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# The deployment of Wireless Networks in High Voltage Substations: A feasibility Study

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# Agenda

- **Introduction & study context**
- **Channel model and simulation parameters**
  - Substation modeling
  - Target technologies and simulation parameters
- **Simulations results and Discussions**
  - Coverage results
  - Throughput results
  - Results discussions and recommendations
- **Impact of impulsive noise**
- **Conclusion & perspectives**

# *Introduction & study context*

## Brief presentation of Hydro-Québec

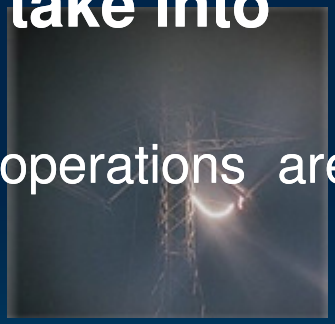
- **Hydro-Québec is the most important hydro-electricity provider in North America**
  - 39 hydro-electric power stations
  - 33 000 km transportation lines (10 000 km @ 735 kV)
  - 505 substations and 18 interconnections with USA and others provinces of Canada
  - 110 000 km of distribution lines
- **HQ works actively to improve the interaction within the grid with Smart Grid applications**
- **The research institute, IREQ is dedicated for R&D activities**

# *Introduction & study context*

## What is particular for wireless in a substation ?

- **The wireless systems are affected by metallic structures**
  - Multiple reflexions
  - Diffractions and scattering

- **In addition, impulsive noise need to be take into account**
  - Partial discharges, corona effects and breaker operations are some potential noise sources.



**We proposed to study the feasibility of deploying WiFi, WiMAX and 900 MHz systems in these specific conditions**

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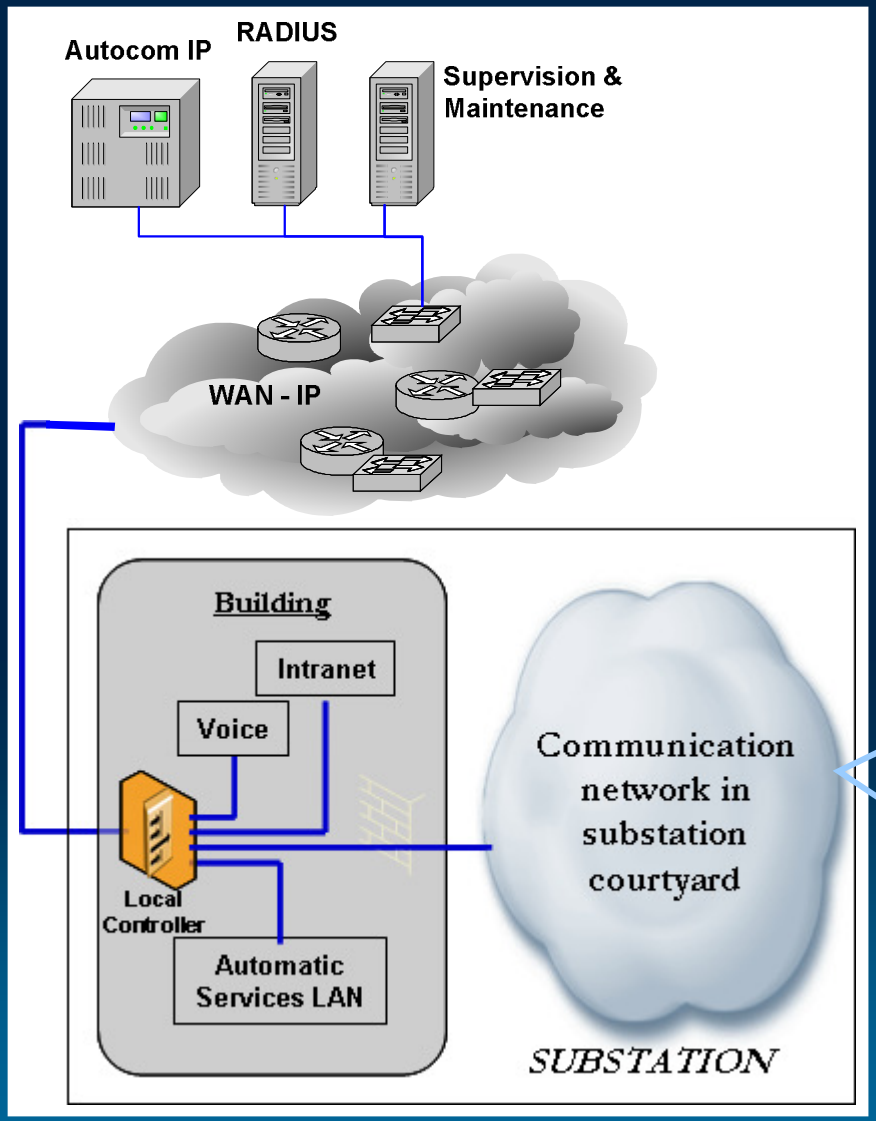
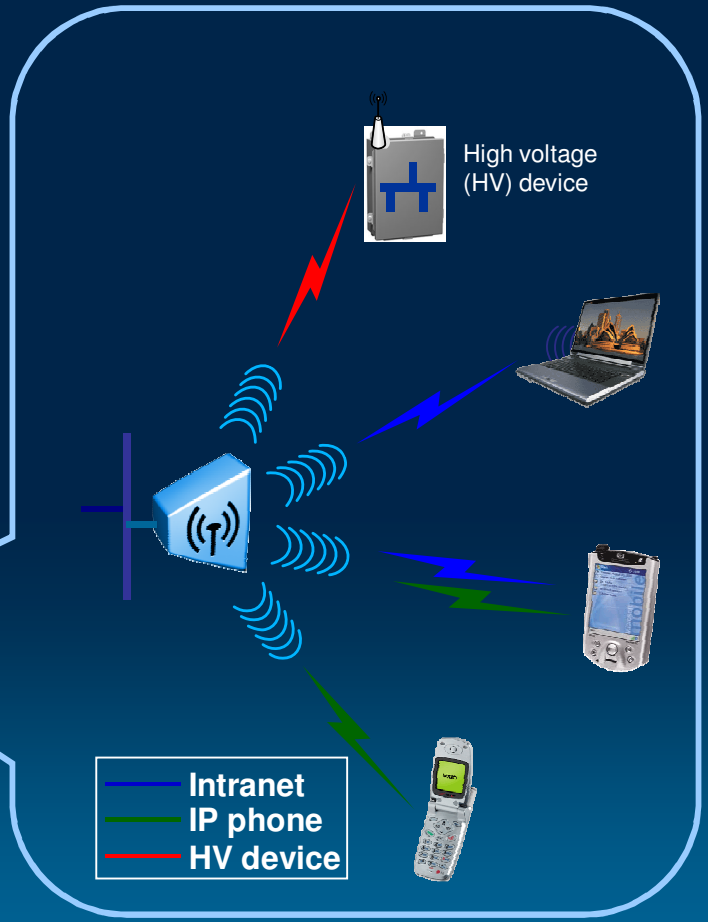
# Channel model & Simulation parameters

