Bundeswehr

HPEM Plenary Talk

Electromagnetic Effects on Systems and Components

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Armed Forces Scientific Institute for
Protective Technologies and NBC Protection

Overview

Bundeswehr

- Introduction
- Threat
- Effects
- Problems / Approach
- Classification of threats, effects and impact
- Exemplary susceptibility data
- General trends of susceptibility behavior
- Conclusion

Introduction

Bundeswehr

Importance of electronic systems in today's daily life

- Security
- Medicine
- Economy
- Traffic
- Communication
- Armed forces

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Threats

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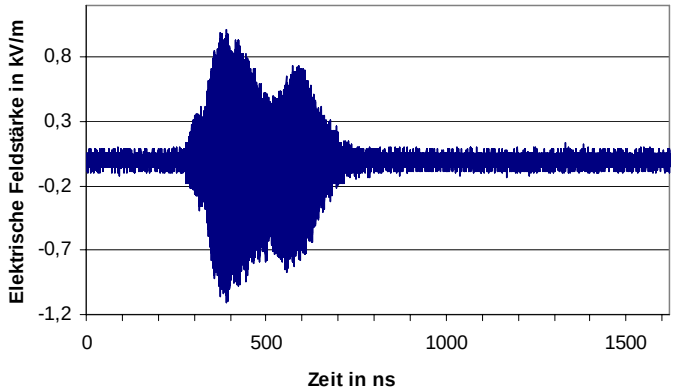
CW:

- Continues Wave
- Hypo / Narrow-Band ($B_F \leq 1\%$)
- AM-Modulated

HPM:

- Pulsed Microwave
- $f_c = 0.5 – 5$ GHz
- Hypo / Narrow-Band ($B_F \leq 1\%$)
- Duration $\leq$ 500 Cycles



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Threats

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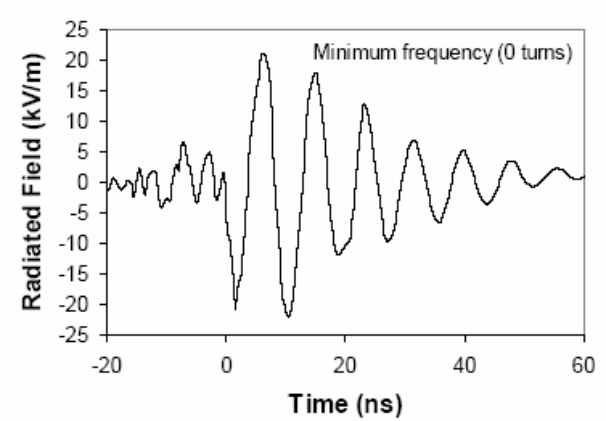
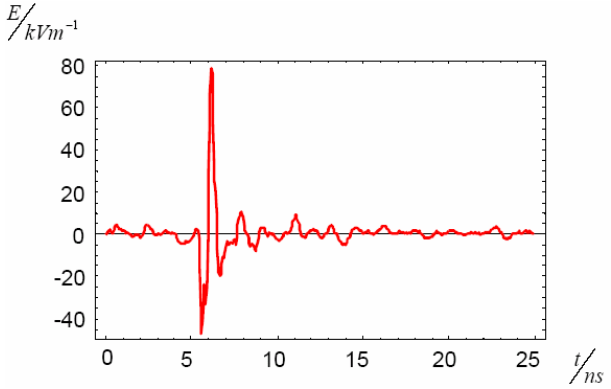
WB:

- Damped Sinusoidal
- Meso / Wide-Band ($1\% < B_F < 25\%$)
- Single Shot – Burst – Repetition



UWB:

- Short-Pulse Signals
- Hyper / Ultrawide-Band ($B_F \geq 25\%$)
- Single Shot – Burst – Repetition



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Effects

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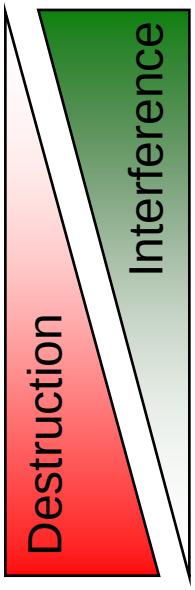
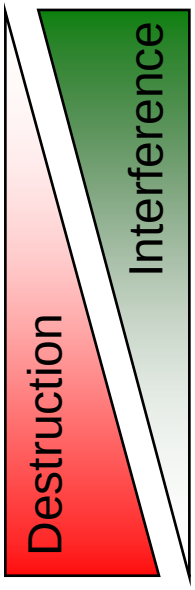


