URSI GASS 2020
Rome, Italy
29 August - 5 September 2020

Evaluation of the Transient EM Interferences Impact on the Clear Channel Assessment in Wi-Fi Communications

Grecia Romero, Virginie Deniau, Eric Pierre Simon and Christophe Gransart

Université Gustave Eiffel

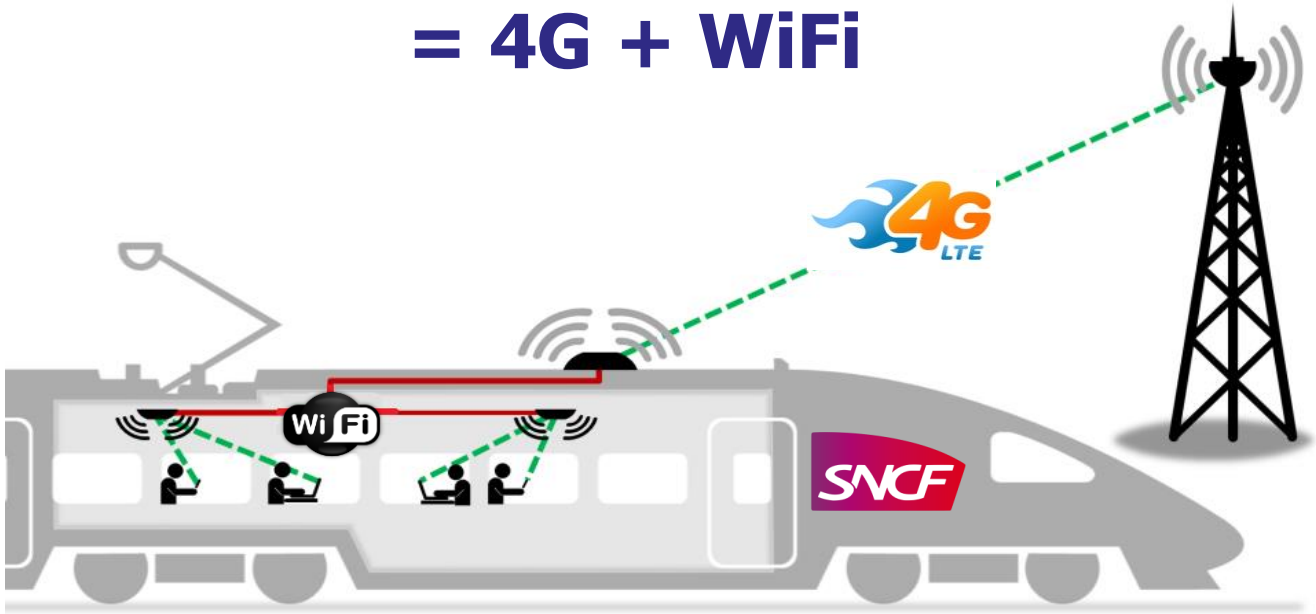
SUMMARY

- Introduction
- Transient EM interferences in Railway
- Wifi and clear Channel Assessment
- Experimentation in laboratory
    - Test bench and Configuration
    - Transient EM interference model
- Analysis of the Experimental results
- Conclusion

