An EM Fault Injection Susceptibility Criterion and its application to the localisation of hotstpots

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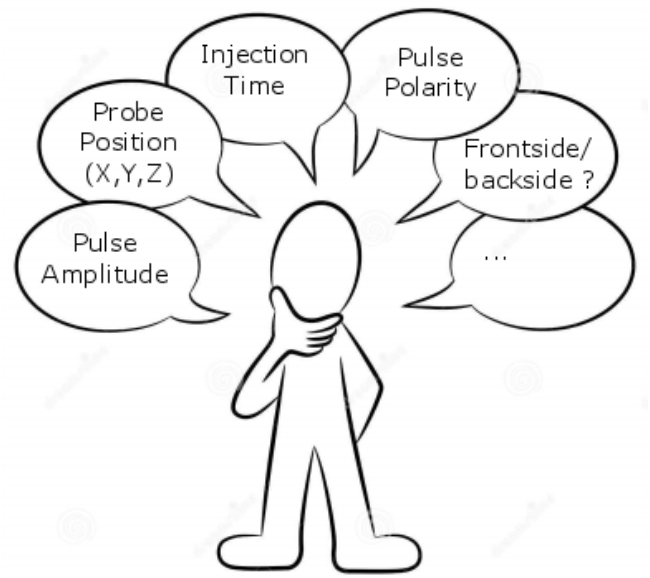
Linking injection/observation channel

"Attack"	Channel	information from observation channel.
Power Glitch	V_{dd} network	temporal information.
Body Bias Injection	bulk	none.
EMFI	EM	temporal and spatial information
Laser	photon	spatial information. Light observation is expensive.

Why binding EM analysis to injection ?

EMFI combinatory complexity:



Time efficiency[a]:

Analysis map → one day for three executables.

Injection map (fixed parameters) → three days for one executable.

[a] timing are relative to our setup

Aim:

Ease and fasten EMFI security characterisation → (X,Y) position.

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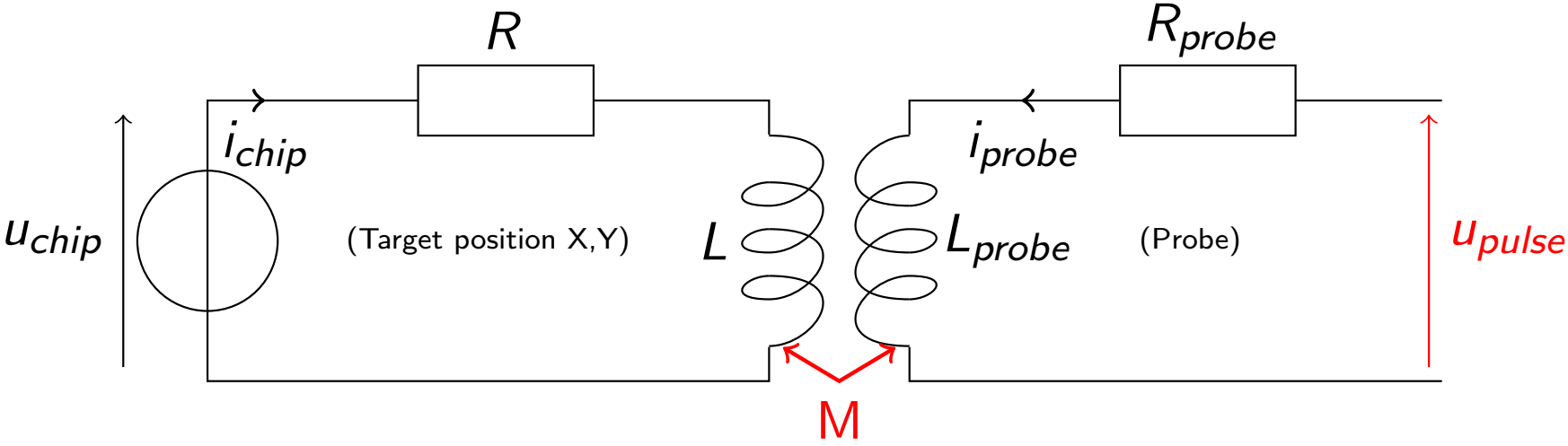
EM coupling



