Resilient indoor to outdoor TVWS wireless system for safety applications

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CEA-LETI

Outline

- Motivation
- Communication system overview
- Specification of the wireless indoor/outdoor system
- Implementation and tests
- Conclusion

Motivation for embedded video in FRs' equipment

The nasty companion of fire: smokes

One minor event happened in the morning of 16th of August 2005 in Saint Gothard tunnel (CH)

4 seconds later

Fire services all over the world agree on the fact that smokes make more casualties than fire.

Most Fire Rescue operations happen in confined spaces: high temperature, smoke require fast decisions!

Communication between First Responders and crisis HQ

- **Weakness of oral report**

Oral report by radio or phone is not sufficient to give a proper account of the situation Stress and individuals' sensitivity make an oral description fairly unreliable.

- **The need for live video feeds**

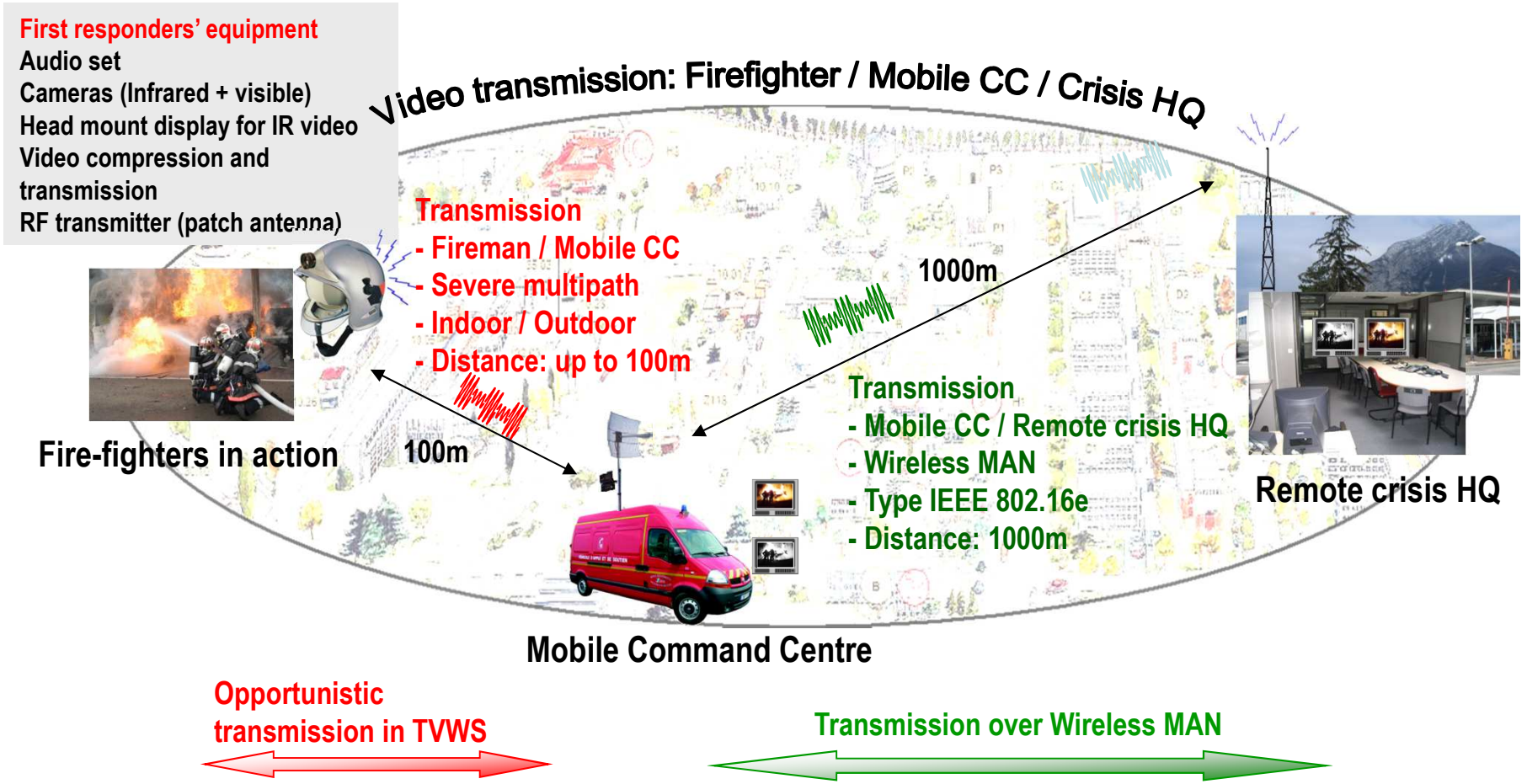
Visible and Infrared live video help take appropriate decision
Type of measures implemented to fight fire and response time needed to realize actions is a determining factor in restoring the situation

- **Embedded sensors and wireless communication**

Camera and sensors should be integrated in equipment (helmet)
The fire-fighter cannot carry any device in his hands
Information is transmitted to management through wireless communication

Robust Video transmission from first responders to remote crisis management HQ via mobile Command Centre

