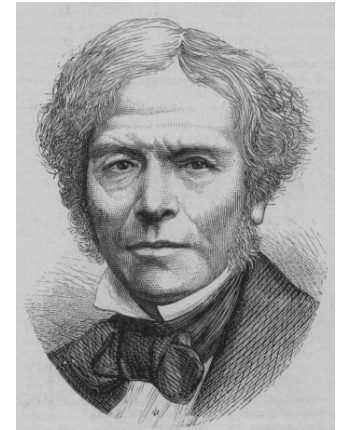
...protection...

Remember that HEMP and HPEM / IEMI is not the same !



Distance protects!

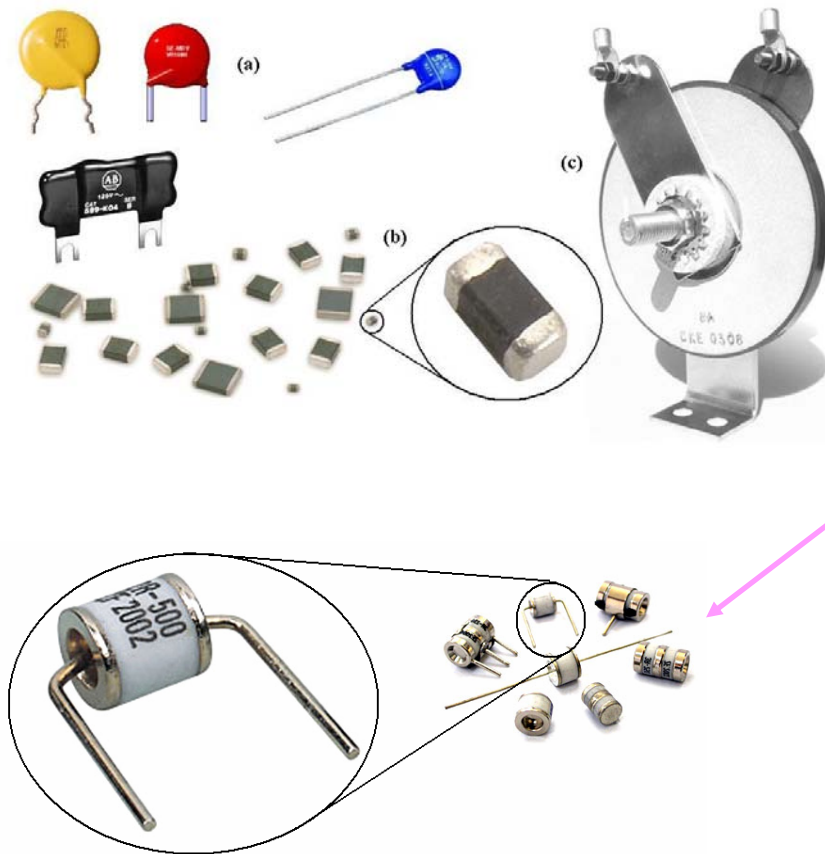
1. ...locks on you're power sockets...
2. Fences
3. Metal mesh/wall (remember our old masters; Faraday)
4. “Texan mentality” ...Keep “them” out!



...but e.g. the railway is distributed and a civilian service; difficult to “harden”

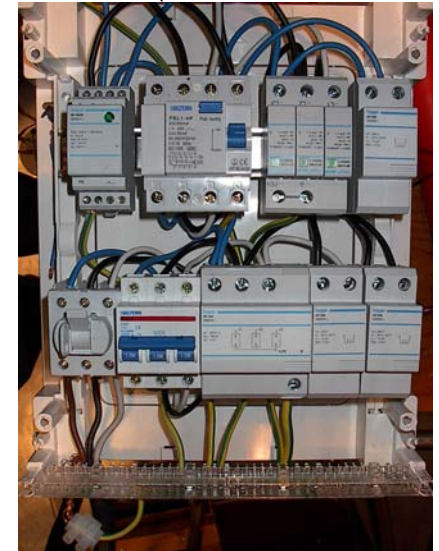
“Modified” EMC procedure and practices good tools ??

Surge protective devices



Labb...

