Susceptibility of COTS sensors to IEMI using pulse modulated signals

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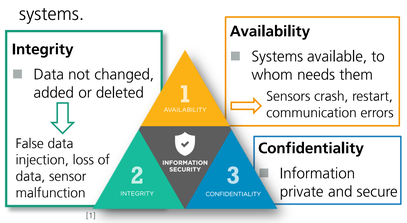
Background

Sensors show up in every aspect of life
- Use growth
- Multiple applications

IEMI [intentional electromagnetic interference] : intentional malicious generation of electromagnetic energy introducing noise or signal into electrical or electronic systems, thus disrupting, confusing or damaging these systems.



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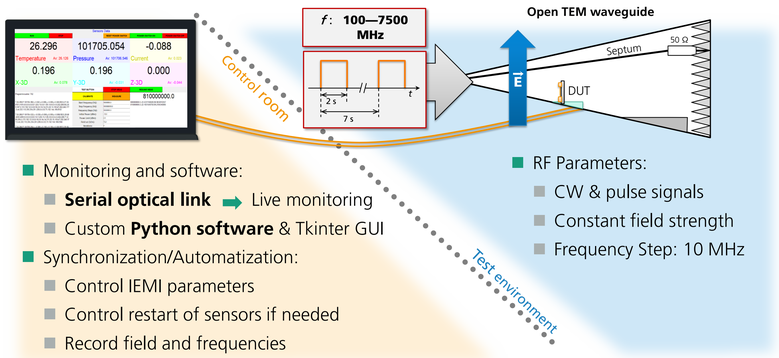
Objectives

Aim: Investigate the susceptibility of **stand-alone sensors** with privileged access to the hardware and software

General Setup
- 3 sensors: Magnetometer, Barometer and Current Sense sensor
- 1 Microcontroller

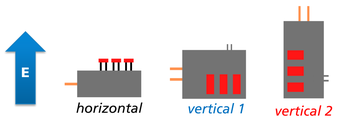
Required features:
- Easy access to raw data for future diagnostics
- Only irradiation of the sensors (shielded box)

Methods



- Monitoring and software:
  - **Serial optical link** ➡ Live monitoring
  - Custom **Python software** & Tkinter GUI
- Synchronization/Automatization:
  - Control IEMI parameters
  - Control restart of sensors if needed
  - Record field and frequencies
- RF Parameters:
  - CW & pulse signals
  - Constant field strength
  - Frequency Step: 10 MHz

- Three DUT orientations:



- Susceptibility measurements:
  - Identification of vulnerable frequencies
  - Classification of errors
  - Use of multiple pulse parameters

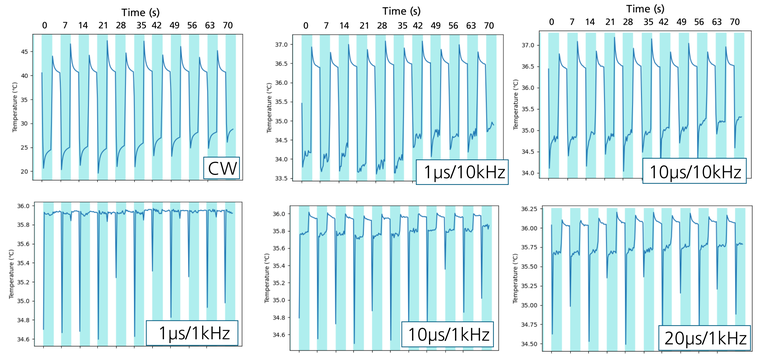
Error	Description
1	Loss of data link under exposure
2	Loss of data link requiring restart
3	Raw sensor values out of tolerance
4	Sensor status errors

Results

Summary of the main differences between CW and pulse signals

Sensors\ Signal type	Magnetometer	Barometer	Current Sense
CW	Multiple crashes at 300-500MHz range starting from 40 V/m Data link loss around 400MHz -> I2C communication affected Forced restart needed everytime	Status errors around 1 GHz Erroneous values at 2.6-2.8 GHz & 5.4-6.2 GHz up to +50°C with 400V/m Steady increase of field strengths leads to new measured standby sensor value	No errors detected
Pulse signals	Higher field strength to cause crashes at 300-500 MHz	Status errors and crashes at 1GHz, 2.5-3GHz causing forced restart Erroneous values at the same frequencies but with lower values (up to 2-3°C maximum)	Erroneous values and status errors at 2.9 & 5.8 GHz

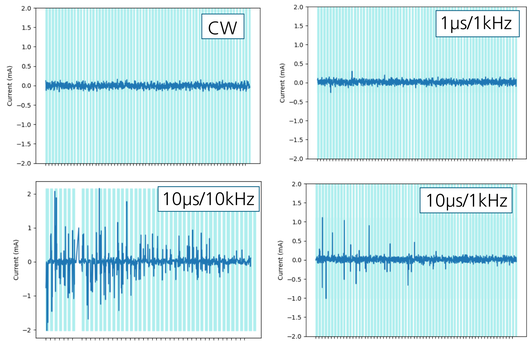
Influence of pulse parameters on the measured temperature (barometer)



Frequency range: 5900 – 6000 MHz
Field : 400 V/m
RF exposure: 2 seconds (plot:)
Signal parameters:
1. Continuous Wave (CW)
2. Different pulse parameters:
   - pulse width : 1µs, 10µs & 20µs
   - pulse repetition rate (PRR) : 1 kHz & 10 kHz

Results:
- Erroneous values only during exposure
- No status errors
- Significant changes of indicated temperature with CW signals
- Various influences of pulse parameters:
  - Shorter pulse width -> narrower peak
  - Higher PRR -> similar behavior to CW qualitatively, not quantitatively

Influence of pulse parameters on the measured current (current sense)



Frequency : 5600 – 6050 MHz
Field : 400 V/m
RF exposure: 2 seconds (plot:)
Results:
- No errors with CW signals
- Influence of PRR
- Value errors & Status errors

Errors occured also at 2900MHz
- Open questions:
  - Influence on the SPI clock?
  - Resonance frequency ?

Discussion & Next Steps

- Limits to measurements:
  - Communication ports exposed
  - Serial connection interrupted
- Influence of the DUT orientations
  - Same vulnerable frequency range
  - Some specific errors only with some orientations (Crashes, Current Sense status errors)
  - Coupling path between sensor and microcontroller?

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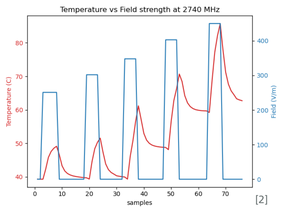
- Identification of coupling paths:
  - Shielding of ports or possible coupling paths
- Repeatibility of the results
  - Use of other temperature sensors
- Observation of communication with bus analyser
  - Understanding I2C or SPI errors communications

- Possible "smart" pulse attacks:

In EMC Europe 2021 Paper [2], CW signals with field strength above a certain threshold caused a permanent change in the indicated temperature until restart.
Can we use short pulses to achieve the same behaviour?
Which field strength level would it require?



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Conclusion

Threat to sensors
- Systems depend on sensor data
- Information Security needed

Availability under IEMI
- Communication errors
- Forced restart

Integrity under IEMI
- Manipulation of sensor readings

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- Better understanding of physical phenomena
- Suitable protection measures

1 Image: https://blog.jamestyson.co.uk/the-cia-and-dad-triads

2 Cesbron Lavau, Louis & Suhrke, Michael & Knott, Peter (2021). Susceptibility of Sensors to IEMI Attacks. EMC Europe 2021 (to be published)

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