CEA's technology: communicate with crisis management in emergency situation



Environment of the First Responders

Harsh Environment

Strong Requirements from the Usage

- Weight
- Antenna fitted on Helmet
  - Limited power
  - Small size (low / no gain)
  - Body obstruction
- Battery has to be carried
  - Limited power
  - Limited autonomy
  - Weight
- Sensors, display and telecom integration
  - Robustness & reliable
  - Easy to use

Reinforced concrete wall

Antenna and Transceiver developed at CEA - LETI

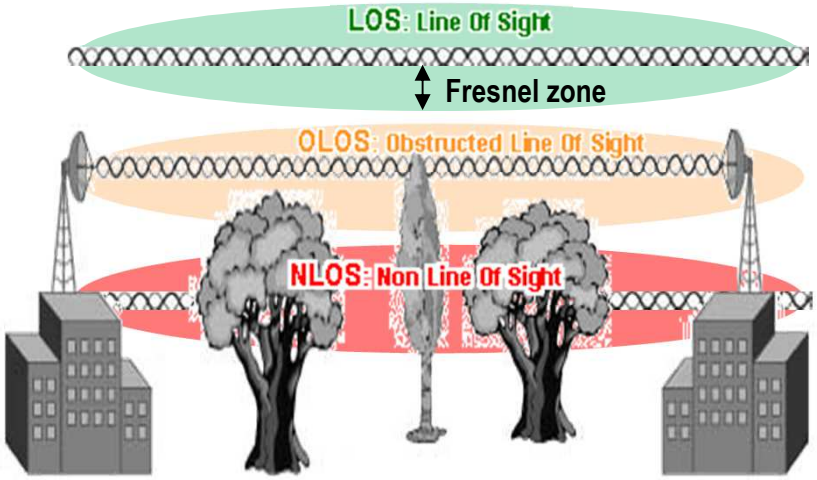
Steel framework

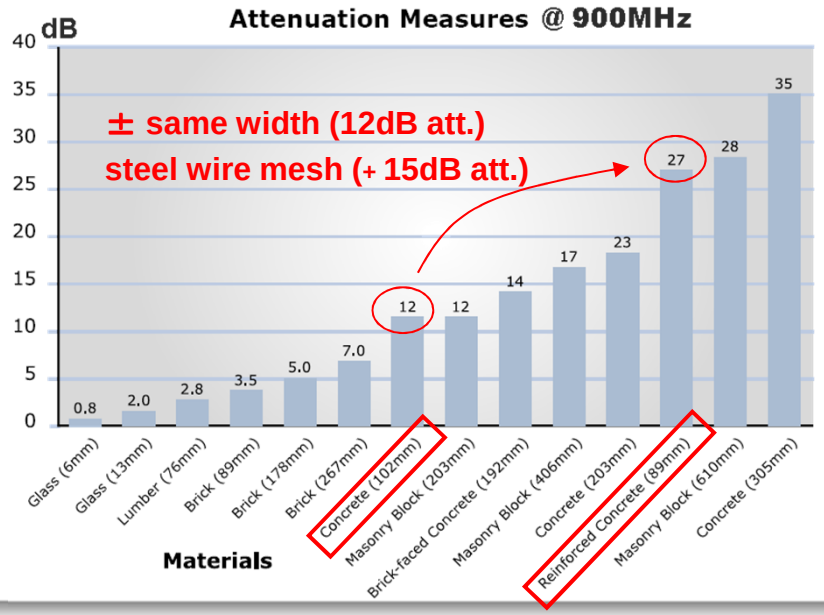
Difficult Propagation Conditions

- Indoor or dense urban transmission
  - Multipath propagation
  - Frequency fading
- L.O.S. almost never exists
- De-Polarization of RF
- Building infrastructure
  - Steel structures, reinforced concrete
  - Frequency selective

Environment of the FRs during building exploration

Path Loss





Free Space Loss – the loss due to radio energy passing through air with a clear Fresnel zone. Generally, a 900 MHz signal travels through air with much less loss than does a higher frequency signal.

Example	900MHz	2.4GHz	5.8GHz
Distance 1 km:	91.5 dB	100.1 dB	107.7 dB

Vegetation Loss – the loss expected due to radio energy being absorbed by the moisture content of the vegetation. This loss will vary for every situation, however the typical tree loss expected at different frequencies has been estimated by the International Telecommunication Union.

Example	900MHz	2.4GHz	5.8GHz
45m of trees	9 dB	25 dB	60 dB

Cable Loss – the loss expected due to radio energy passing through RF cables

Example	900MHz	2.4GHz	5.8GHz
LMR400	0.131 dB/m	0.222 dB/m	0.358 dB/m
LMR900	0.058 dB/m	0.098 dB/m	0.160 dB/m
LMR1200	0.042 dB/m	0.076 dB/m	0.124 dB/m

Wall and Glass Loss – the loss expected due to radio energy being absorbed while passing through the walls and windows of a building. The amount of absorption varies depending on the construction materials and thickness of the material. Generally more energy is absorbed at the higher frequencies.