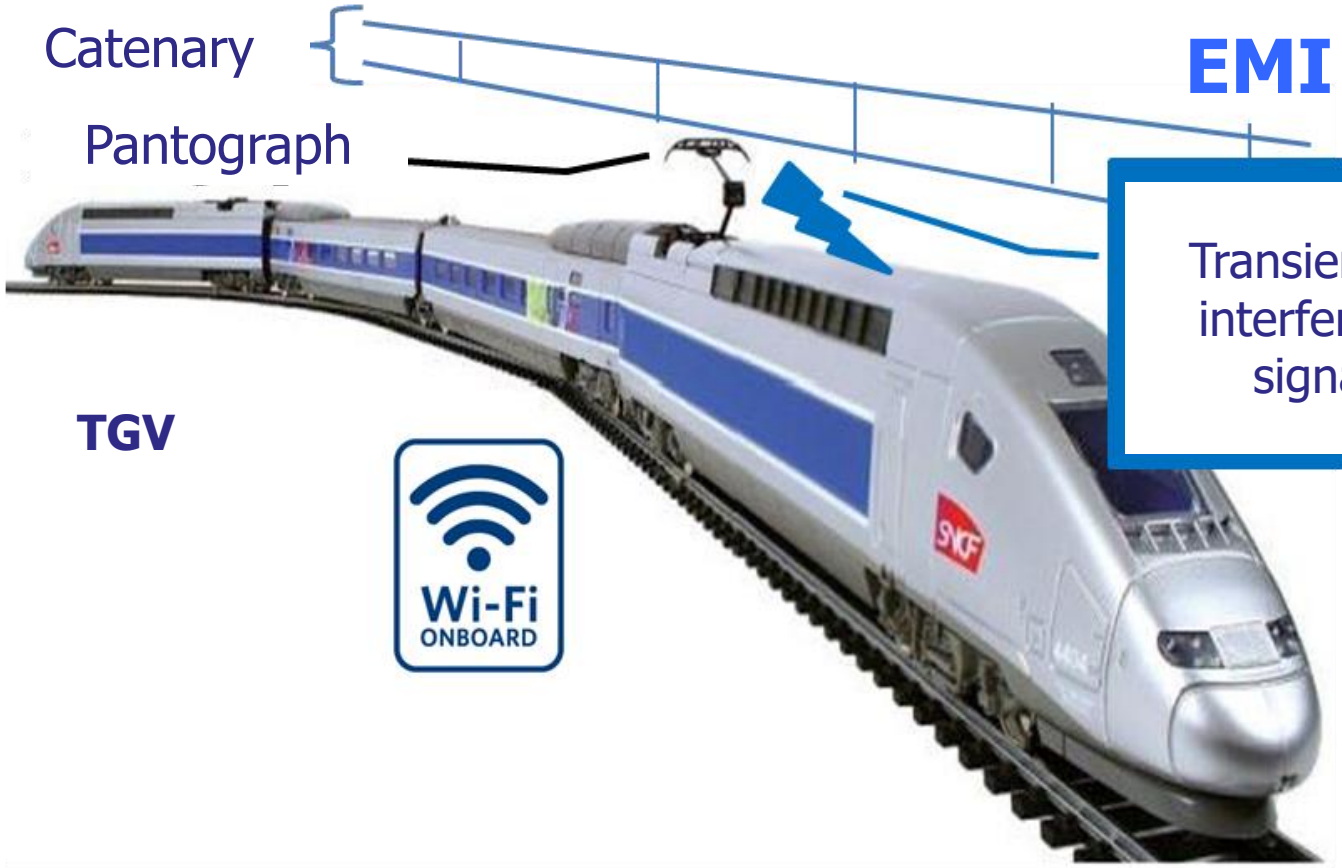
INTRODUCTION

Too many passengers on board trains to access internet with an 4G high bit rate connexion