## Global architecture



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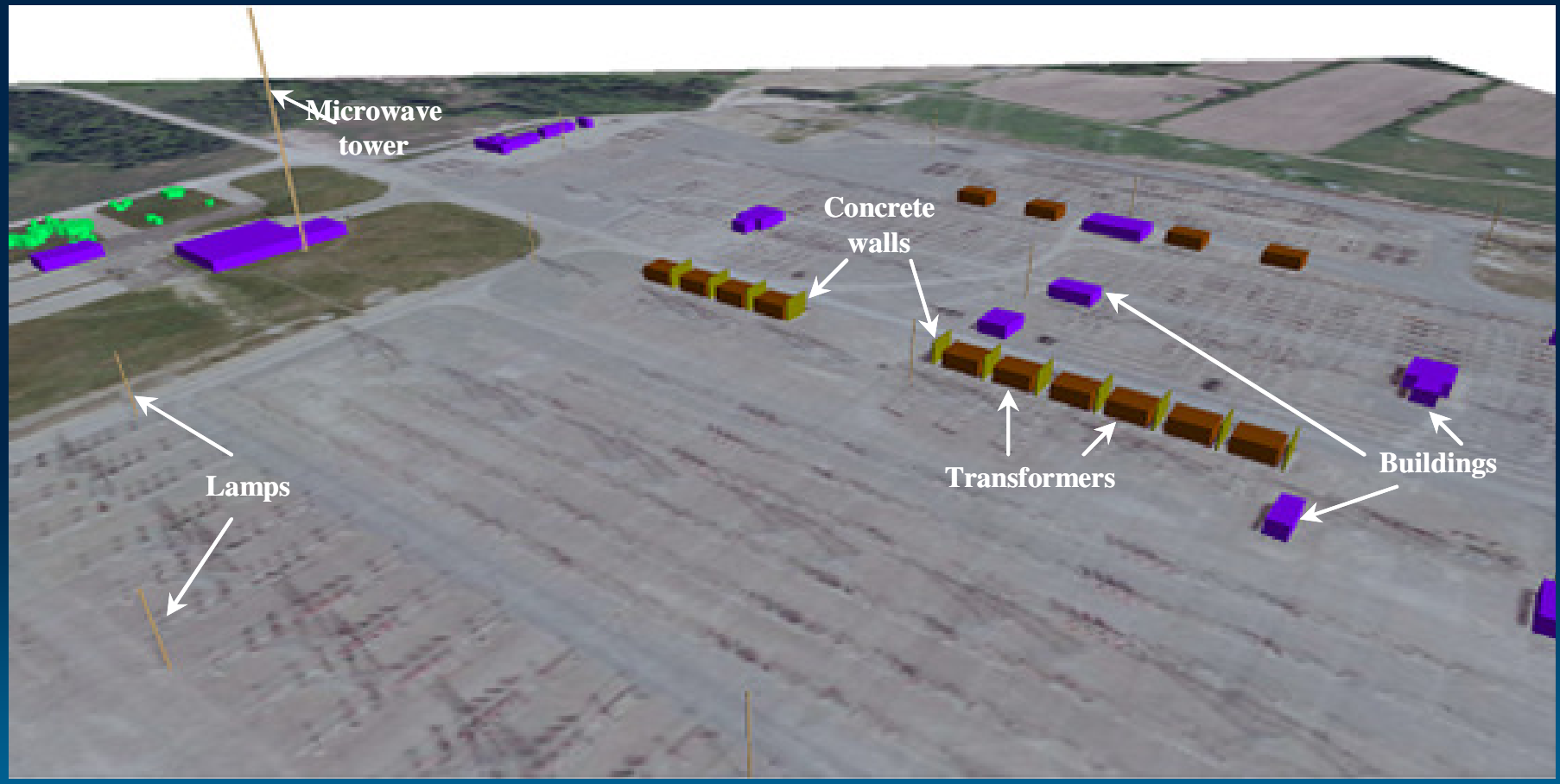
# Channel model & Simulation parameters