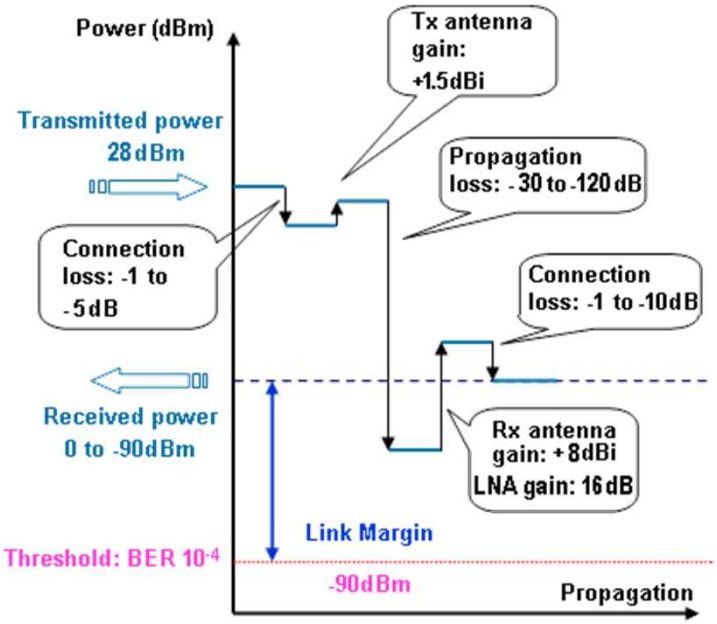
Environment of the FRs during building exploration

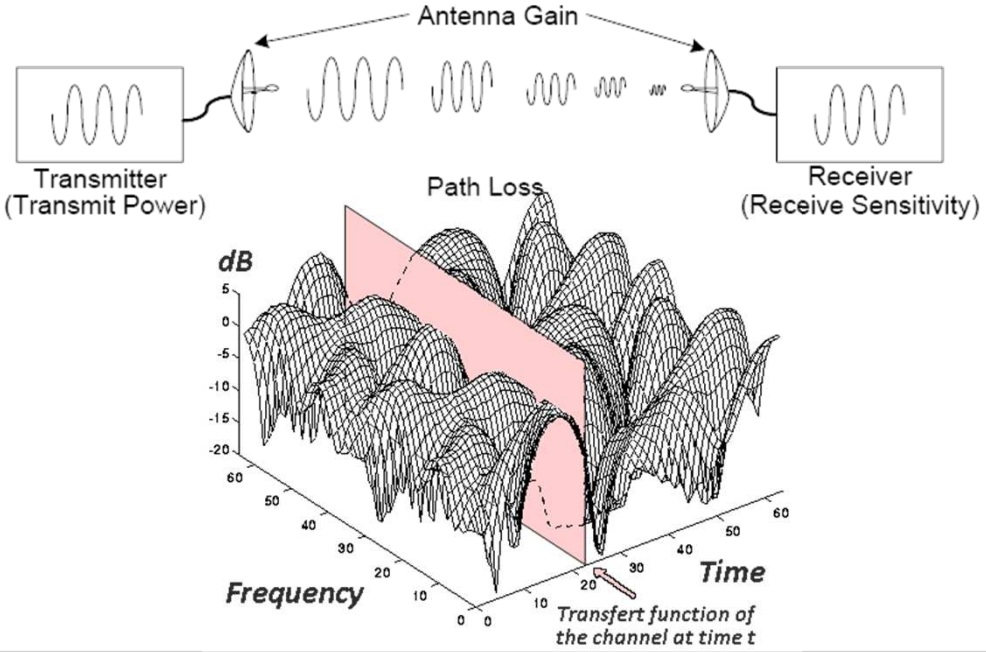
Link Budget

$$\frac{P_r}{P_t} = G_t\,\eta_t\left(1-|s_{11}|^2\right)\;G_r\,\eta_r\left(1-|s_{22}|^2\right)\;|\vec{u}\,.\,\vec{v}|^2\;\left(\frac{\lambda}{4\pi R}\right)^2\;\left|1+\sum_{n=1}^{N}\Gamma_n\frac{R}{R_n}e^{-j\frac{2\pi}{\lambda}(R_n-R)}\right|^2$$