Solution
= 4G + WiFi

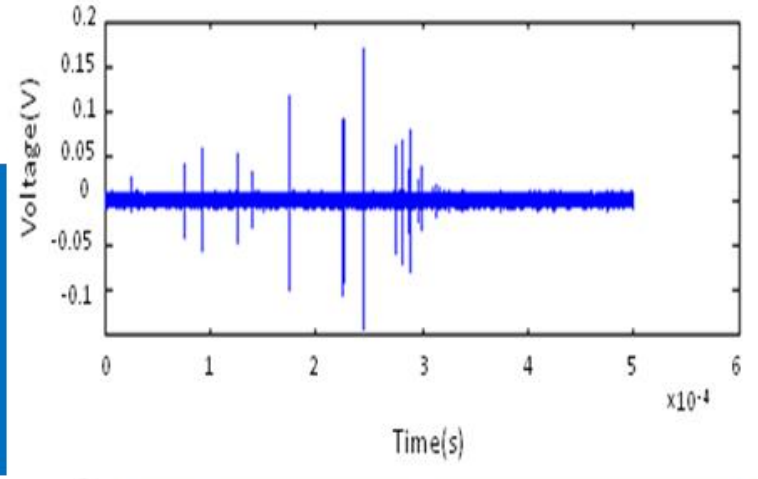


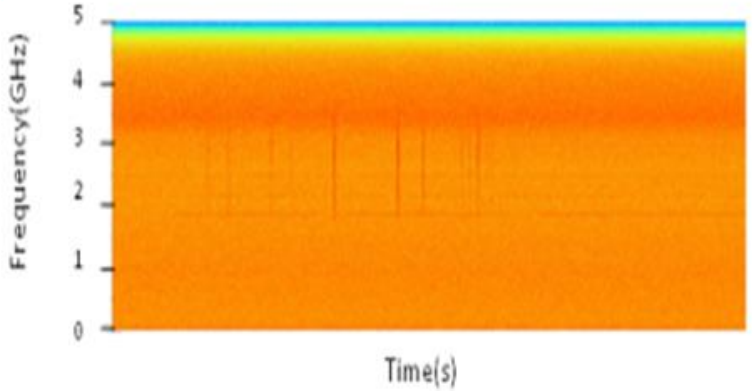
Railway transient EM Interferences



EMI

Transient EM interference signals

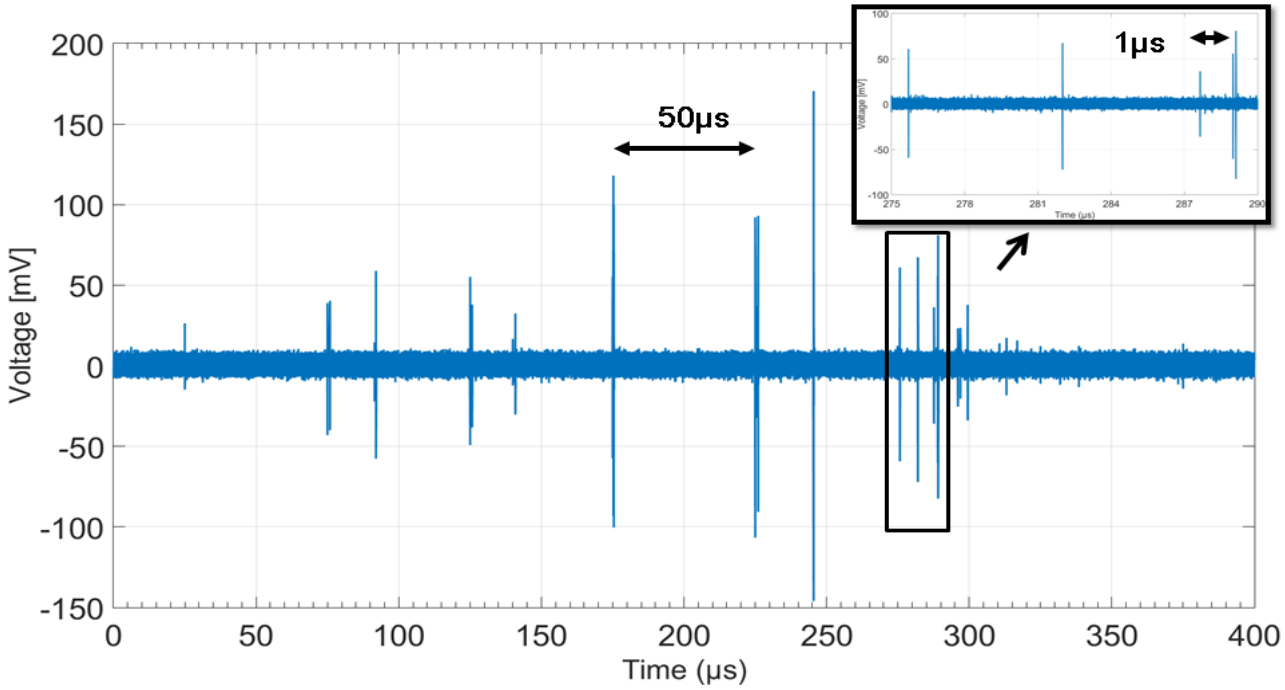


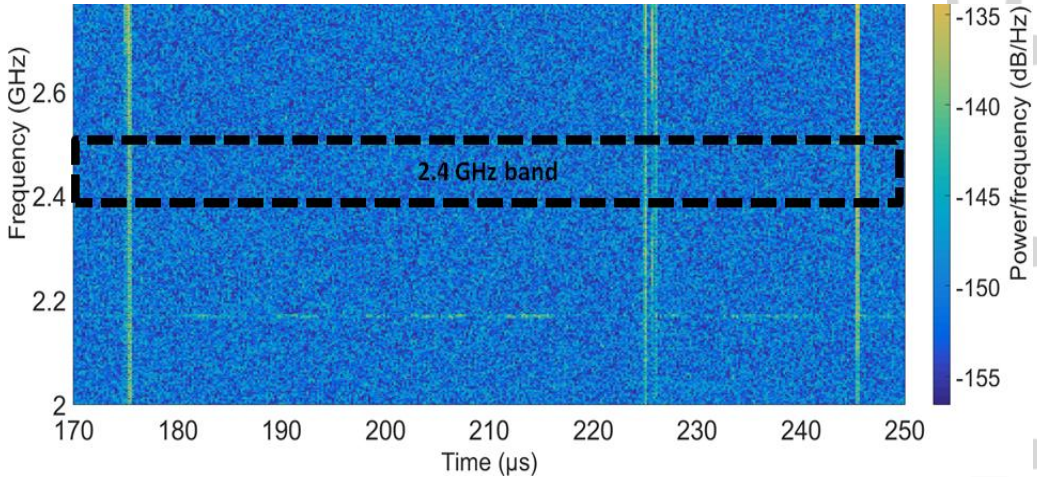


Université Gustave Eiffel

Railway transient EM Interferences

- Measurements on board train with a wideband antenna





The transient EM interferences produced by the catenary-pantograph contact cover the Wi-Fi frequency band

In this work, we analyse the potential susceptibility of the Wi-Fi communications to these transient EM interferences

Université Gustave Eiffel

WiFi and Clear Channel Assessment

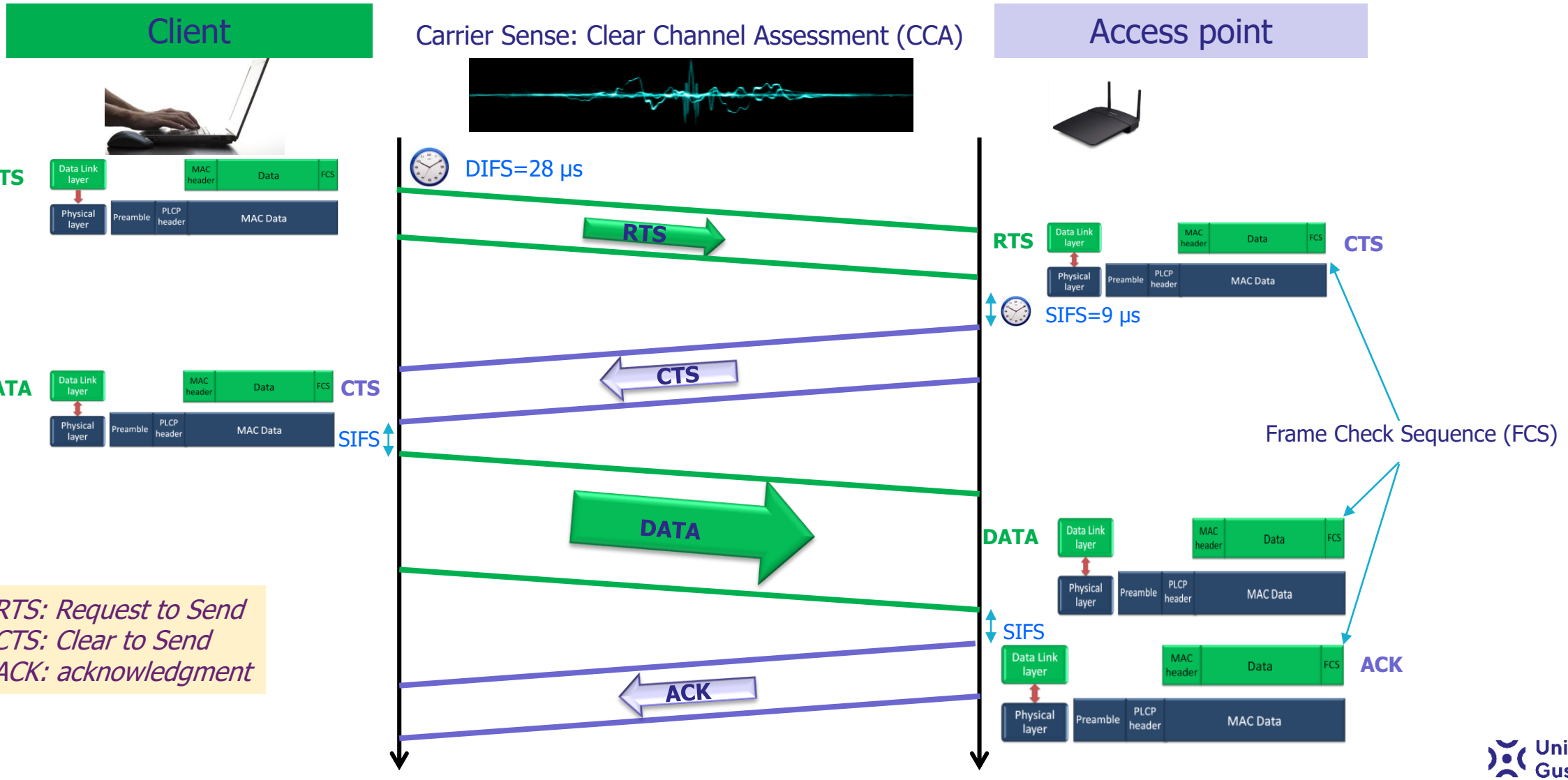
The Clear Channel Assessment (CCA) is a mechanism for checking whether the medium is idle or not.
It consists in measuring the highest average power (*PHighestAvg*) over the channel during the DIFS period (by time windows of 4 µs) and to compare it to a threshold of -72 dBm (for a 20 MHz bandwidth).