## Substation modeling

**To reduce the computation time, only main structures are included**



# Channel model & Simulation parameters

## WiFi (IEEE 802.11b/g/a) simulation

- **BS parameters:**
  - EIRP allowed in each frequency band is used:
    - 36 dBm in 2.4 GHz for 802.11 b/g (Belair ARM3)
    - 30 dBm in 5 GHz for 802.11a (Belair AP radio ERM 2)
- **CPE parameters:**
  - A fixed CPE ( 20 dBm of transmit power, 6 dBi of antenna gain and 1 dB loss)
  - A mobile CPE (Cisco *Unified IP Phone 7921 G,* with 17 dBm of transmit power)

## WiMAX (IEEE 802.16e) simulation

- **BS parameters:**
  - Airspan - MicroMAX (36 dBm of EIRP at 5.8 GHz and 10 MHz bandwidth)
- **CPE parameters:**
  - Airspan-ProST-2 (20 dBm of transmit power, 9 dBi antenna gain and 1 db loss)

## 900 MHz Mesh simulation

- **BS and CPE parameters:**
  - 36 dBm of maximum EIRP:
  - 900 MHz – FHSS: GE-MDS radio, iNET-II 900
  - 900 MHz – OFDM: GE-MDS radio, Mercury

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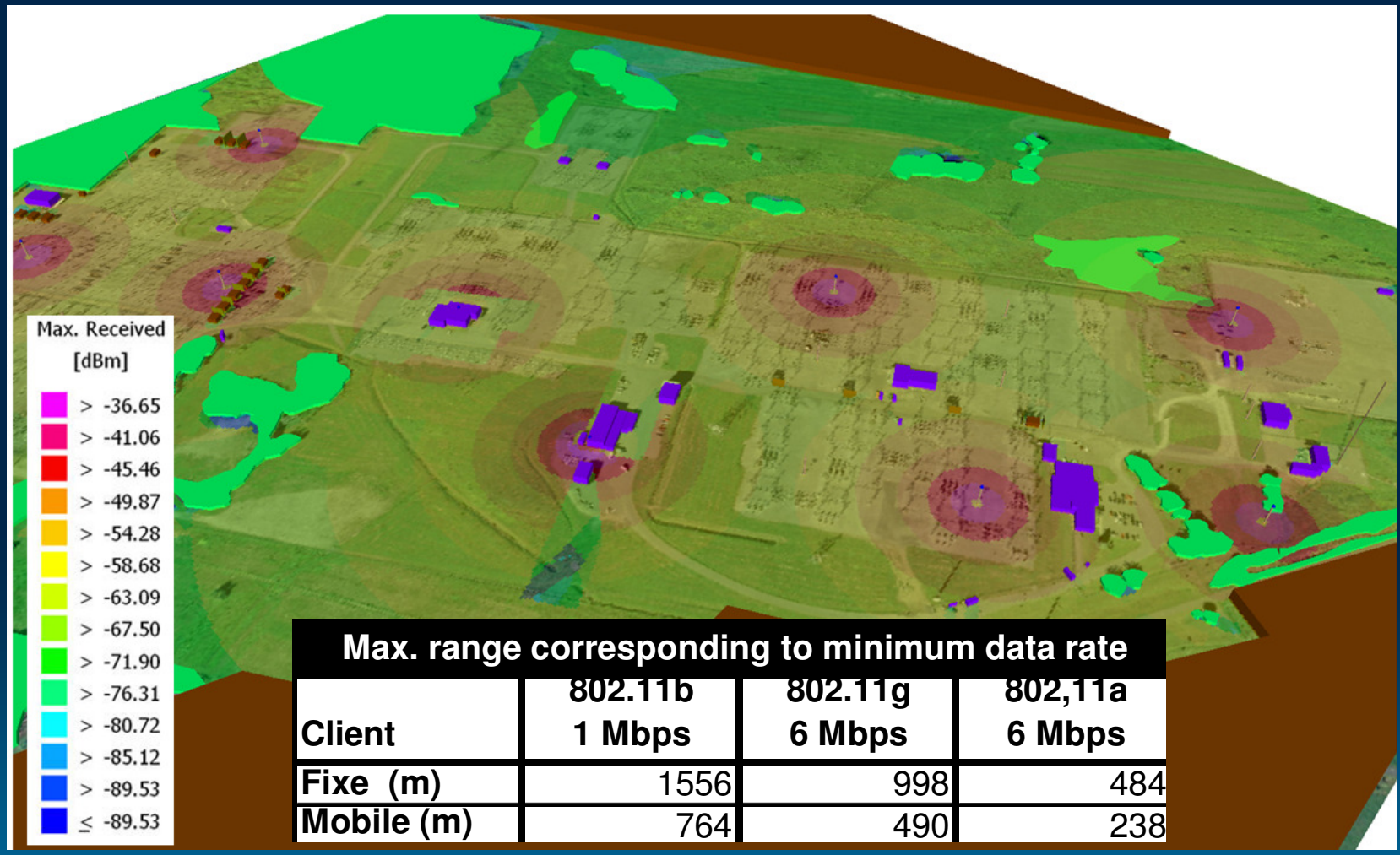
# Simulation results: Coverage