- Bit-Flip
- Latch-Up
- Flashover
- On chip wire melting
- Bond wire destruction

Effects

Bundeswehr



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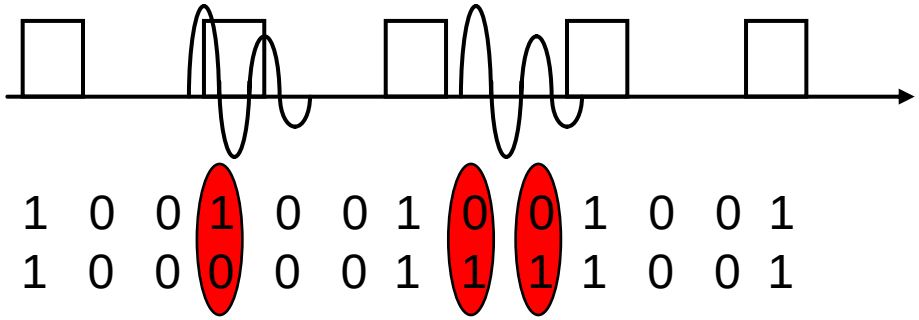

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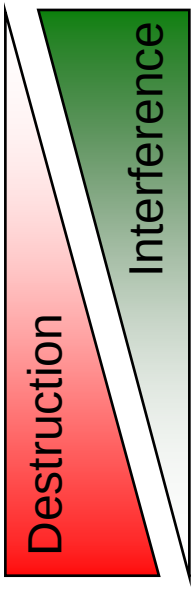

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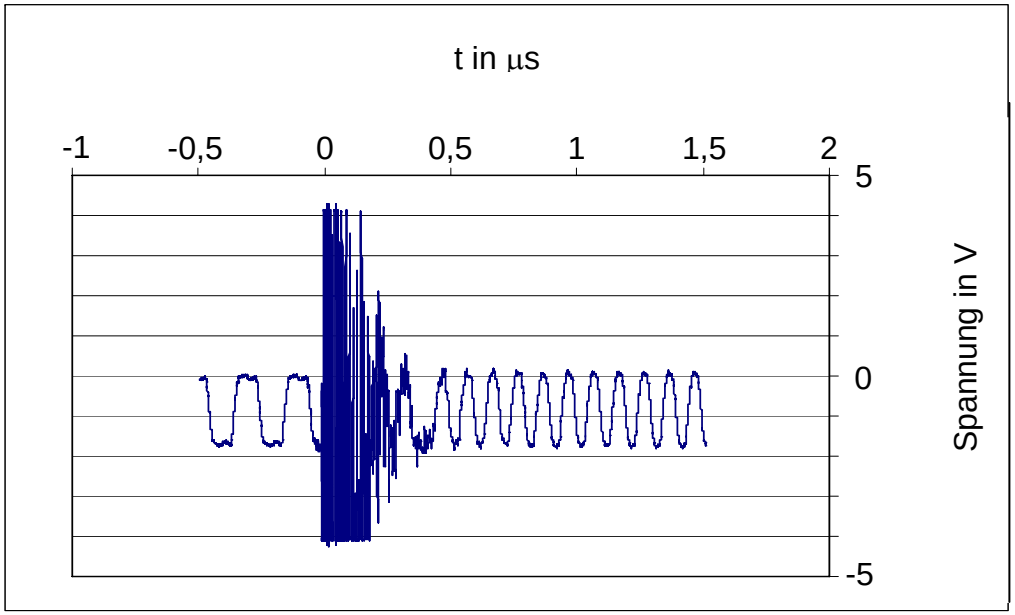

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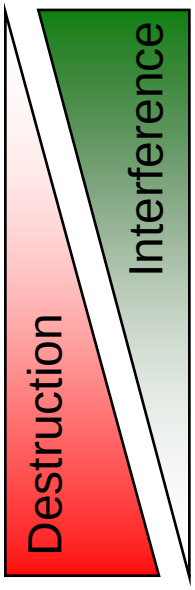