Coupling: *(injection case)*

$$u_{chip} = Ri_{chip} + L\frac{\mathrm{d}i_{chip}}{\mathrm{d}t} + M\frac{\mathrm{d}i_{probe}}{\mathrm{d}t}$$

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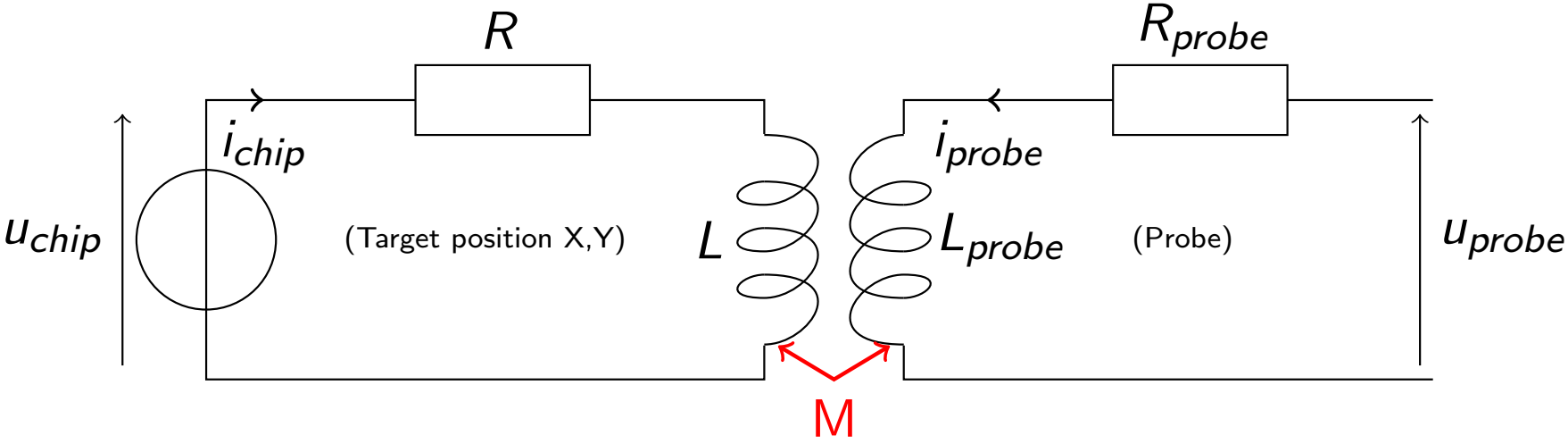
EM coupling



Coupling: *(analysis case)*

$$u_{probe} = Ri_{probe} + L_{probe}\frac{\mathrm{d}i_{probe}}{\mathrm{d}t} + M\frac{\mathrm{d}i_{chip}}{\mathrm{d}t}$$

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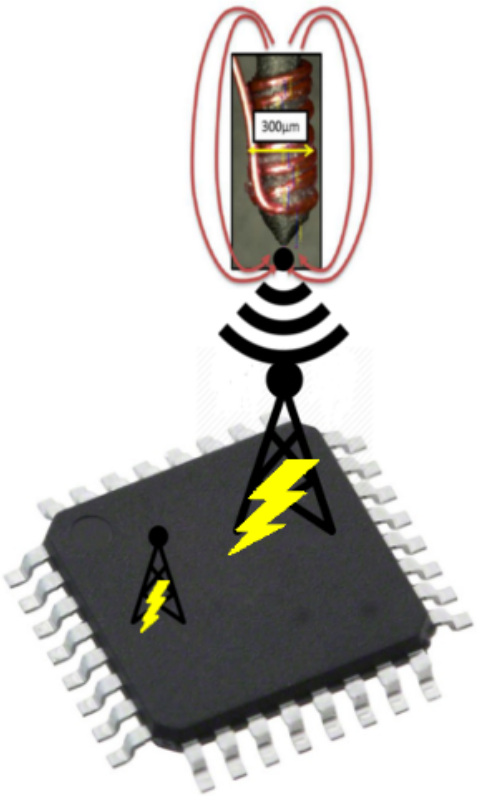
Antenna reciprocity