If PHighestAvg exceed – 72 dBm, the medium is considered as busy. If PHighestAvg < – 72 dBm, the client can send a Request To Send (RTS)

Glossary:

FCS : Frame Check Sequence is an error-detecting code added to a frame in the communications protocol
RTS: Request to Send
CTS: Clear to Send
ACK: Acknowledgment
DIFS : Distributed coordination function Interframe Space period = 28 µs
SIFS : Short Interframe Space
MCS : Modulation Coding Scheme

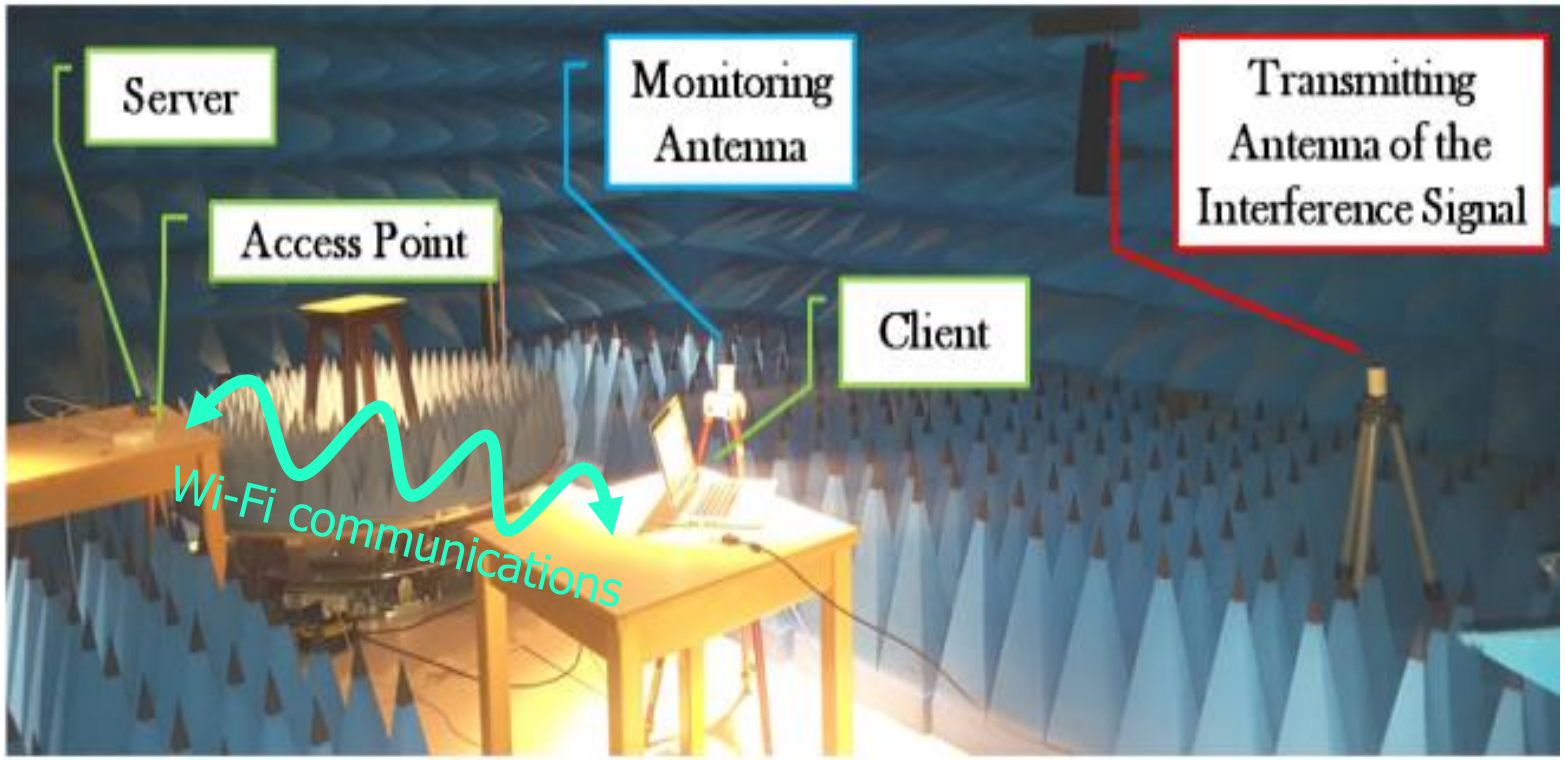
WiFi and Clear Channel Assessment