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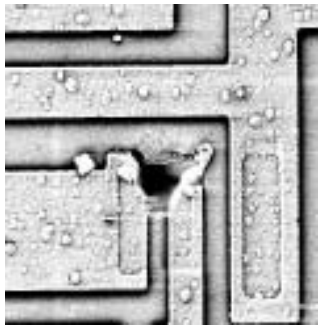

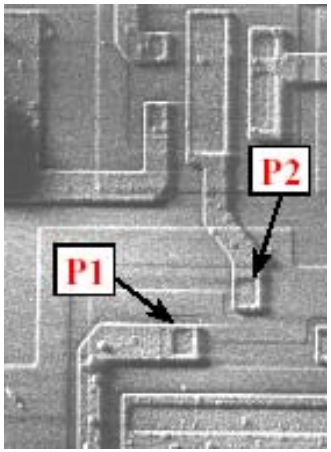

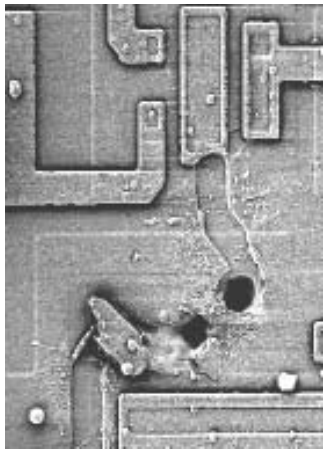

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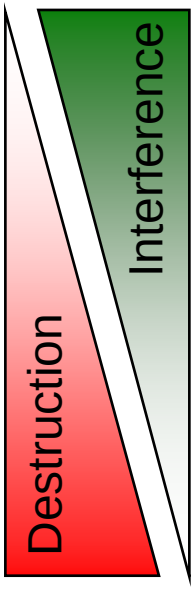

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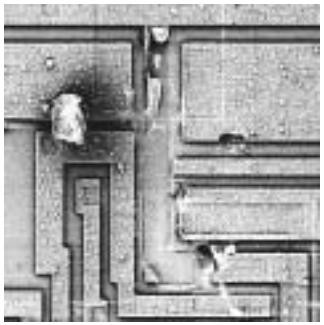

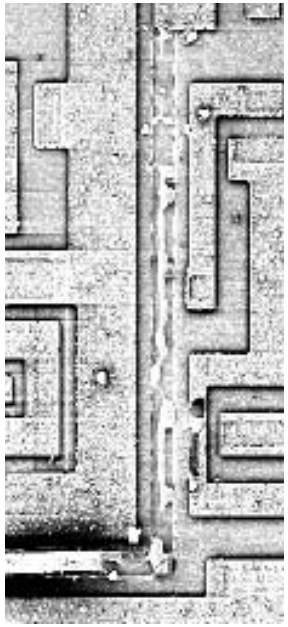

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Effects

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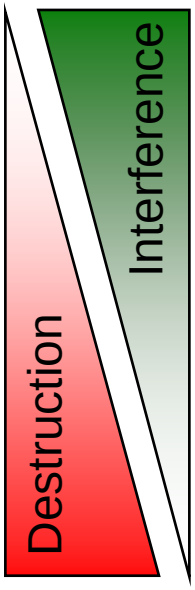

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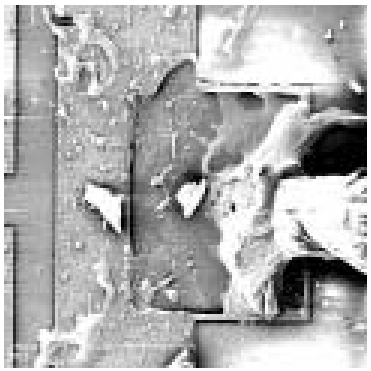

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Task

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Survey of worldwide HPEM susceptibility data

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Problems / Approach

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Problems:

Large number of susceptibility tests

- Different test setups comparable? (Sources, cells, antennas, chambers)
- Different definition / assessment of effects
- Large number of classified data

Large number of parameters

- Characterization of the electronic device
  - Level (system / component)?
  - Digital / analog device?
  - Design age?
  - Hardening status?
- Detailed threat description
  - Waveform?
  - Field strength?
  - Rise time / duration?
  - Bandwidth?
  - Repetition rate (PRF)?
- Detailed effect description
  - Reproducibility?
  - Effect level?
  - Mission criticality?