Antenna reciprocity:

The efficiency of a receiving antenna is as important as its transmitting efficiency.

Conclusion 1:
Finding high emission antenna

$\rightarrow$ best coupling positions on circuits.

Conclusion 2:
High emission antenna $\neq$ best entry point

$\rightarrow$ not necessarily linked to data.

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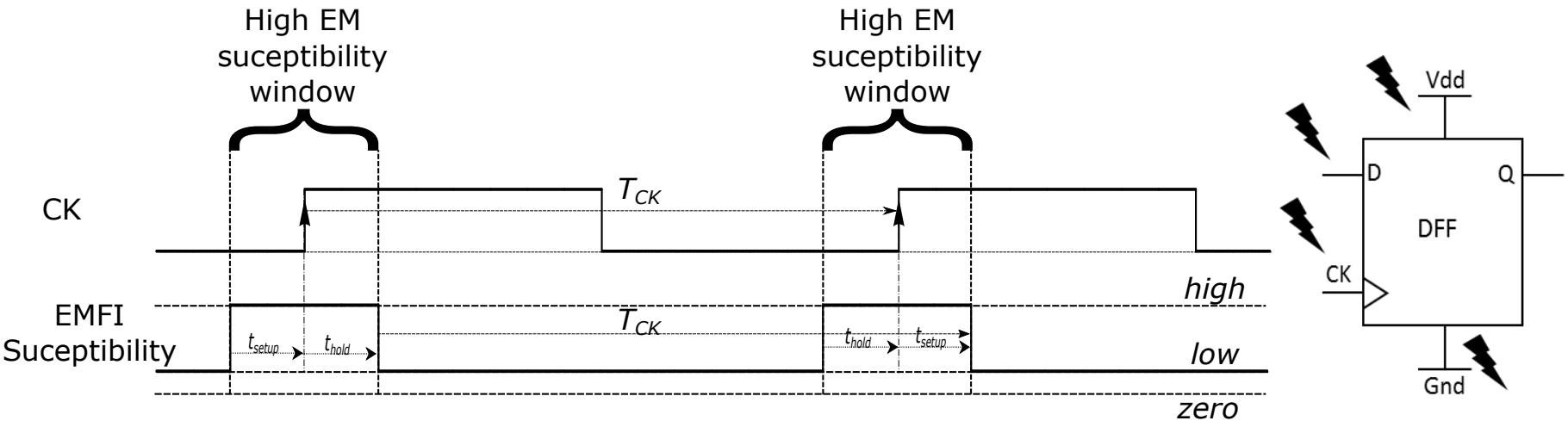
Sampling fault model[1]



System target:

↪DFF are more likely to be faulted by EM injection.

↪Target event occurring at f_{CK}

[1] *EM injection: fault model and locality* S. Ordas, L.Guillaume-Sage, P. Maurinne FDTC 2015.

EMFI Criterion definition

Area to target are positions:

- *(guideline 1)* emitting the strongest signal (in terms of power) associated to the clock signal or clock tree.

  $\rightarrow$ tool: Power Spectral Density $PSD(f_{CK})$

- *(guideline 2)* emitting signal tightly bind to both targeted algorithm and clock frequency (f_{CK}).