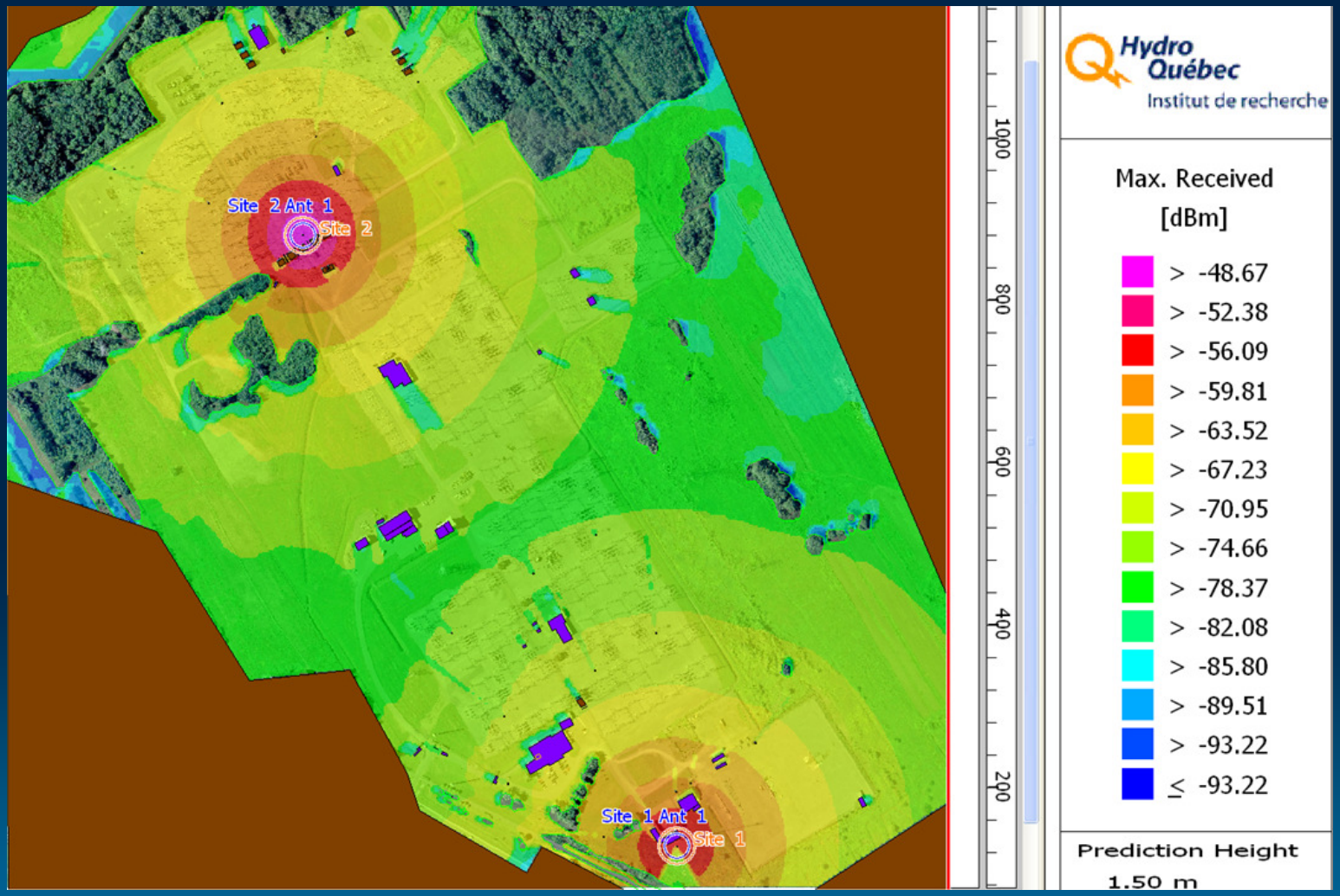
## WiFi – 802.11 g (mobile CPE at 1.5 m AGL)




| Max. range corresponding to minimum data rate | | | |
|---|---|---|---|
| Client | 802.11b 1 Mbps | 802.11g 6 Mbps | 802,11a 6 Mbps |
| Fixe (m) | 1556 | 998 | 484 |
| Mobile (m) | 764 | 490 | 238 |