Problems / Approach

Bundeswehr

Problems:

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Problems / Approach

Bundeswehr

Approach:

- Classification of threat, effects and their mission impact → Comparability / structure
- Abstraction and compilation of data → Clearness / use of classified information
- Homogeneous presentation of the data → Clearness / comparability
- Identification of trends → Comparison of threat types (cw vs HPM vs WB vs UWB) / identification of important source qualities (eg. PRF)

Classification: Threat Level

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Threat Level	Description	Amplitude
XL	Extreme Low	< 0,1 kV/m
L	Low	0,1 – 1 kV/m
M	Intermediate	1 – 10 kV/m
H	High	10 – 100 kV/m
XH	Extreme High	> 100 kV/m

Classification: Effect Level

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Level	Effect	Duration	Description
U	Unknown	-	unable to determine due to effects on another component or not Observed
1	No Effect	-	
2	Interference	only during RF illumination	Effect that is present only during RF illumination
3	Disturbance	some time after RF illumination	Effect is present some time after RF illumination, but system eventually recovers
4	Upset	till human intervention	Effect that require human intervention (e.g. reset) to restore normal system functionality
5	Damage	permanent	Effect that damages hardware to the point is must be replaced or software to the point it must be reloaded

Classification: Criticality / Mission Impact

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Level	Criticality	Description
U	Unknown	unable to determine due to effects on another component or not observed
I	No Effect	the system can fulfill his mission without influence
II	Interference	the appearing disturbance does not influence the mission
III	Degradation	the appearing disturbance reduces the efficiency and capability of the system
IV	Mission Kill	the appearing disturbance prevents that the system is able to fulfill its mission

Overview: Effect Level vs. Criticality

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		Criticality				
	U	I	II	III	IV
Effect Level	U					
	1		1 / I			
	2		2 / I	2 / II		
	3		3 / I	3 / II	3 / III	3 / IV
	4			4 / IV	4 / IV	4 / IV
	5				5 / III	5 / IV

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Input

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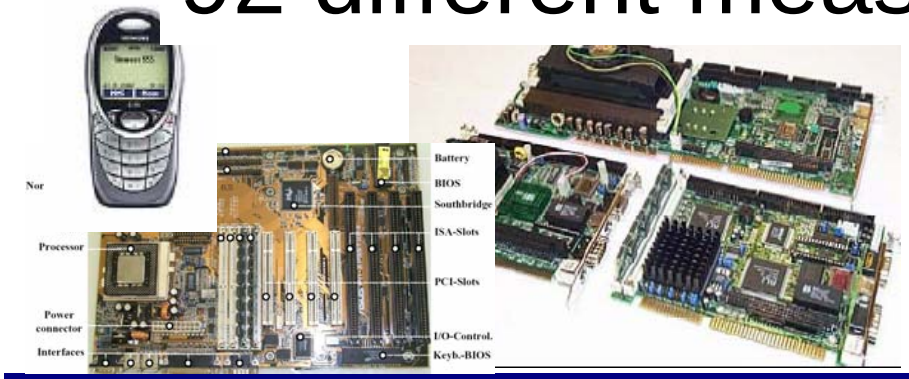
Commercial systems:

- Flip flop counter
- NANDs NORs
- Microcontroller
- Microprocessors
- Cell phones
- GPS receiver
- PC M
- PC S
- PC N
- Cars

Military systems:

- Missiles
- Tanks
- Pods
- Helicopters

Overall:
16 system classes
92 different measurement campaigns



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Exemplary susceptibility data

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- Microcontrollers
- PCs
- PC-Networks
- Cars

Microcontroller

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Threat		Effect Level					
	band	U	1	2	3	4	5
CW	Hypo					L	M
HPM	Hypo					L / M	H
WB	Meso			N / D	N / D	N / D	N / D
UWB	Hyper			L / M	M	M / H	H