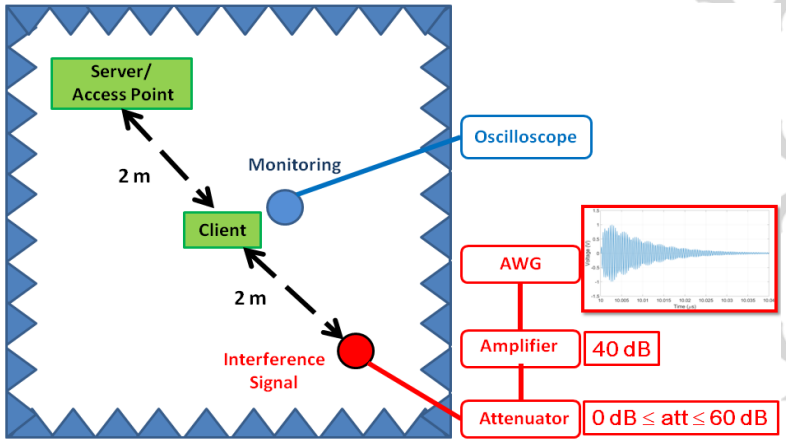


RTS: Request to Send
CTS: Clear to Send
ACK: acknowledgment

Université Gustave Eiffel

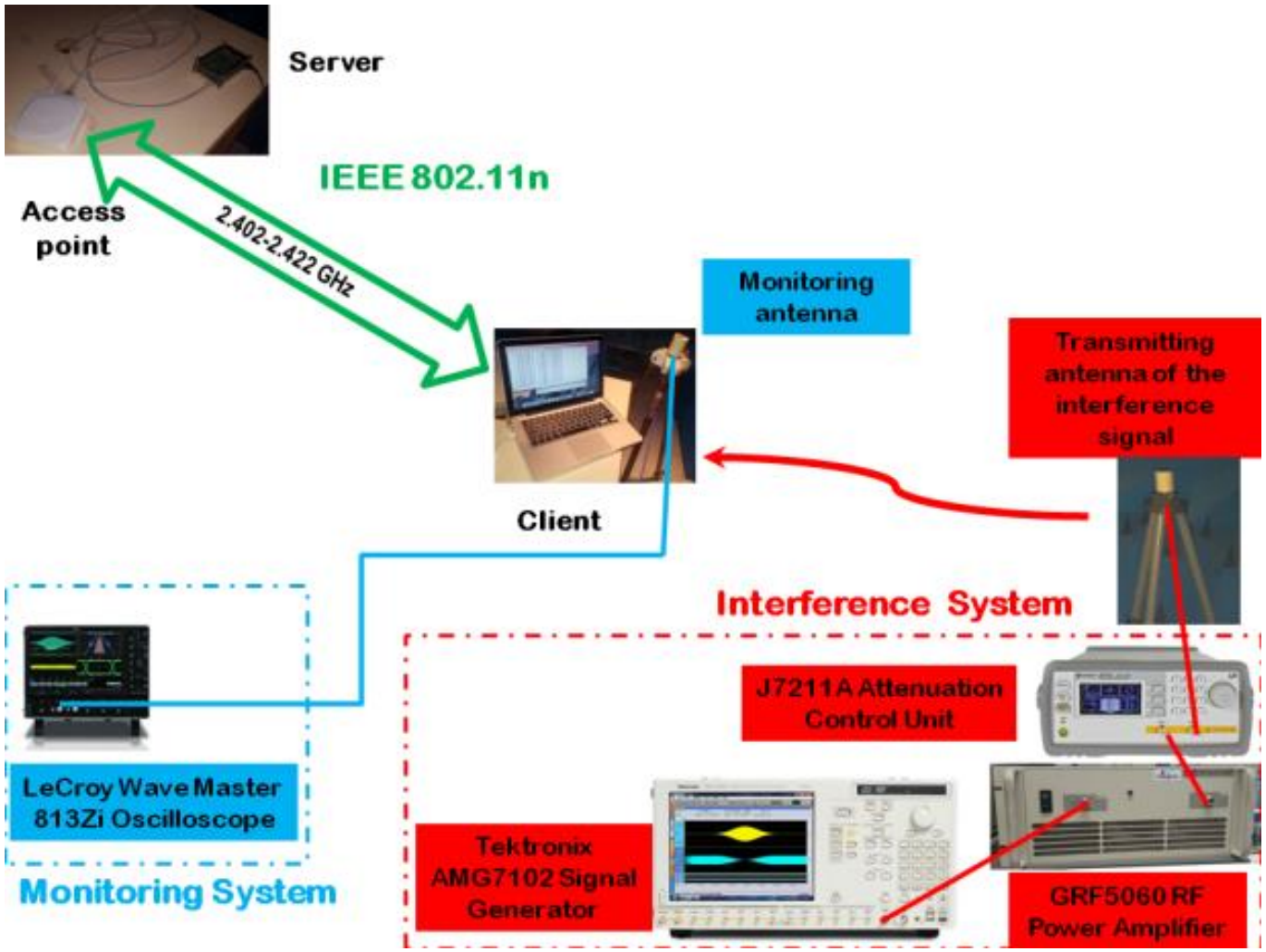
Experimentations on Wi-Fi in laboratory



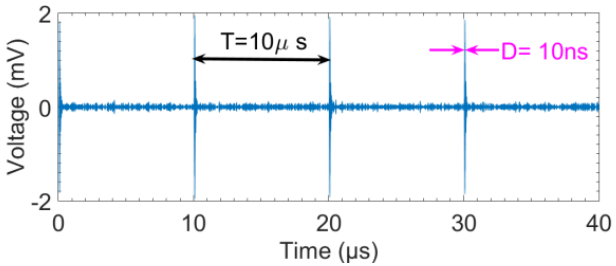


Université Gustave Eiffel

Experimentations on Wi-Fi in laboratory



Tests were carried out for different values for T



Université Gustave Eiffel

Experimentations on Wi-Fi in laboratory

Transient EM interference model applied in experimentations

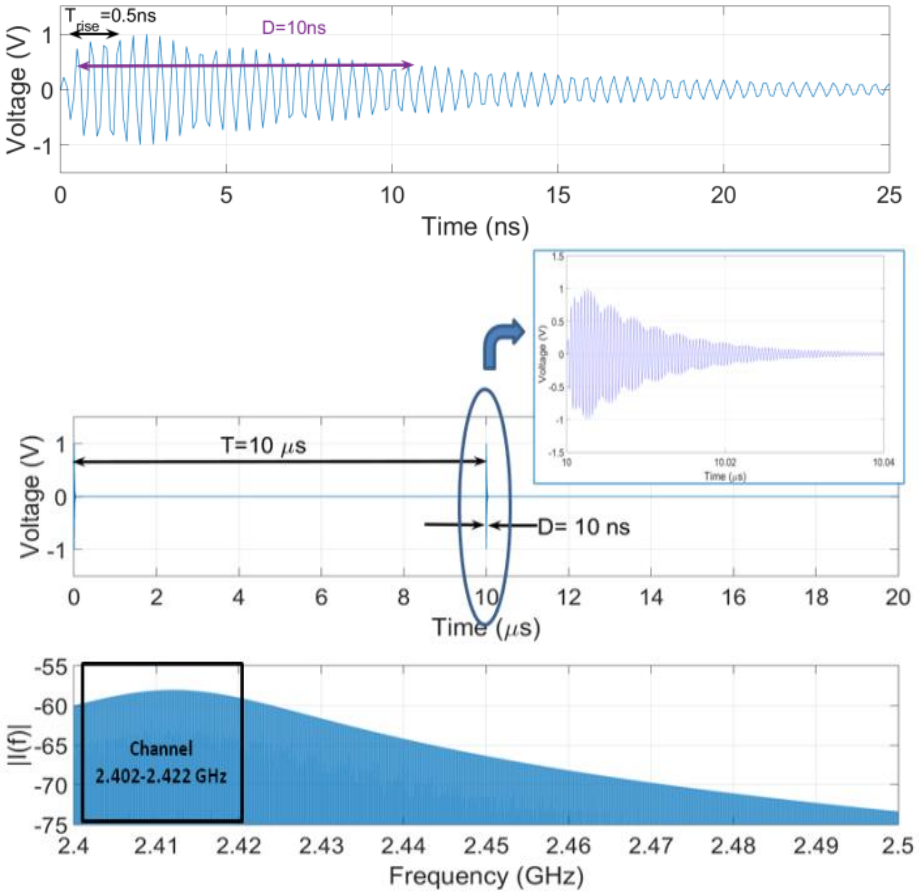