# Simulation results: Coverage

## WiMAX – 802.16e (CPE with 9 dBi gain, 20 dBm power)



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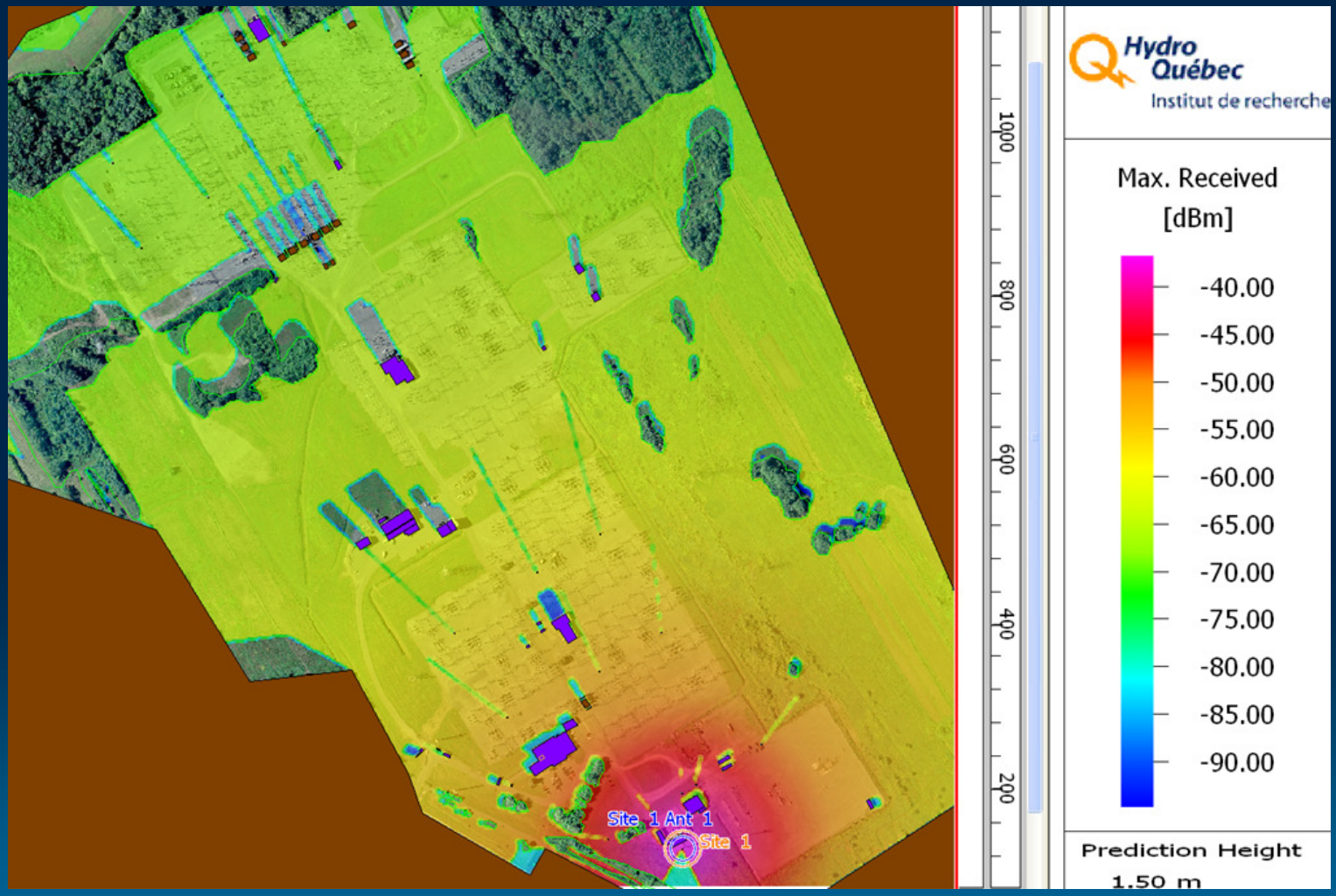
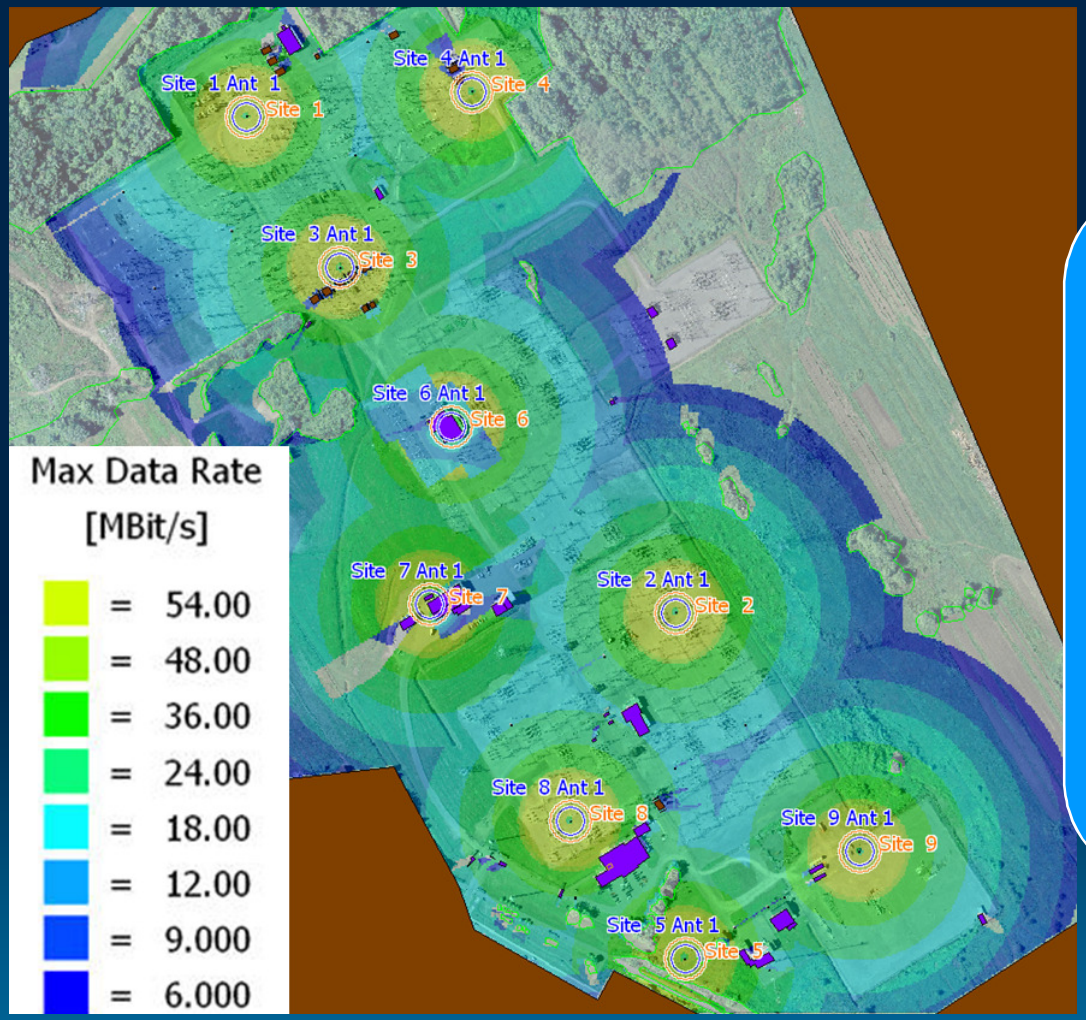
# *Simulation results: Coverage*