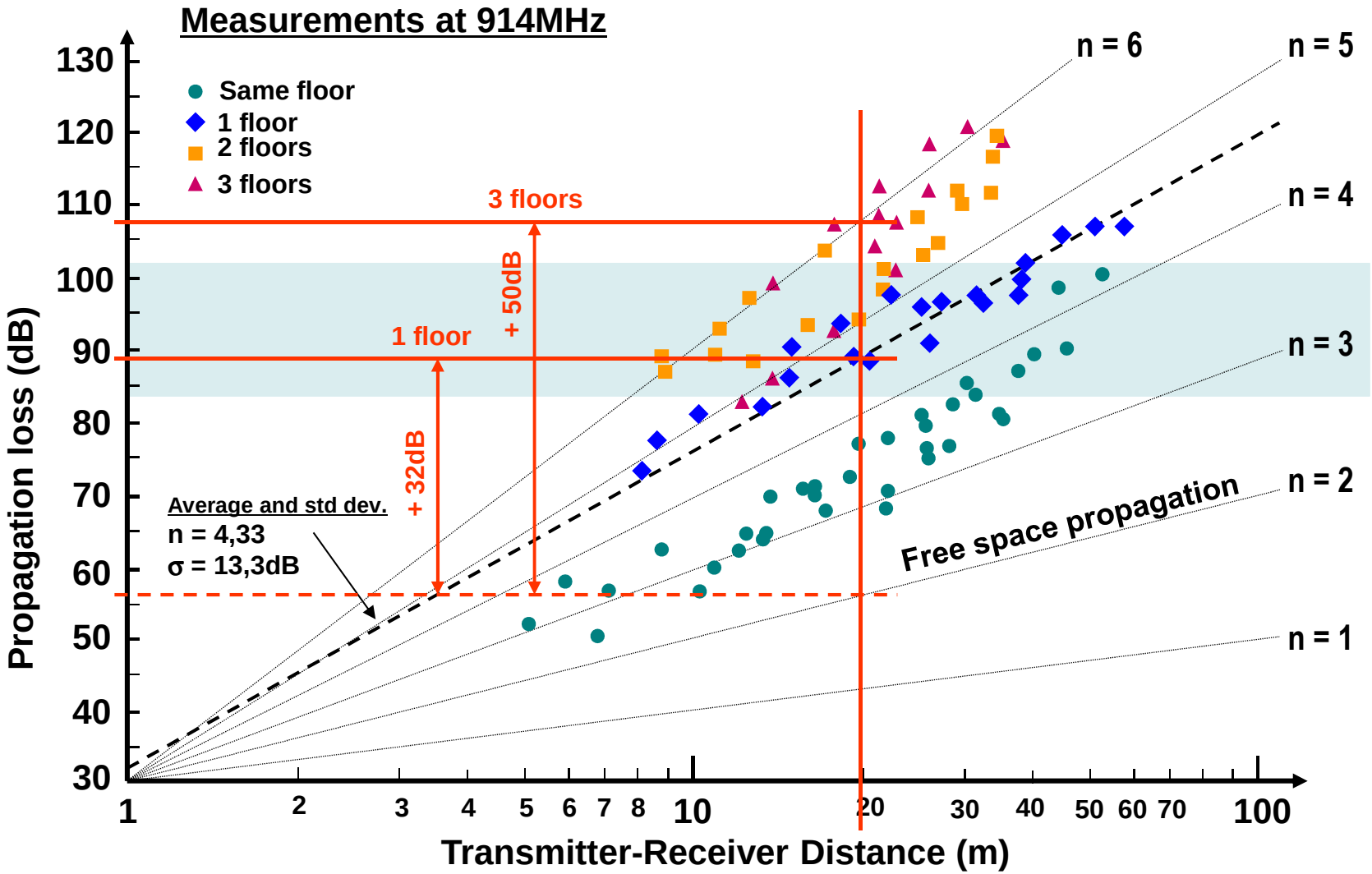
Tx antenna	Rx antenna	Polarization	Attenuation	Multipath
▪ Gain	▪ Gain	▪ Wave	▪ Wavelength	▪ Ricean channel
▪ Efficiency	▪ Efficiency	▪ Rx antenna	▪ Distance	▪ Rayleigh channel
▪ Adaptation	▪ Adaptation			

Link Margin = Transmit Power – Receiver Sensitivity + Antenna Gain – Path Loss – Connection Loss





Indoor transmission inside a 4-floor building



From S. Y. Seidel, T. S. Rappaport, "914 MHz Path Loss Prediction Models for Indoor Wireless Communications in Multifloored Buildings," *IEEE Transactions on Antennas and Propagation*, Vol. 40, No. 2, February 1992, pp. 207-217.