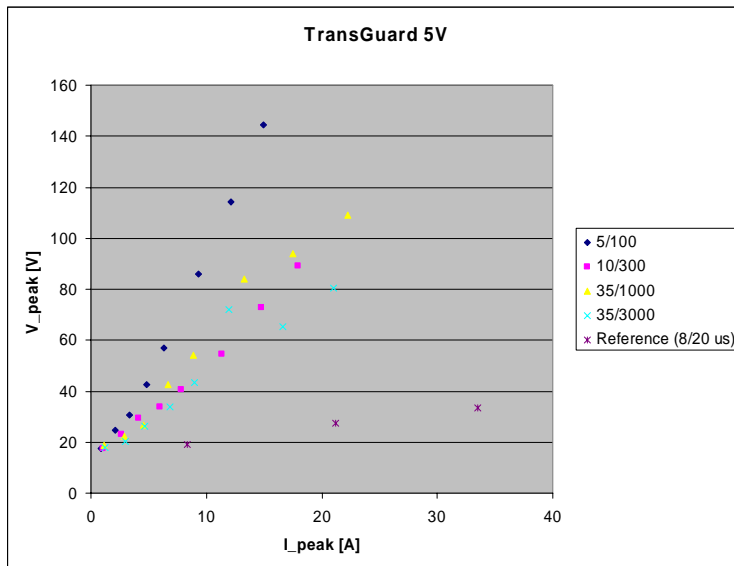
Reality...



SPD may not work as expected to nanosecond rise-time transients ... V-I characteristics

MOV

Dissimilar, much larger impedance than for reference.



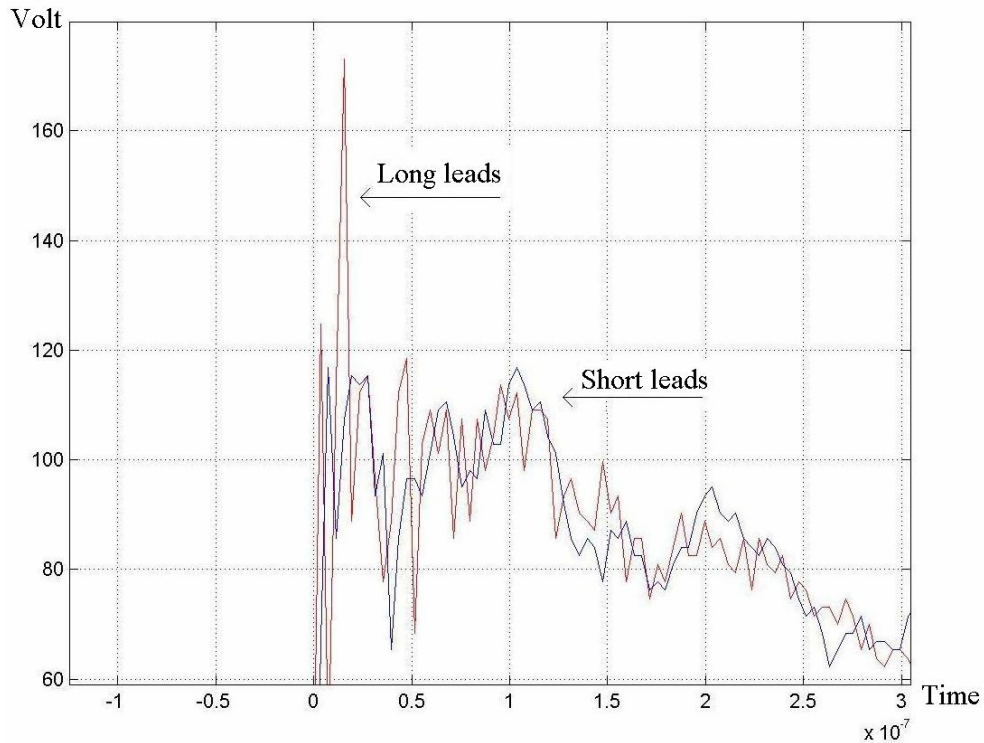
SPD may not work as expected to nanosecond rise-time transients ... Breakdown / clamping voltage

MOV → V_{clamp} approximately as from LEMP (8/20 us) experiment and data sheets

GDT → $V_{\text{breakd.}}$ >> than from LEMP (8/20 us) experiment and data sheets