## 900 MHz (GE-MDS CPE  with OFDM)



# *Simulation results: Throughput*

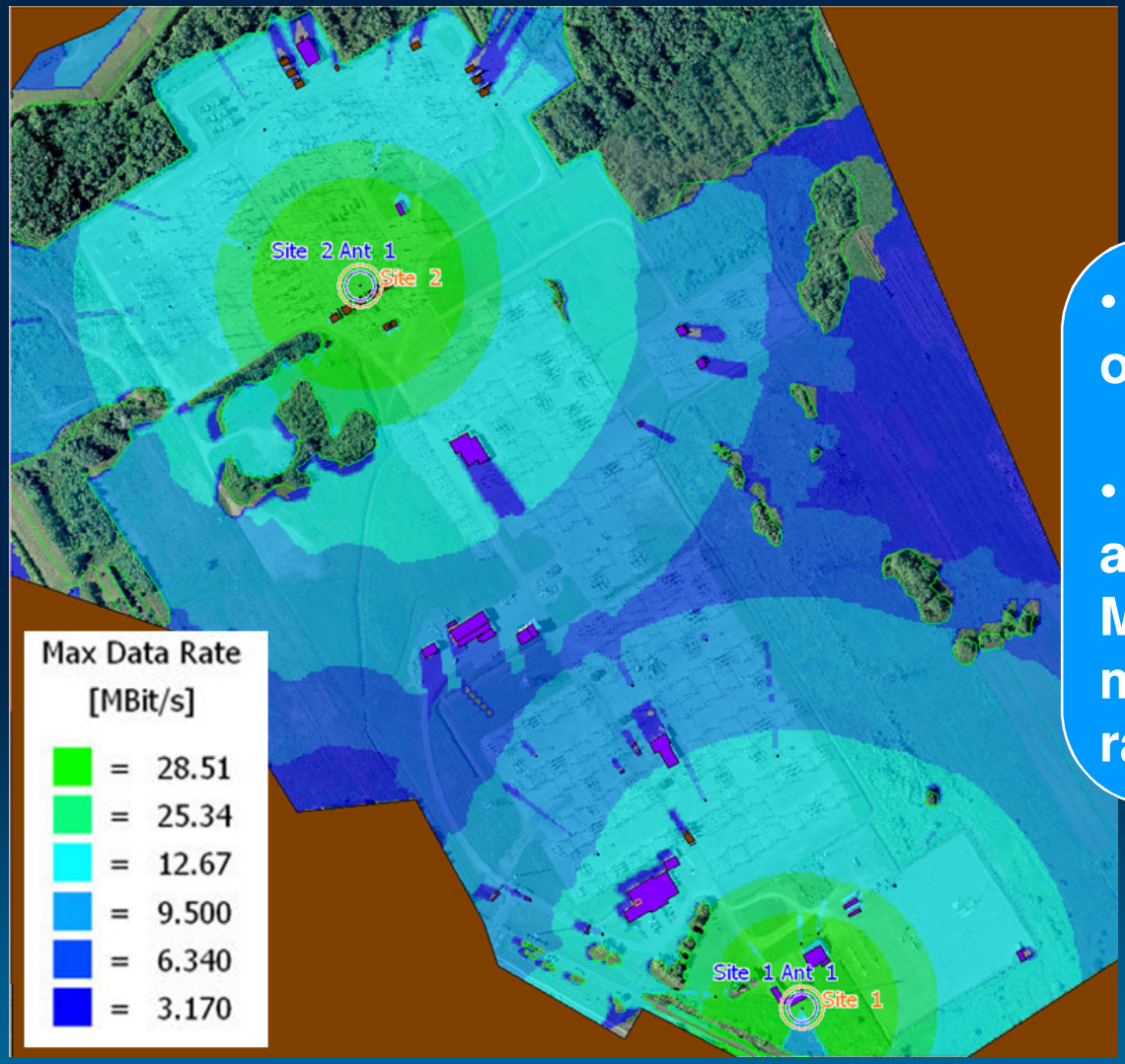
## WiFi – 802.11 g (mobile CPE at 1.5 m AGL)




- 9 AP are used with independent channels (1, 6 and 11)
- The substation area is completely covered with 75 % above 18 Mbps and 25 % between 6 Mbps and 18 Mbps

# Simulation results: Throughput

## WiMAX – 802.16e (CPE with 9 dBi gain, 20 dBm power)




- 2 BS are used for optimization
- 40 % of the coverage area is above 12.7 Mbps and the minimum achievable rate is 3.2 Mbps.