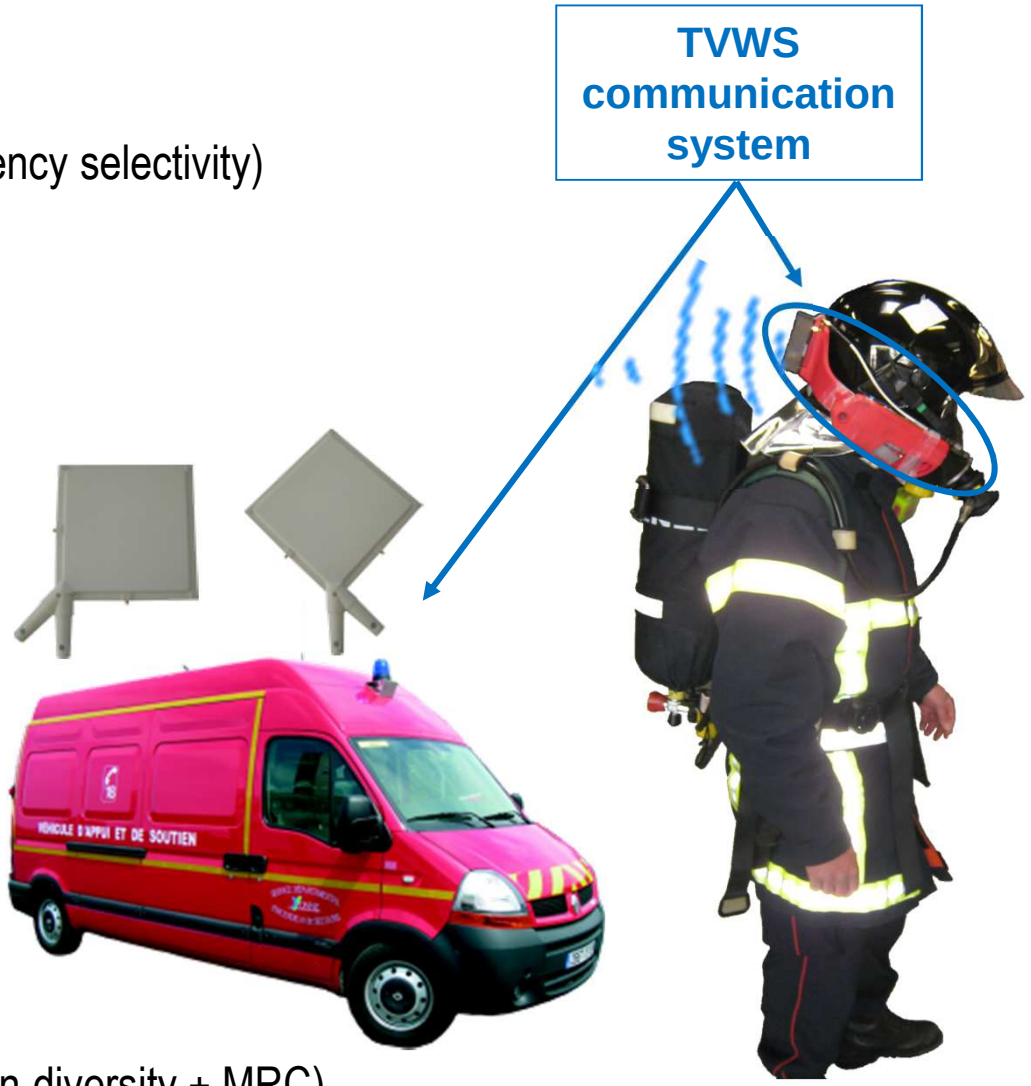
Opportunistic use of TVWS

Key issues

- Indoor / outdoor propagation
- Unknown channel characteristics (NLOS)
- Multipath propagation environment (frequency selectivity)
- De-polarization
- Close to fast road / fast fading
  - Coherency time : 3.7ms
  - Coherency bandwidth: > 40kHz

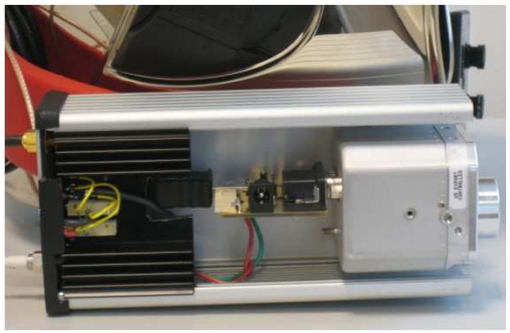
System specification

- Antenna
  - fo = 650MHz (BW: 35MHz)
  - Gain: 1.5dB (Omni)
- RF Tx
  - Frequency: 650MHz
  - BW: 12MHz
  - Electrical power = 19 dBm
- Baseband
  - COFDM 1024 sub-carriers
  - Effective data rate: 8Mbps
  - 1 - 4 SIMO (spatial and polarization diversity + MRC)