  $\rightarrow$ tool: **inc***oherence*(f_{CK})

Guideline 2 tools:

$$inc_{s_1,s_2}(f) = 1 - \frac{psd_{s_1,s_2}(f)^2}{psd_{s_1,s_1}(f) \cdot psd_{s_2,s_2}(f)}$$

Notation:

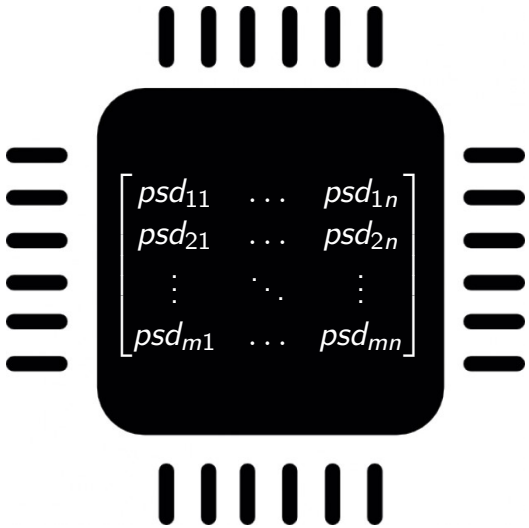
s_1 = EM emission for input 1.

s_2 = EM emission for input 2.

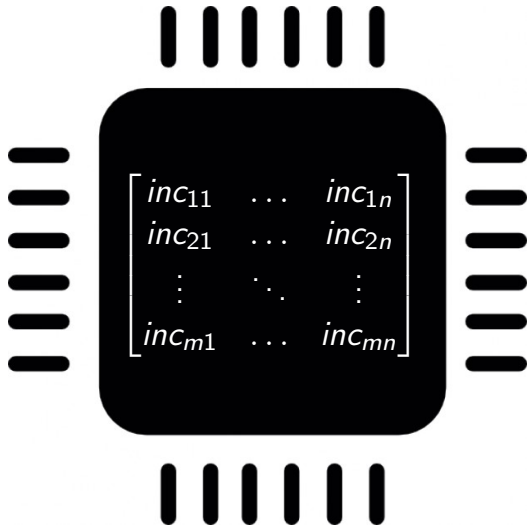
Aim

$\hookrightarrow$ Look for differences in spectrum occurring at f_{CK} *ie* DFF used by algorithm.

How to combine and weight those two measures ?