$$i(t) = \mathrm{A}\left(e^{-\frac{t}{\mathrm{D}}} - e^{-\frac{t}{\mathrm{T}_{rise}}}\right)$$

D: duration T_{rise} : Rise time

In order to have a flat distribution over the Wi-Fi channel

$$i(t) = \mathrm{A}\left(e^{-\frac{t}{\mathrm{D}}} - e^{-\frac{t}{\mathrm{T}_{rise}}}\right)\sin\left(2\pi f_0 t\right)$$

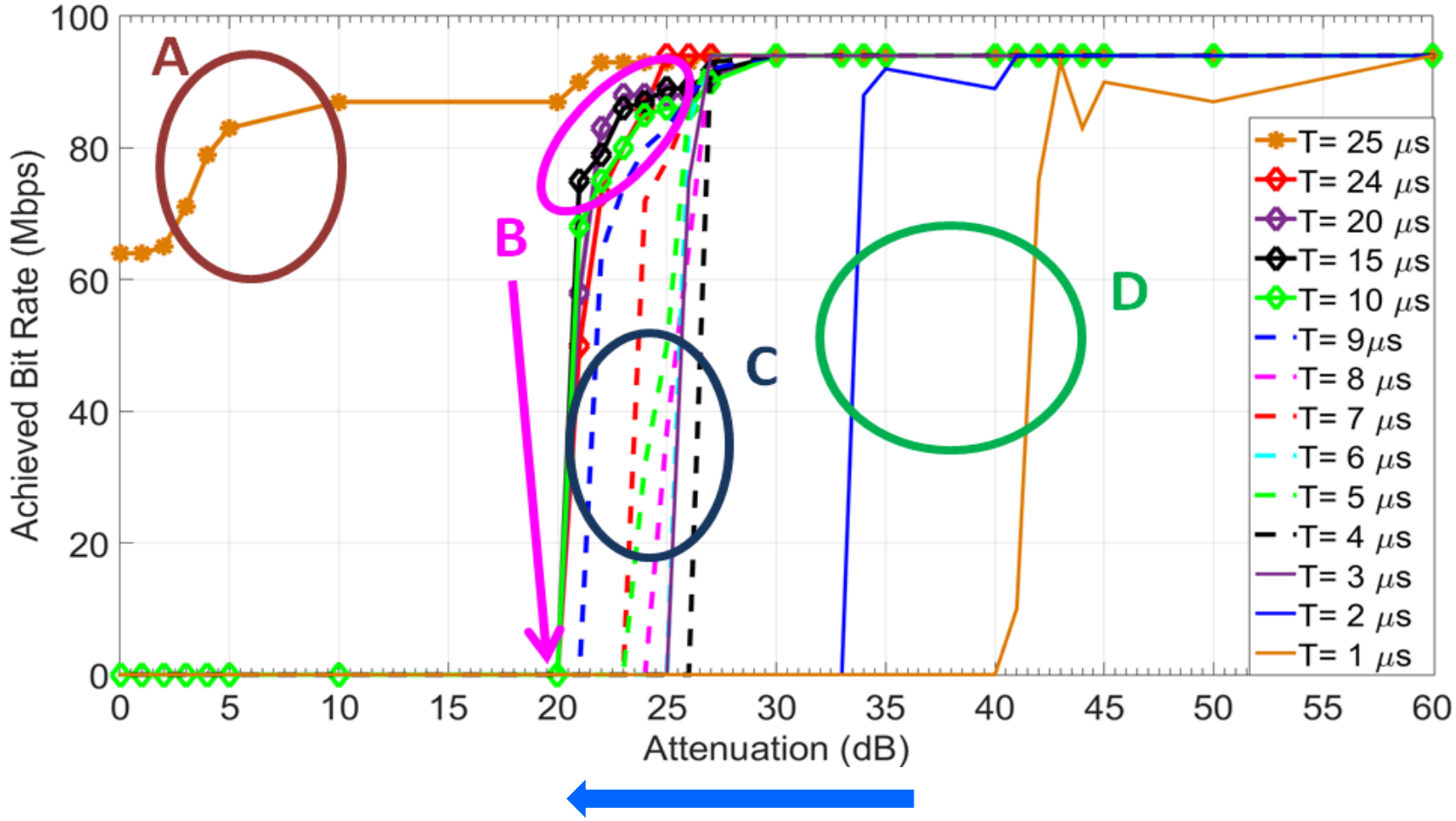
f_0: center frequency
f_0 = 2.412 GHz



Université Gustave Eiffel

Experimental Results

A : T=25 µs ⇔ No Wi-Fi breakdown ⇔ CCA does not detect the transient interference if T≥ 25 µs