Embedded transmitter system

Head-Platform



RF PA

IR camera

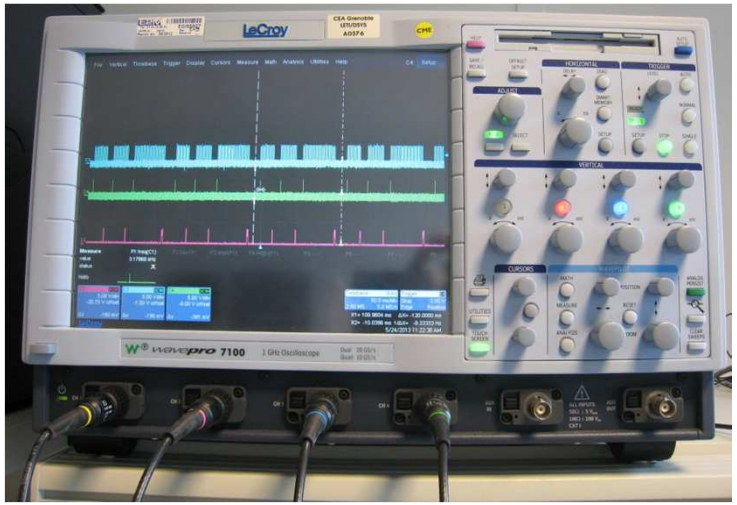
Antenna at the rear

BW camera

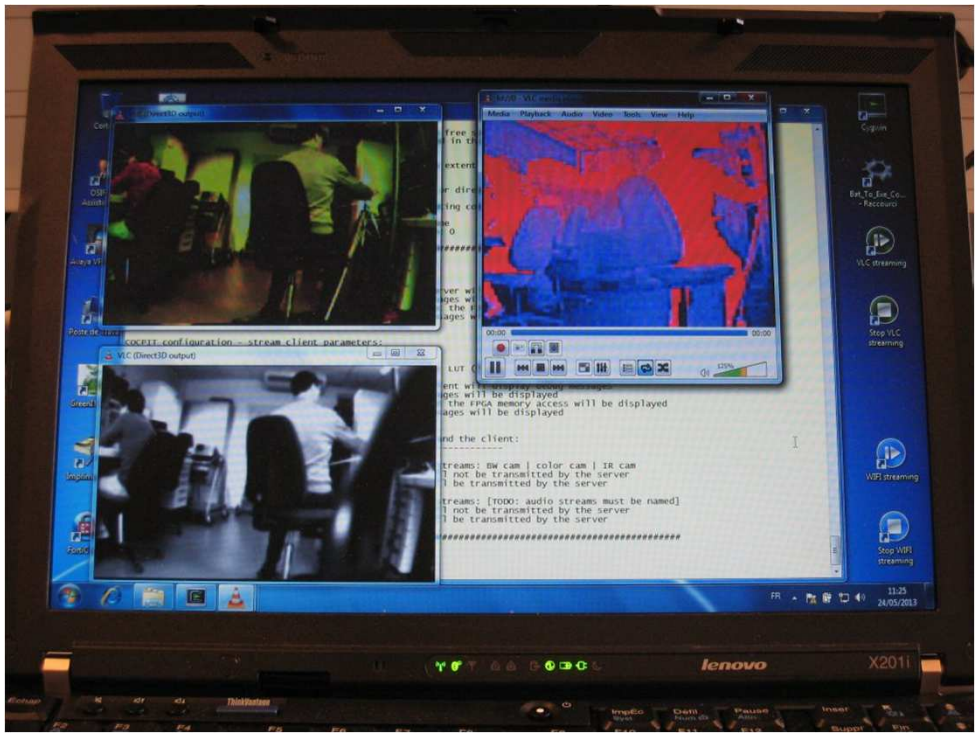
Baseband

RF Tx

Receiver system