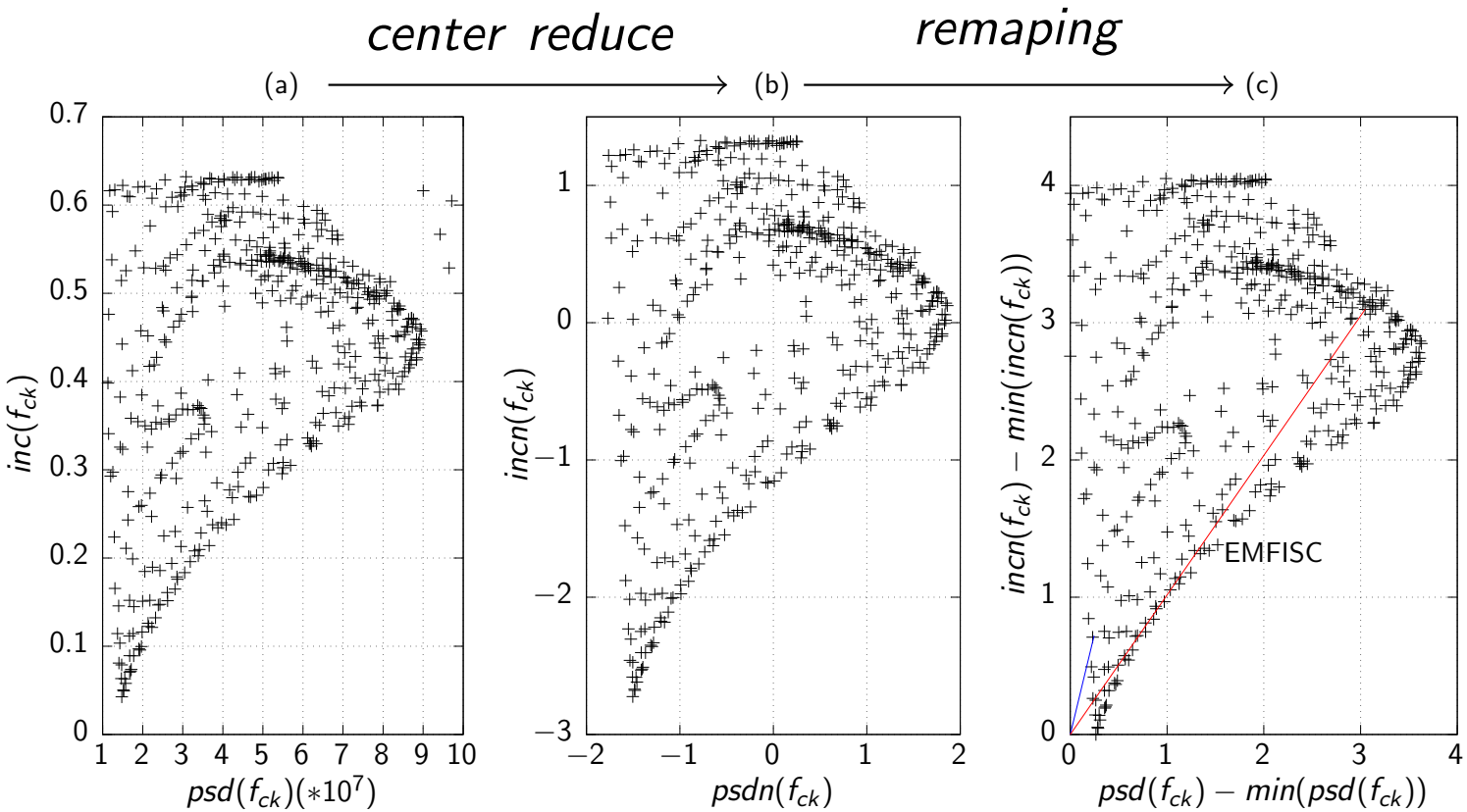


$0 \leq psd \leq ?$



$0 \leq inc \leq 1$

Raw data: PSD, Incoherence view



$$inc_{s_1,s_2}(f) = 1 - \frac{psd_{s_1,s_2}(f)^2}{psd_{s_1,s_1}(f) \cdot psd_{s_2,s_2}(f)}$$

EMFISC Procedure

Algorithm 1 EMFISC

Input: f_{CK}, matrix of s_1 and s_2,
α (% chip to keep),
a (weight *psd* compared to *incoherence*)
Output: $emfisc_{x,y}$

1: **for** X,Y positions **do**
2: compute $psd_{s_1}(f)$
3: compute $inc_{s_1,s_2}(f)$
4: **end for**
5: $psdn_{x,y}$ and $incn_{x,y}$ = center reduce $psd_{x,y}$ and $inc_{x,y}$ population
6: remap $psdn_{x,y}$ and $incn_{x,y}$ population
7: compute $emfisc_{x,y} = \sqrt{(1-a) * psdn_{x,y}^2 + a * incn_{x,y}^2}$
8: quantile($emfisc_{x,y}$,α)

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Experimental protocol

Target algorithm:

Algorithm 2 Pattern (AddrSRAM32, AddrSRAM96)

```
1: PUSH { lr }
2: ADD R0,R0,#0; 11 times
3: LDR R2,[R0]; read SRAM32
4: STR R2,[R1]; write SRAM96
5: LDR R3,[R1]; read back
6: ADD R0,R0,#0; 11 times
7: POP { pc }
```