Increase of the transient interference signal power

B: 10 µs ≤T≤ 24 µs

C: 3 µs ≤T≤ 9 µs

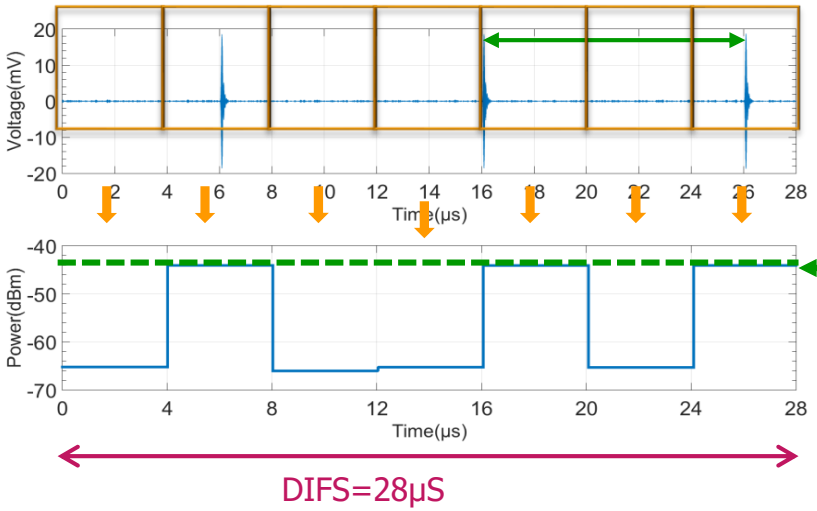
D :1 µs ≤T≤ 2 µs

Université Gustave Eiffel

Results interpretation based on CCA

Standard 802.11-2012: *"CCA-ED shall indicate a channel busy condition when the received signal strength exceeds the CCA-ED Threshold »*
"For OFDM PHY operation with CCA-ED, the thresholds shall be less than or equal to –72 dBm for 20 MHz"

Example of CCA calculation for T=10 µs

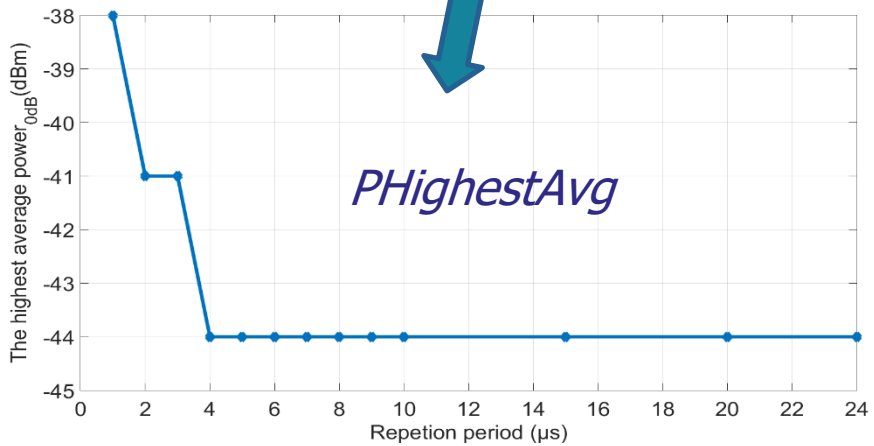


Time window for CCA calculation ≤ 4µs = OFDM symbol + guard interval

Paverage in the channel over 4µs (here with 0 dB attenuation)

The highest Average Power value over the DIFS period = -44 dBm For T=10 µs

For different values of T

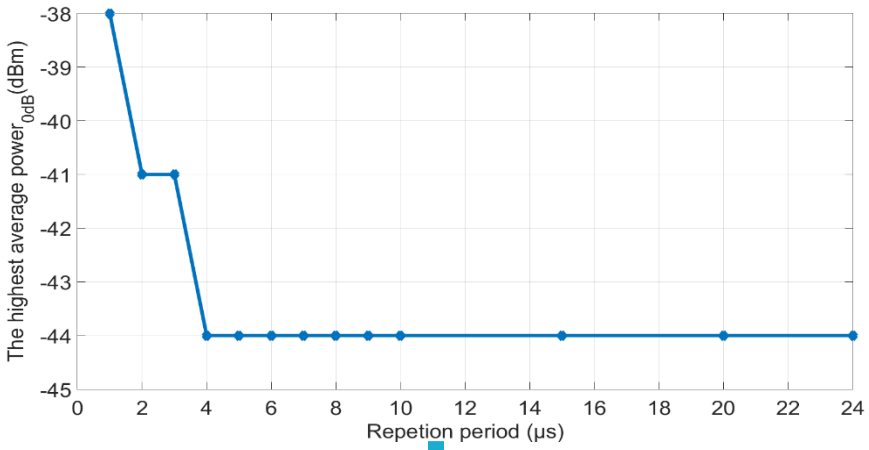


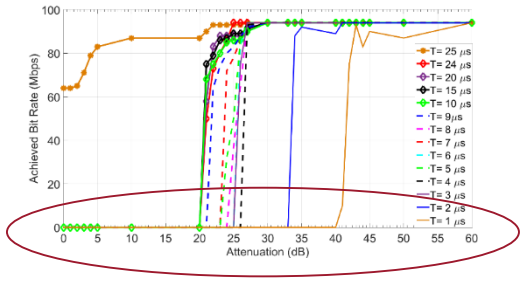
The highest average power values within 28 µs with 0 dB attenuation, as a function of T