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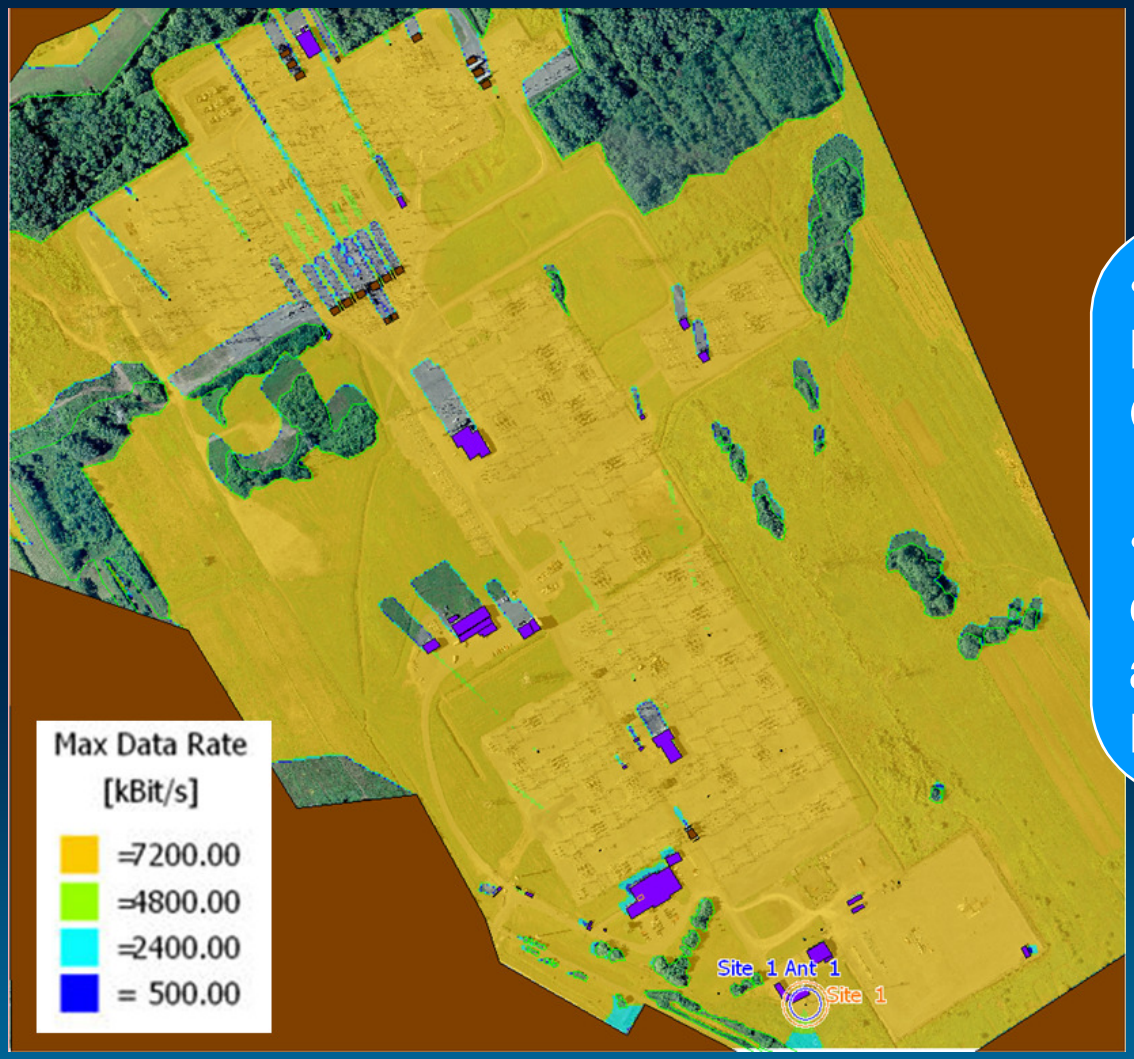
# *Simulation results: Throughput*

## 900 MHz (GE-MDS CPE with OFDM)




- 1 BS is used for 900 MHz system under OFDM modulation
- About 99 % of the coverage area is achieved with 7.2 Mbps using one BS

# *Simulation results: Discussions*

## We make analysis based on the six criteria and we propose a synthesis with a qualitative assessment of each criterion:

- *"Excellent"* when the test is very good
- *"Good"* when it is satisfactory
- *"Passable"* when it is acceptable
- *"Insufficient"* when it is unsatisfactory.

| | WiFi | WiMax | 900 MHz |
|---|---|---|---|
| **Propagation** | GOOD | GOOD | EXCELLENT |
| **Clients' number** | GOOD | EXCELLENT | INSUFFICIENT |
| **Data rate** | EXCELLENT | EXCELLENT | PASSABLE |
| **Paquets' number** | GOOD | GOOD | N / A |
| **Cybernetic security** | GOOD | GOOD | PASSABLE |
| **Other requirements** | GOOD | GOOD | INSUFFICIENT |
| **Global evaluation** | **SATISFACTORY** | **SATISFACTORY** | **UNSATISFACTORY** |



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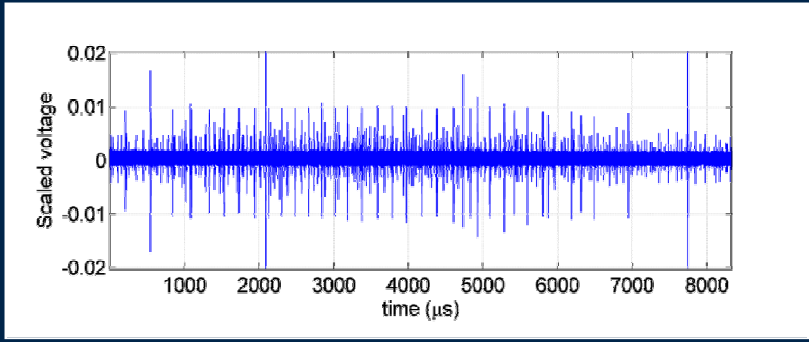
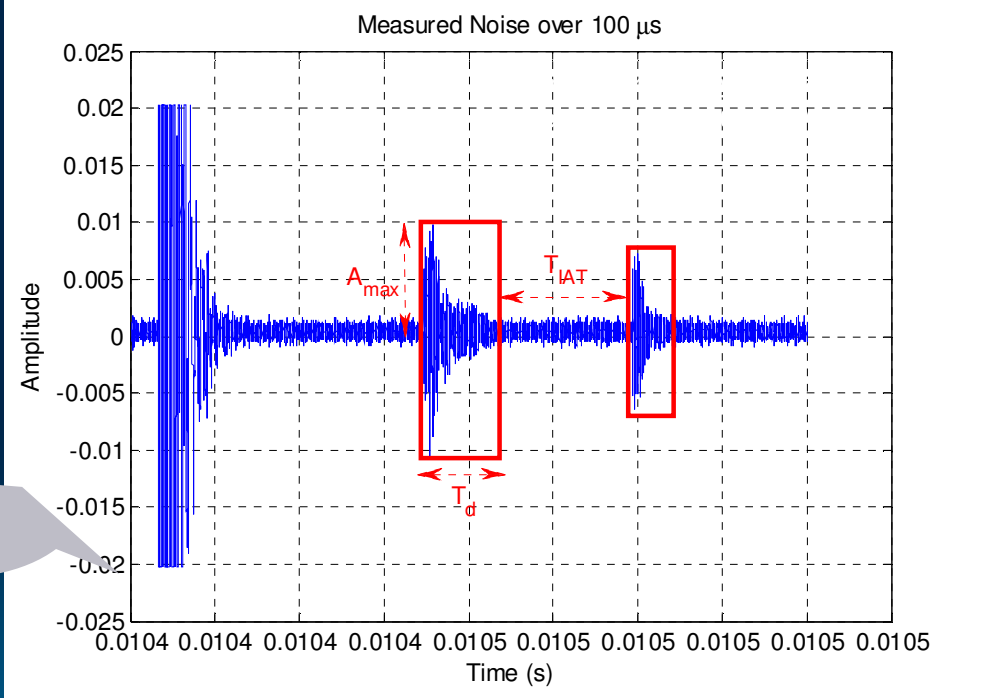
# *Impact of impulsive noise (on-going work)*