N / D: No Data Available

PC System

Bundeswehr

Threat		Effect Level					
	band	U	1	2	3	4	5
CW	Hypo			XL / L	L / M	M	N / D
HPM	Hypo		XL	L	L / M	M	N / D
WB	Meso		XL / L	L	M	M	N / D
UWB	Hyper		XL / L	L	M	M	H

N / D: No Data Available

PC Network

Bundeswehr

Threat		Effect Level					
	band	U	1	2	3	4	5
CW	Hypo			L	L	L / M	M
HPM	Hypo			L	L	L / M	M / H
WB	Meso			N / D	N / D	N / D	N / D
UWB	Hyper		L	M	M	M / H	N / D

N / D: No Data Available

Car

Bundeswehr

Threat		Effect Level					
	band	U	1	2	3	4	5
CW	Hypo		XL	L	L	N / D	N / D
HPM	Hypo			L / M	M	H	H
WB	Meso			L / M	M	H	H
UWB	Hyper		M	H	H	XH	N / D

N / D: No Data Available

Susceptibility Threshold

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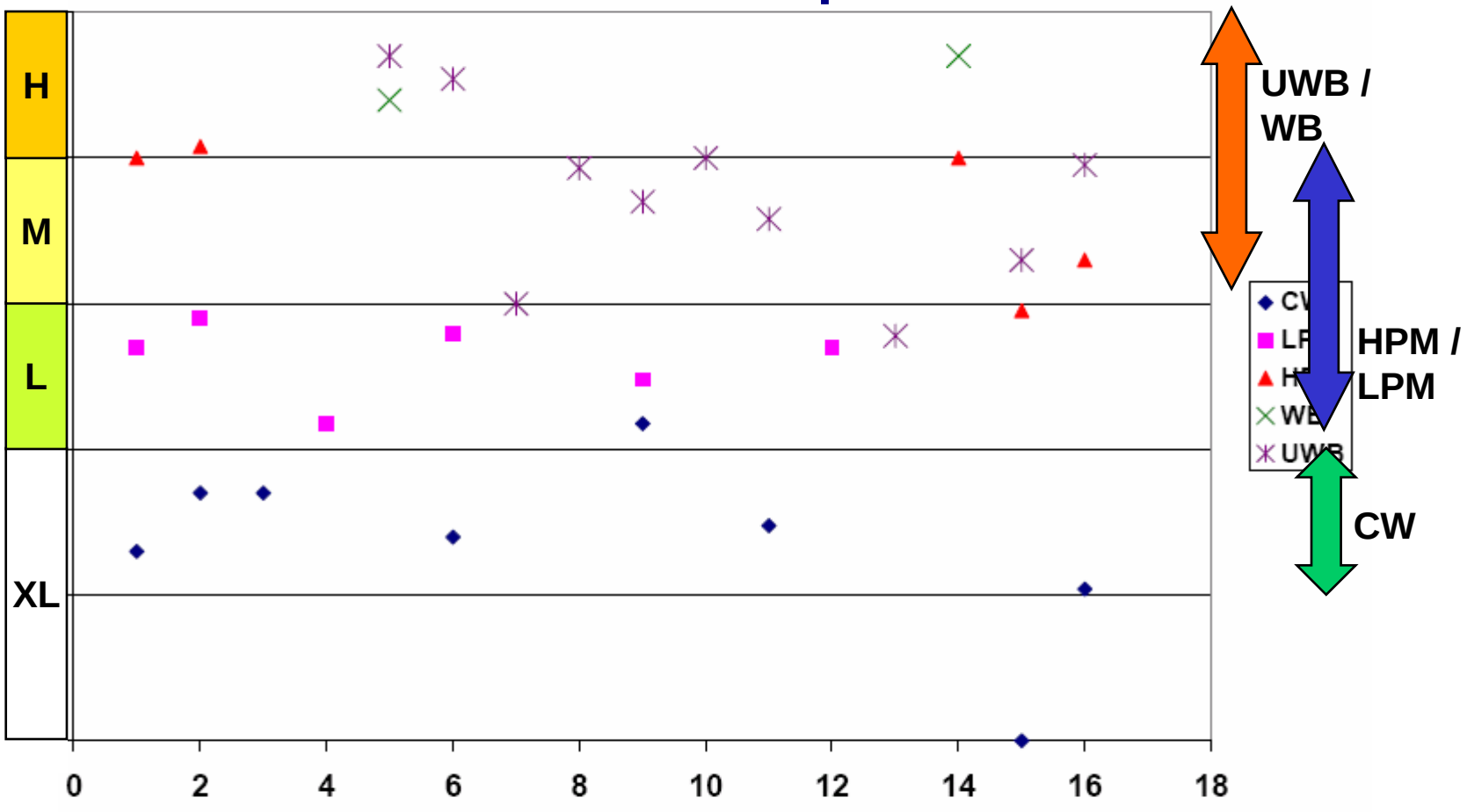
Effect Level 4 “Upset”