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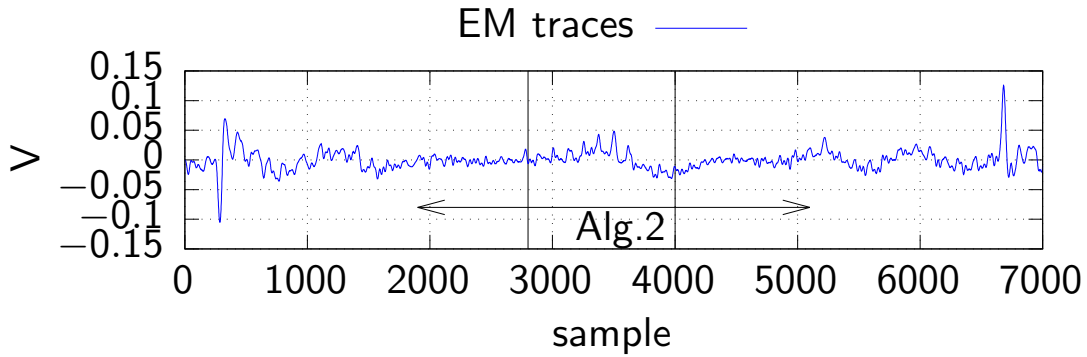
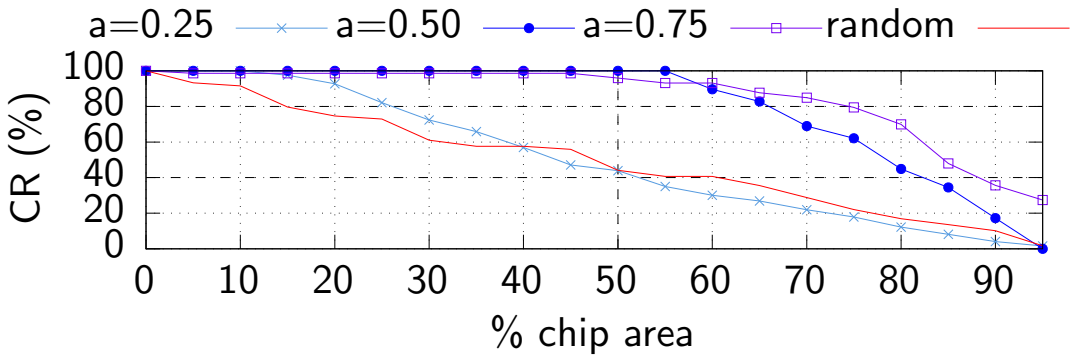
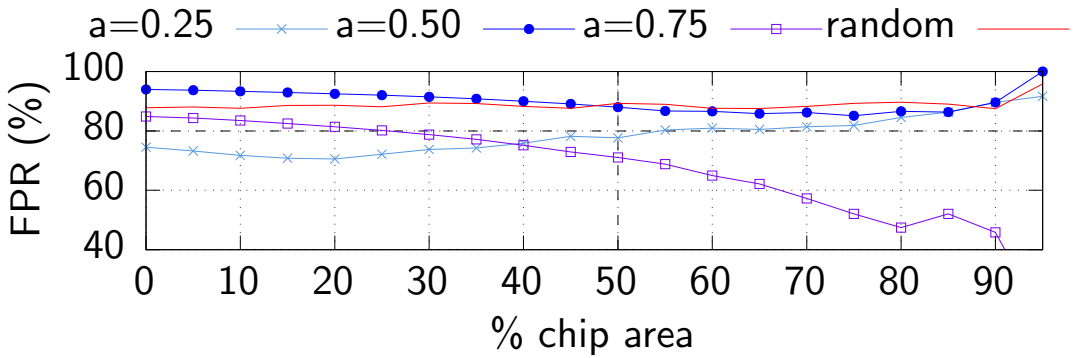
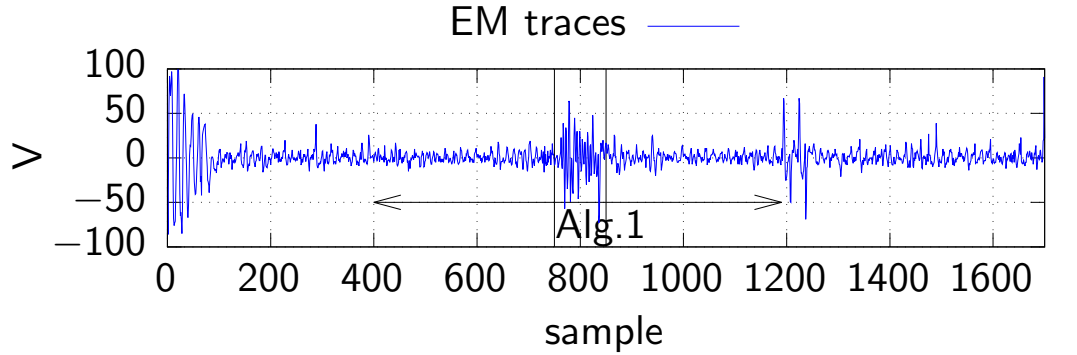
EMFISC figures of merit (target 1 130V)