## Many measurements are carried out in a substation in order to derive an analytical model of HV environment

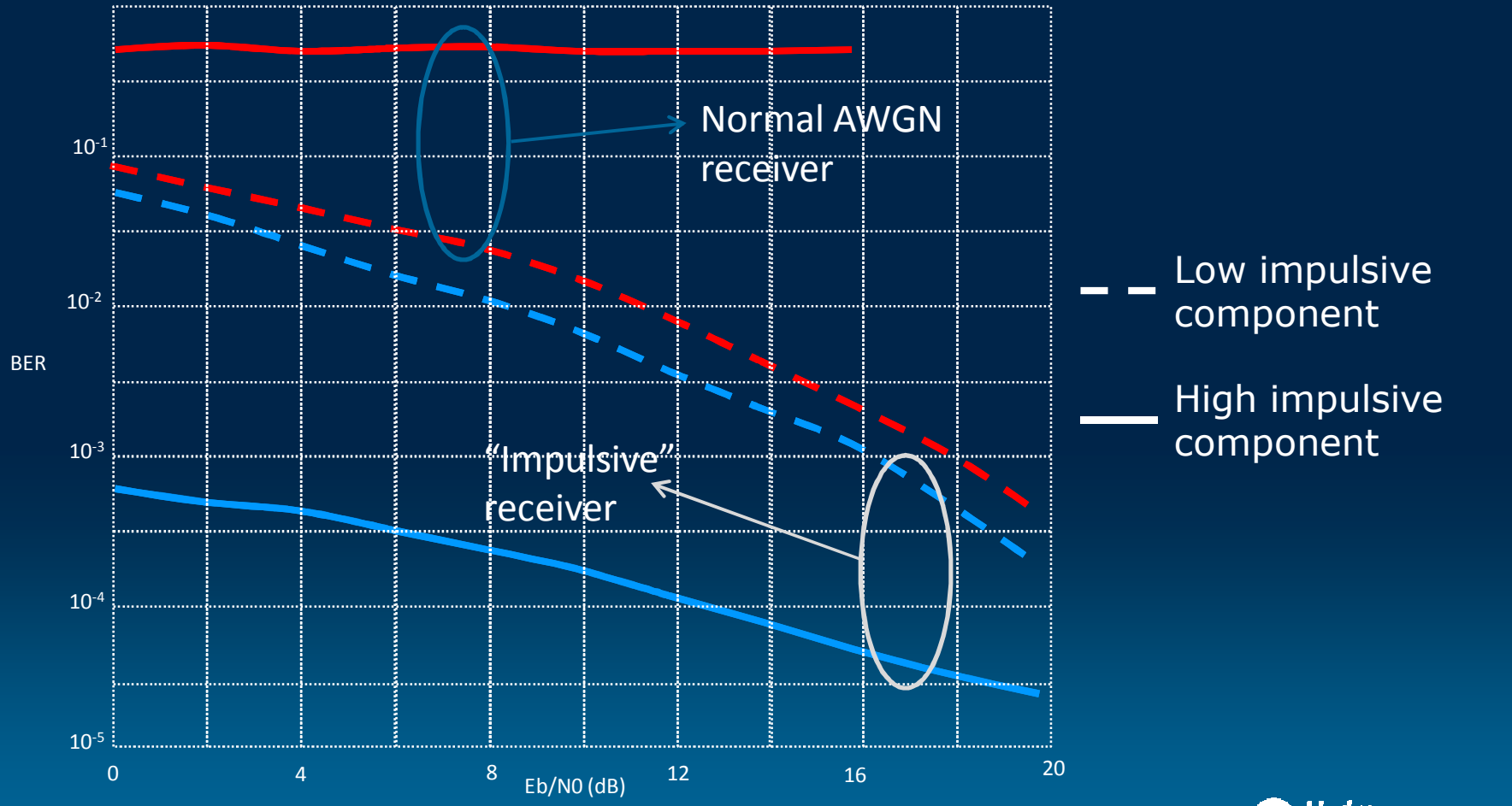



- ✓ $A_{max}$: Max amplitude
- ✓ $T_{IAT}$: Interval between pulses
- ✓ $T_d$: Pulse duration

# *Impact of impulsive noise (on-going work)*

## Knowing the channel characteristics in HV environment, we can design an optimised receiver



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# Conclusions

- The 900 MHz technology stands out when considering only the propagation aspect but the analysis has highlighted its inadequacy with some requirements such as the simultaneous number of customers, the bandwidth limitation and the lack of interoperability
- The WiFi and WiMAX technologies are sufficient for these requirements
- WiMAX seems to be the most cost-effective wireless solution that meets the bandwidth need of HQ applications (In practice, a combination of technologies will be more relevant)
- The economic analysis showed that the number of AP or BS required in a substation is the determining factor of the overall deployment cost

Thanks !

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Questions ?

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