Eth. link

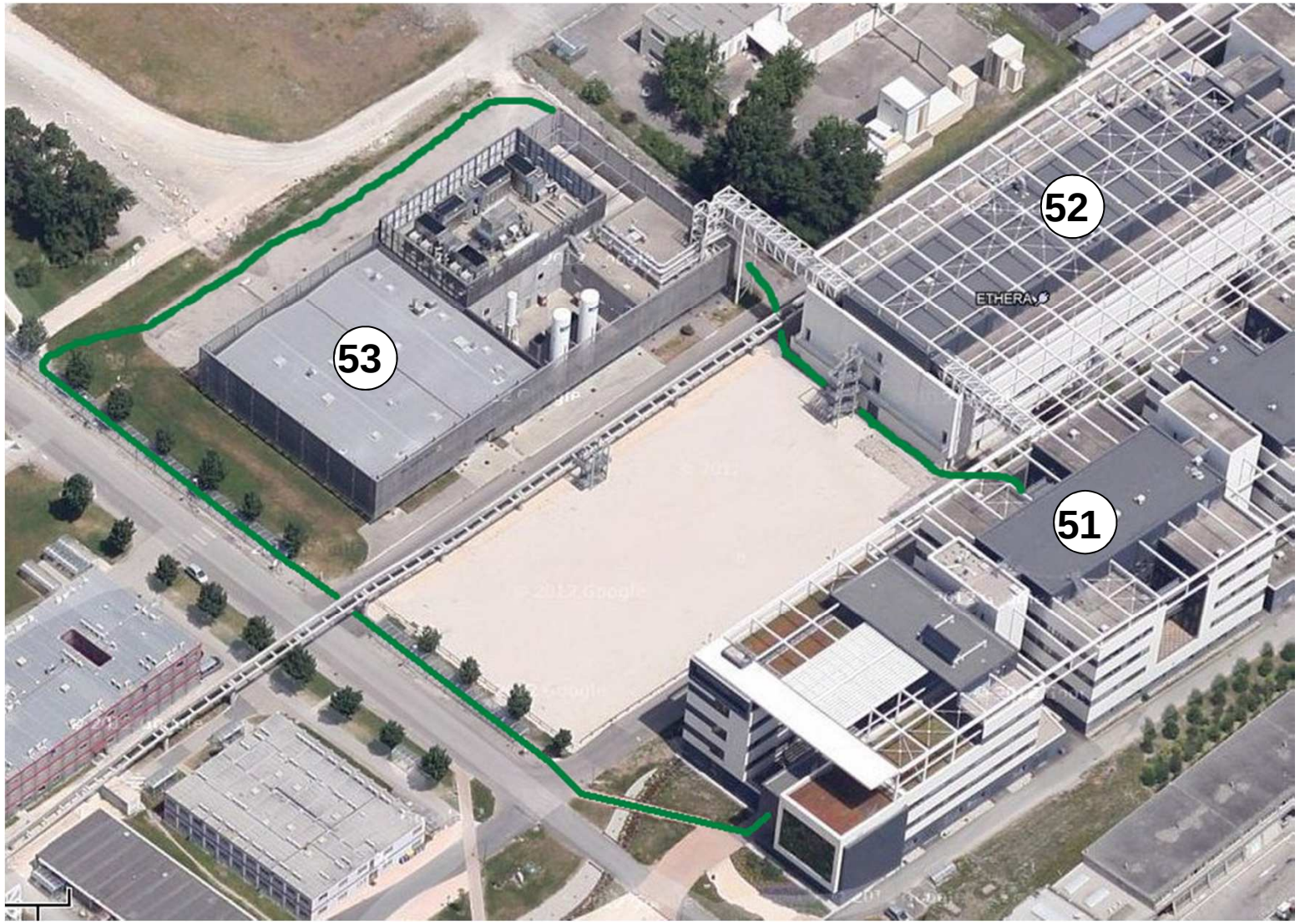


Dual polar. antenna

RF Rx **Baseband ARM9 (video server)**

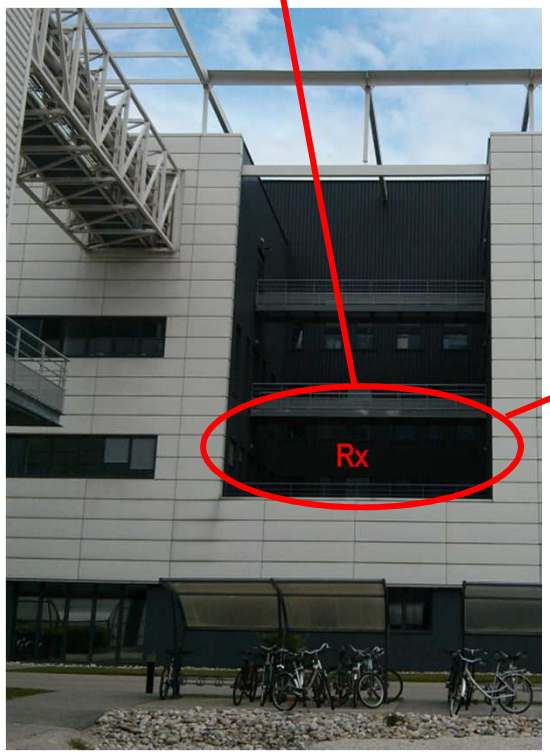
Laptop (Windows 7 – Cygwin) (video client) => VLC