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Trend: Computer Susceptibility

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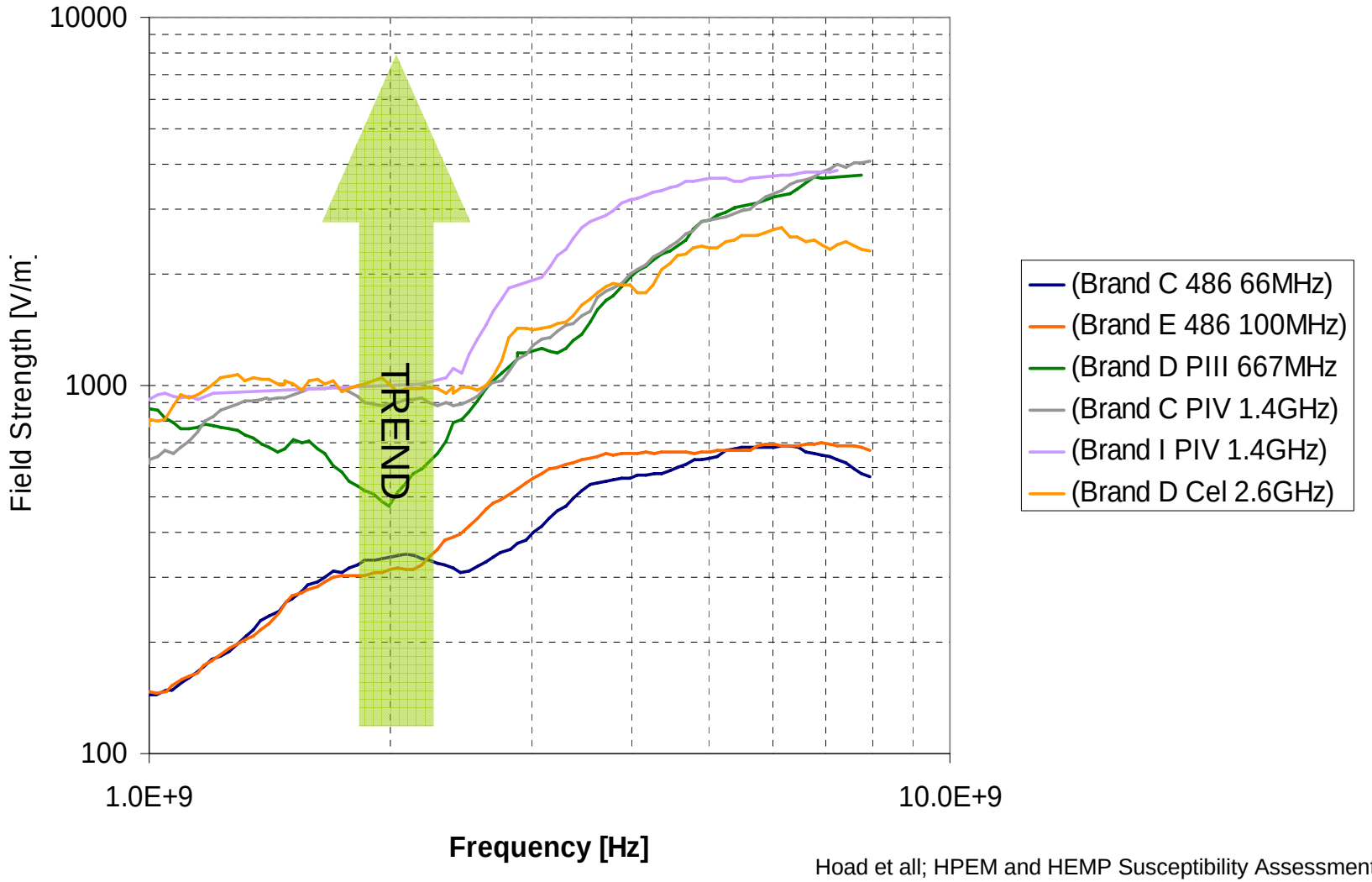