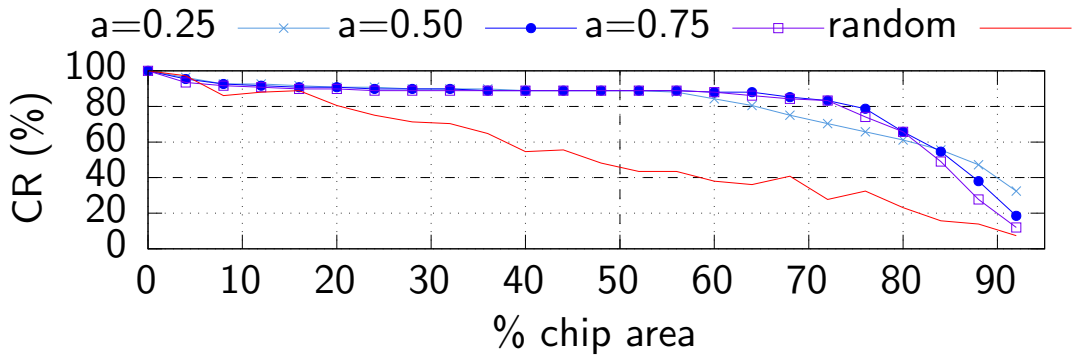


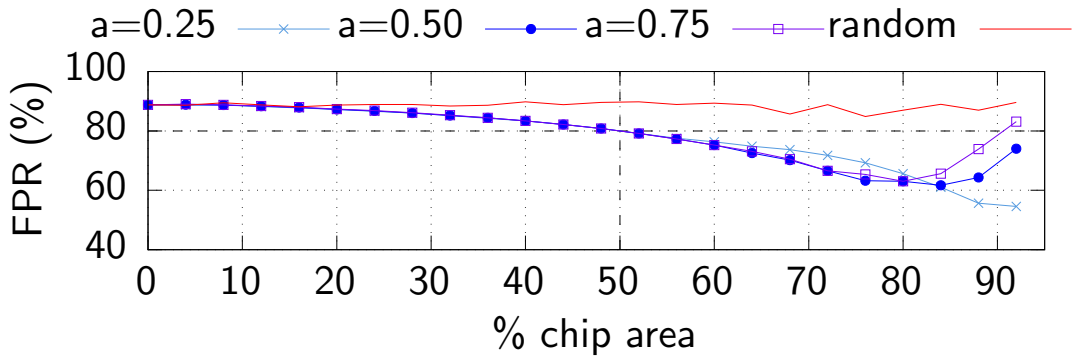




EMFISC figures of merit (target 2 198V)