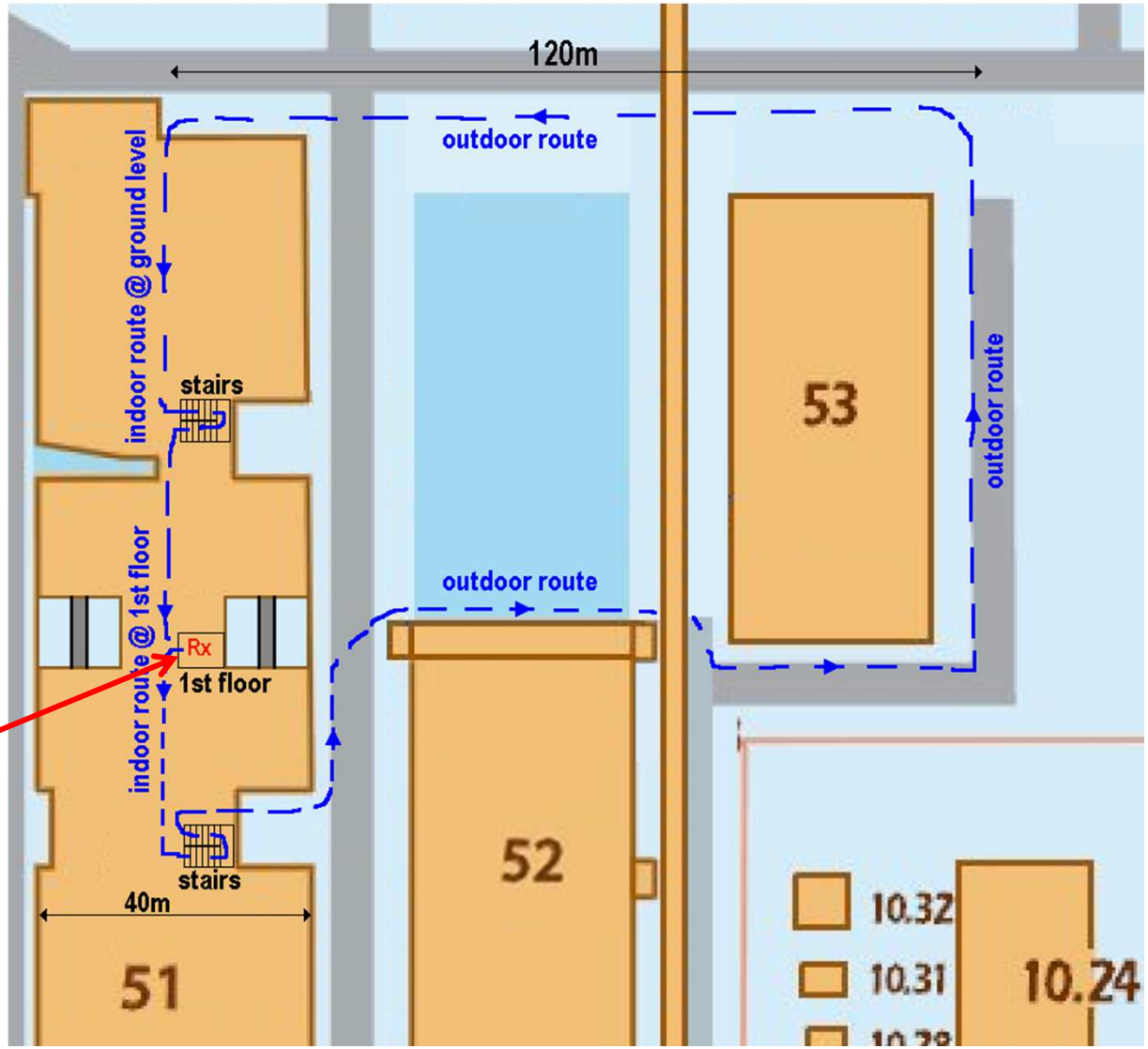
NLOS Indoor/Outdoor transmission



MINATEC area at CEA Grenoble

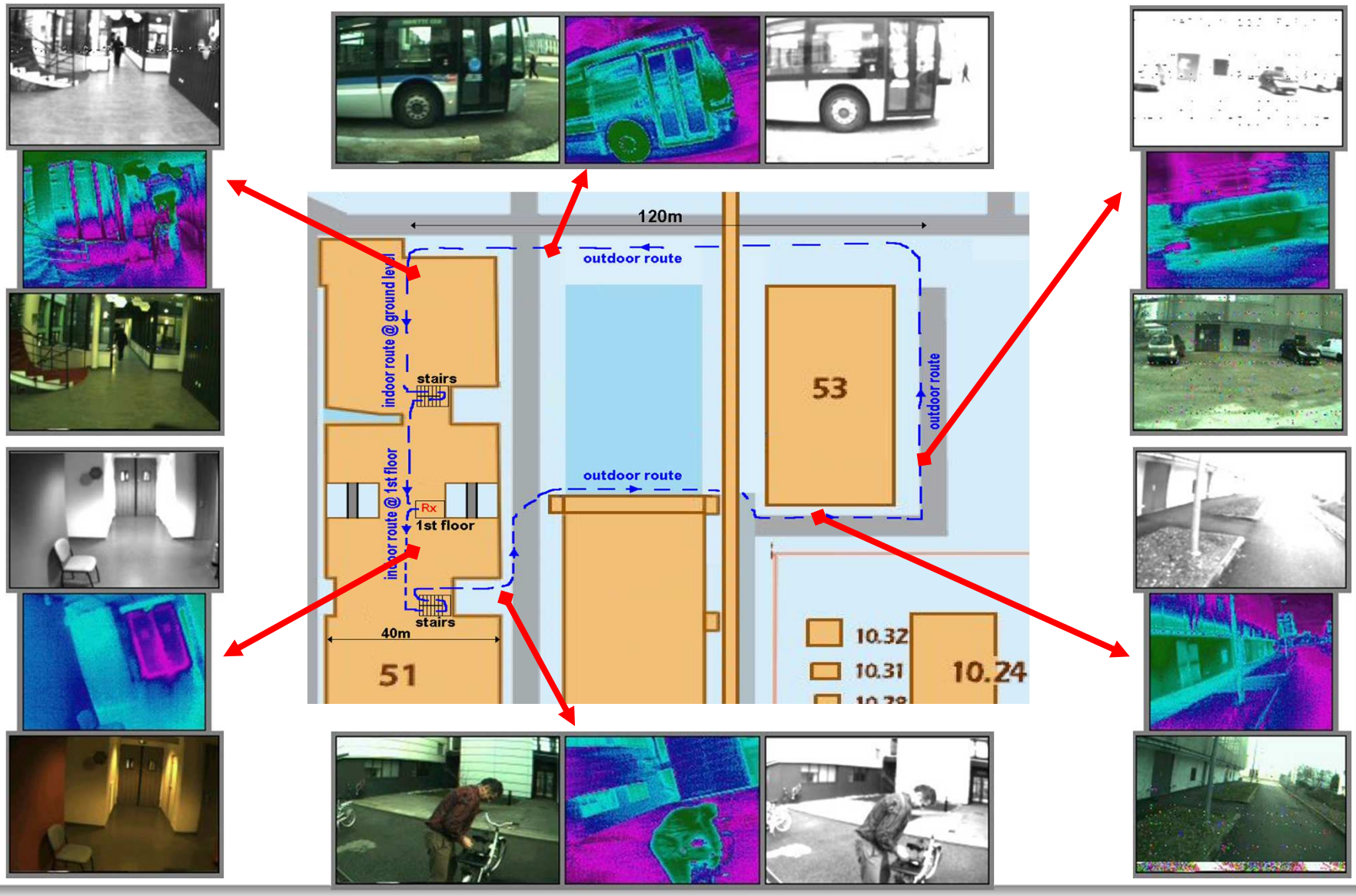
NLOS Indoor/Outdoor transmission





NLOS Indoor/Outdoor transmission

Simultaneous transmission of BW, colour and infrared videos



NLOS Indoor transmission

This building is mainly composed of offices, labs and long corridors. Made of reinforced concrete walls and metallic panels. Windows are equipped with heatstop glass, containing nanoparticles of metal that strongly attenuates the radio waves.

Successful indoor transmission through main parts of this building

Ground/1st/2nd/3rd floors/stairs => Rx @ 1st floor

Conclusion

- Live reporting is important in emergency management
- Video reporting has a strong added value compared to audio only
- Propagation conditions are severe and a specific transmission system is required
- TVWS radios is a relevant solution thanks to low pathloss and good indoor/outdoor propagation
- CEA has designed a proof of concept demonstrator, which outperforms off the shelf radio systems in these conditions
- The system has been tested in large buildings on CEA's campus

Thank You!

Leti

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