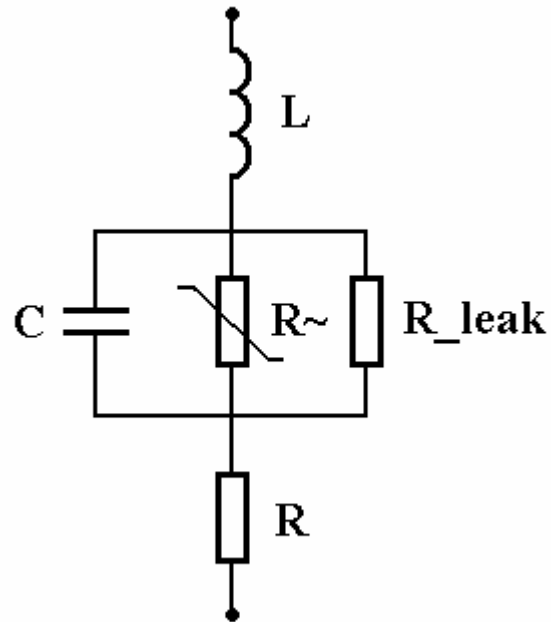
Packaging...

e.g. effect from leads



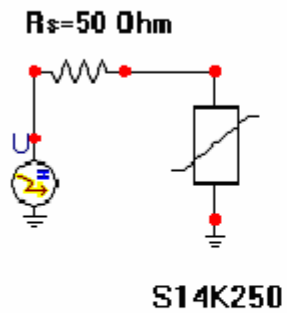
Packaging...

...what happens to the MOV component ?

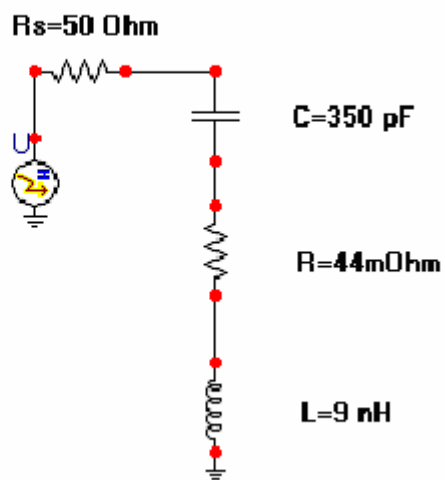


Packaging...