Université Gustave Eiffel

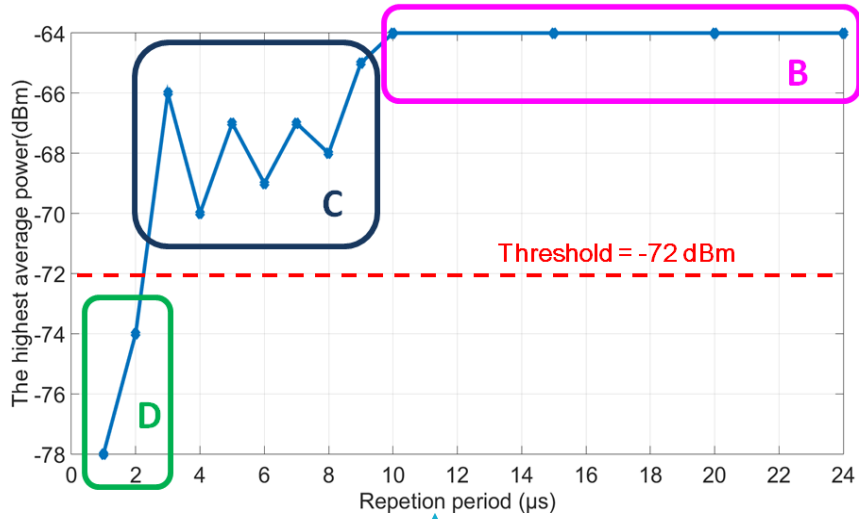
Results interpretation based on CCA

The highest average power values within 28 µs with 0 dB attenuation, as a function of T





PHighestAvg (dBm)

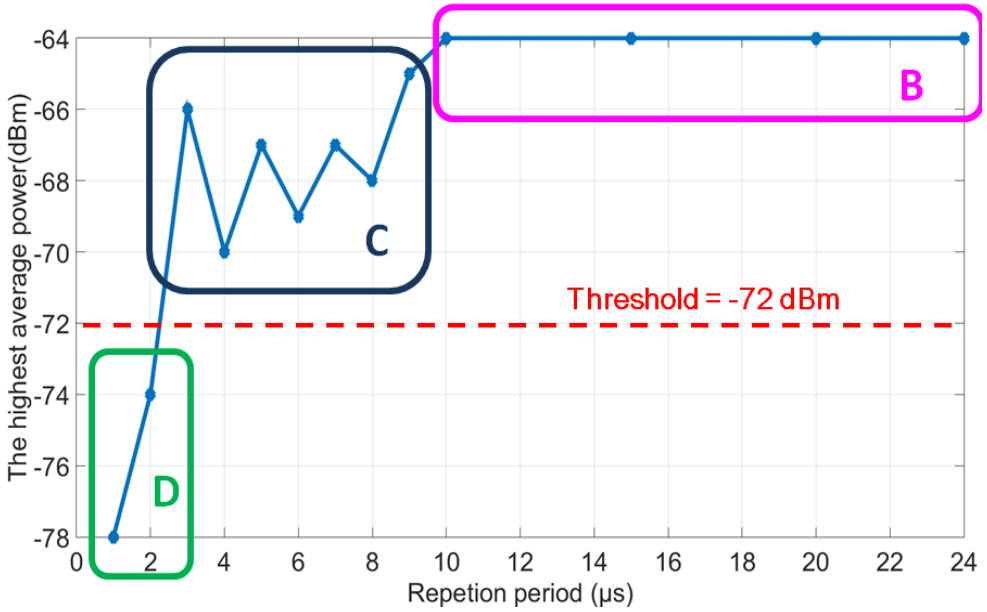


In deducing the attenuation level provocking the Wi-Fi breakdown

Université Gustave Eiffel

Results interpretation based on CCA

PHighestAvg (dBm)



B : 10 µs ≤ T ≤ 24 µs the *PHighestAvg* values are above the threshold of -72 dBm. Moreover, for these T values, the bit rate progressively decreases with the attenuation=Modulation and coding schemes (MCS) mechanism adjusts the bit rate to reduce errors caused by the interferences, until the power reaches the threshold for which the CCA-ED considers the medium busy.

D : 1 µs ≤ T ≤ 2 µs the communication is interrupted with power levels below the threshold. This indicates that the CCA-ED mechanism does not cause the interruption, but probably the too frequent errors in the frames (FCS) due to the short interval of time between successive transient interferences.

C : 3 µs ≤ T ≤ 9 µs the *PHighestAvg* varies and are slightly above -72 dBm. Knowing that this power is measured by the monitoring antenna, it can be slightly different from the power received by the client antenna. It is likely that the real power obtained at the client level by the CCA mechanism varies around the threshold. By consequence, the interruption of the communication can be due to the CCA-ED mechanism as well as to the errors.

Conclusion

For Internet on board trains:

- if transient interferences are repeated with a time interval T lower than 25 µs the performances of the Wi-Fi network could be degraded due to the CCA-ED mechanism and errors.

$\Rightarrow$ the interferences should be taken into account in the design of the Wi-Fi system.

$\Rightarrow$ access point locations have to be defined to reduce coupling with transient interferences in such a way that the received interference power is < -72 dBm in order that the CCA mechanism does not consider the medium as busy.

For $T \geq 25$ µs, the CCA mechanism does not detect the transient interferences and do not limit the access to the medium.

Thank You !

Virginie DENIAU

virginie.deniau@univ-eiffel.fr

Université Gustave Eiffel