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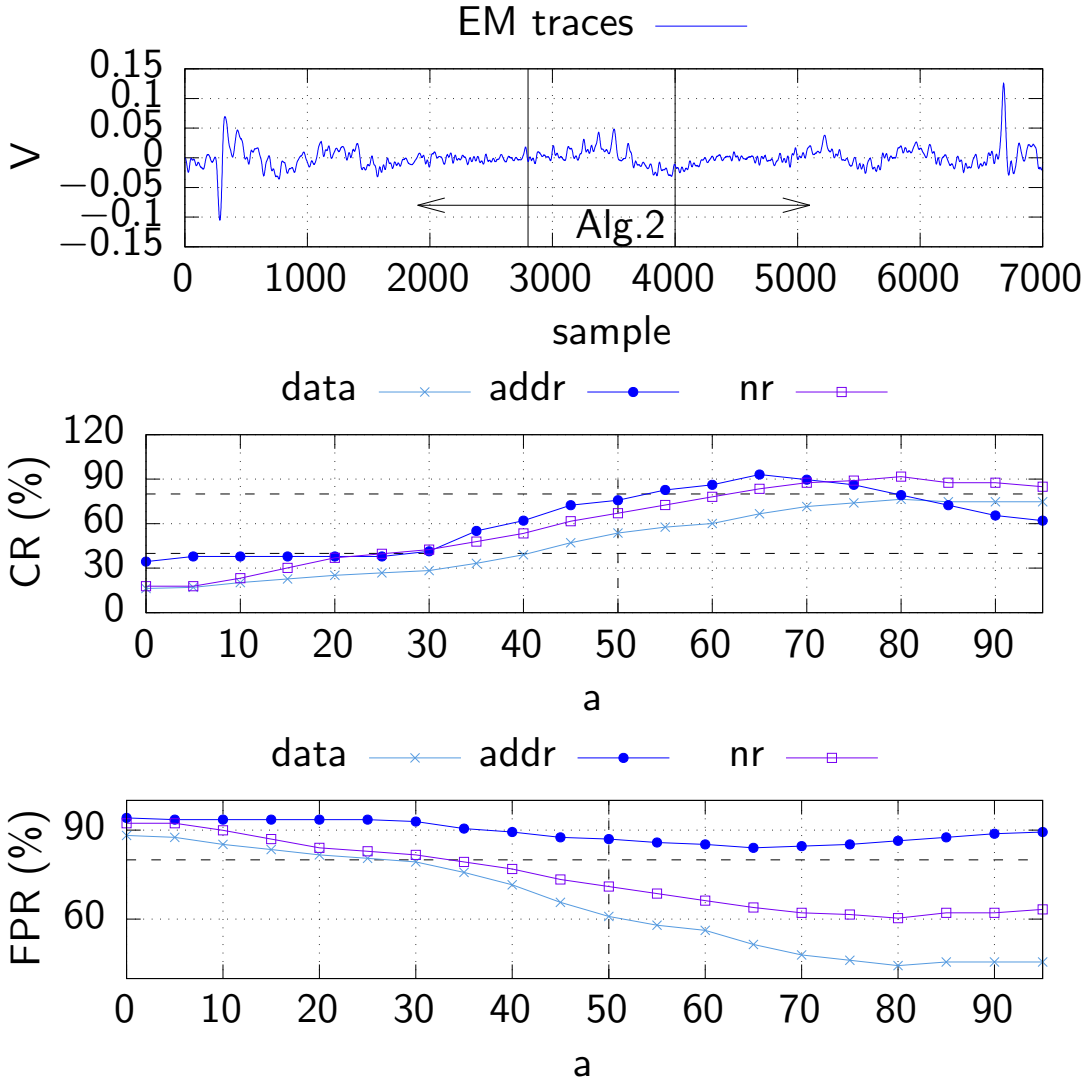
Quantile fixed at 60% target 1



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Results:

- There is a link between EM emissions and EMFI.
- This link can be use to ease EMFI characterisation.

Refining the criterion:

- Other combination of PSD and Incoherence curves.
- Finding a way to weight PSD and Incoherence.
- Adding a criterion more target specific, such as a better measurement of M parameter.

Thanks
Any questions ?