Varistor

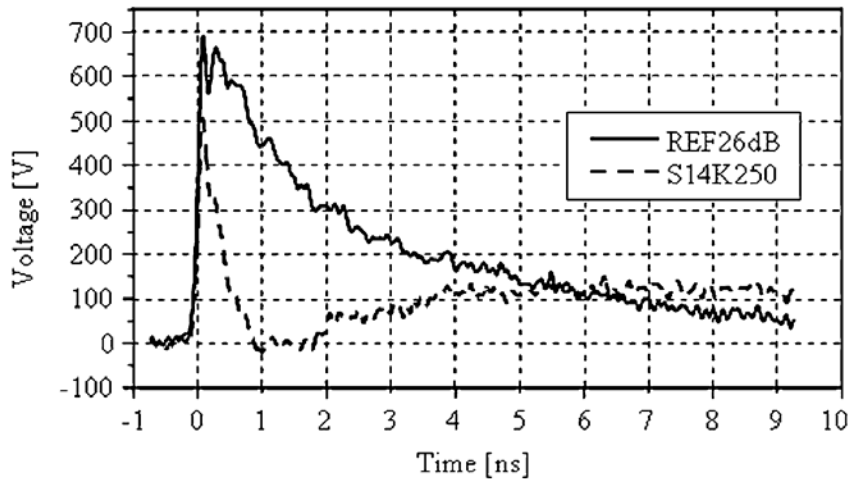


Capacitor model

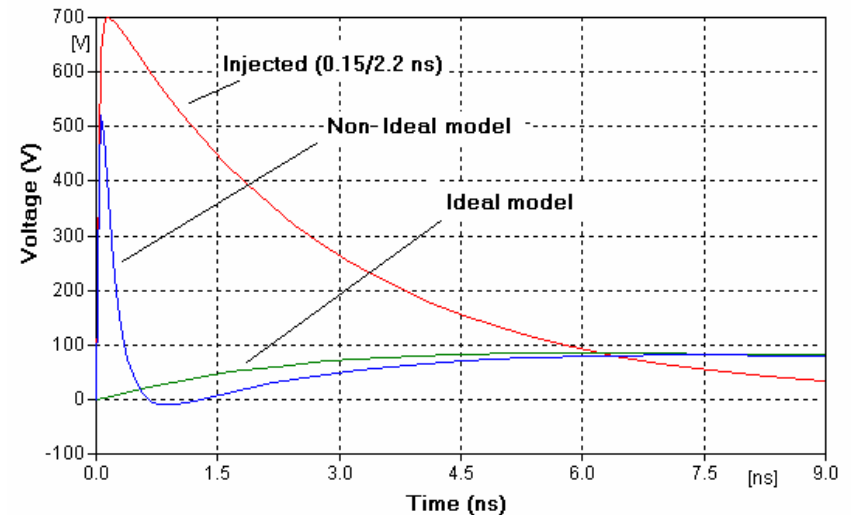


Packaging...

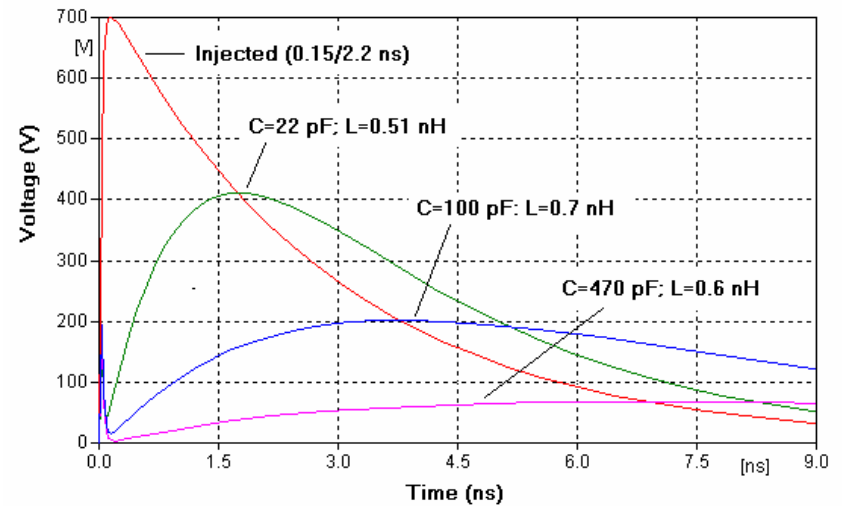
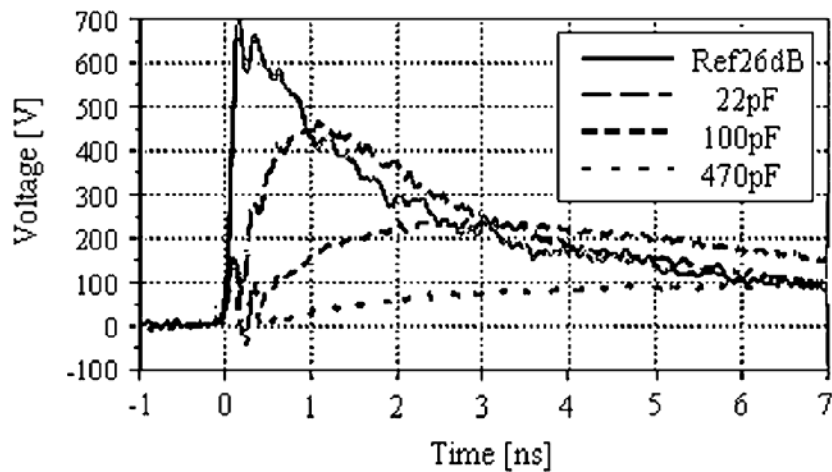
T. Weber and J. L. ter Haseborg, "Measurement Techniques for Conducted HPEM Signals", *IEEE Transactions on Electromagnetic Compatibility*, Vol. 46, No. 3, August 2004



Daniel Månsson and Rajeev Thottappillil; "Comments on "Linear and nonlinear Filters Suppressing UWB Pulses"", *IEEE Transactions on Electromagnetic Compatibility*, Vol. 47, No. 3, August 2005



Packaging...



Finally...

Nothing new ...

Thank you !

Questions ?