Hoad et all; HPEM and HEMP Susceptibility Assessments of Computer Equipment

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Trend: PRF

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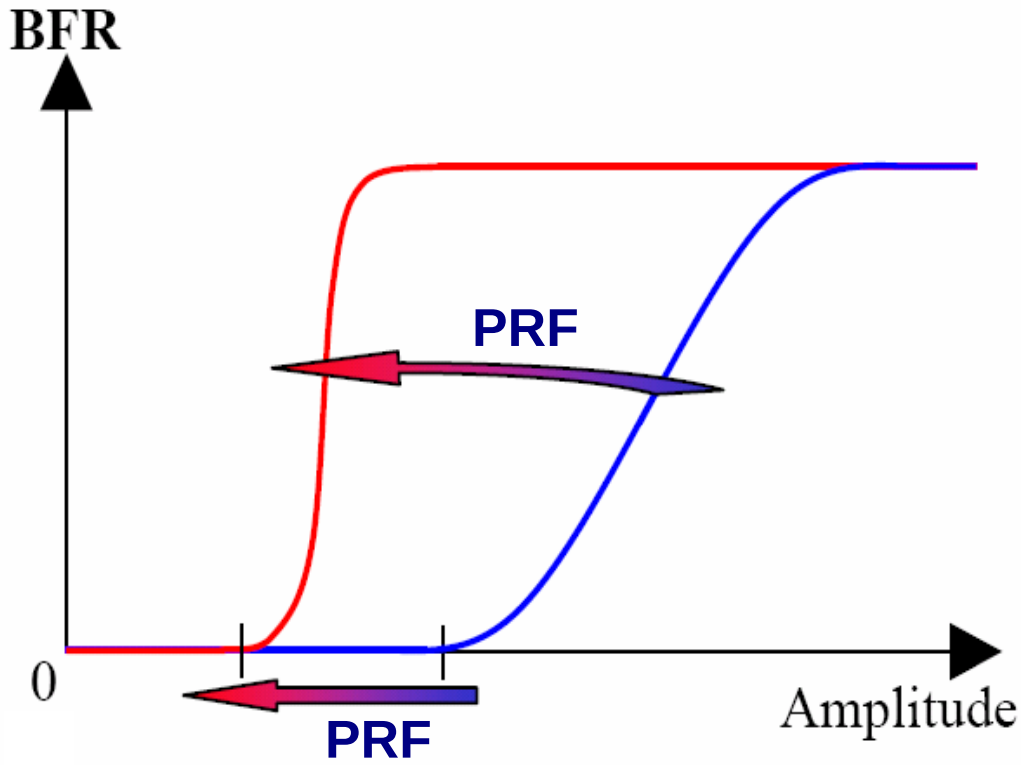

Increased PRF:

+ reduced Breakdown Threshold
+ reduced Breakdown Bandwidth

Trend: Susceptibility Threshold

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Effect Level 3 “Disturbance”

System	Threat Level			
	CW	HPM	WB	UWB
Civil Electronic (general environment)	XL	L	L	L / M
Civil Electronic (industrial environment)	XL	L / M	L / M	M / H
Cars	L	M	M	H
Avionics	L	M	N / D	N / D
Military Electronics (general)	L	H	M / H	H
Military Electronics (special requirements)	L	H	H	XH

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Conclusion

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- HPEM has the potential to cause a wide range of effects to electronic systems
- The last decade has witnessed an increasing interest in investigations of EM effects
- Suggestion of a uniform systematic classification of
  - threats,
  - effects
  - criticallity / impact
- The shown trends can used as a base for future investigations
- Generalizing of data makes the exchange easier
- Data base of unclassified susceptibility data (only for active participants)