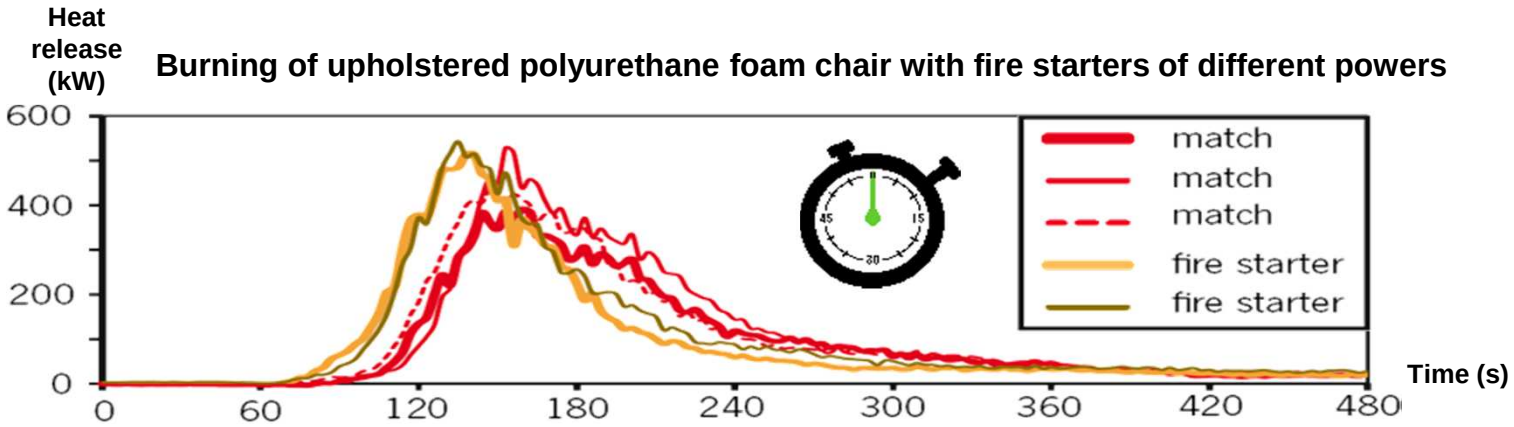
Dependable indoor-to-outdoor wireless technology in the TVWS for first responders' assistance

Rosolino Lionti, Dominique Noguet
(CEA-LETI)

Motivation for embedded video in FRs equipment

Fire fighting: a speed race



You need a bucket of water to extinguish this fire after one minute

You need a huge flow of water to extinguish this fire after a few minutes

The nasty companion of fire: smokes

Fire event happened 16th of September 2006 in Vialama tunnel (CH)

36 seconds later

Whereas in early times the fear of fire was connected only to the fire itself, nowadays fire services all over the world agree on the fact that <u>smokes make more casualties than fire</u>.

Communication between First Responders and crisis HQ

The fire and rescue services are faced in most of the cases with operations in confined spaces: high temperature, smokes require fast decisions!

Weakness of oral report

- not sufficient to give a proper account of the situation.
- stress and individuals' sensitivity make an oral description fairly unreliable.
- **This is however how reporting is handled nowadays in such situations.**

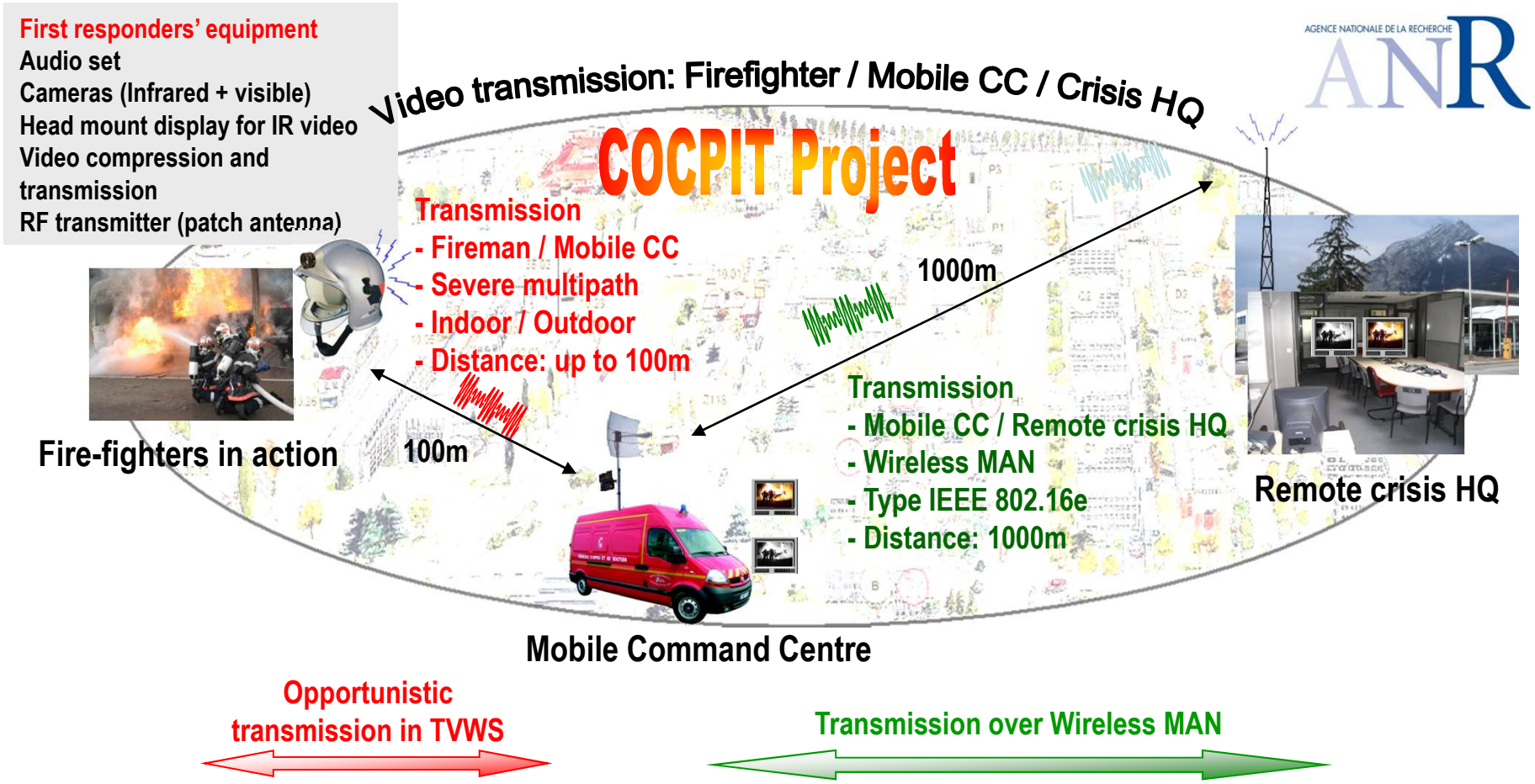
The need for additional image/video info

- Help of live video (visible and infrared) is required by People in charge of security
- Enablres to consider the actual situation and take appropriate decision
- **The adequacy between the type of measures implemented and the length of time needed to do so is a determining factor in restoring the situation.**

Embedded sensors, head mount display and wireless communication

- Helmet embedded camera and sensors ➔ hand free operation
- Situation awareness at HQ **thanks to resilient wireless communication**

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



Equipment & Environment constraints

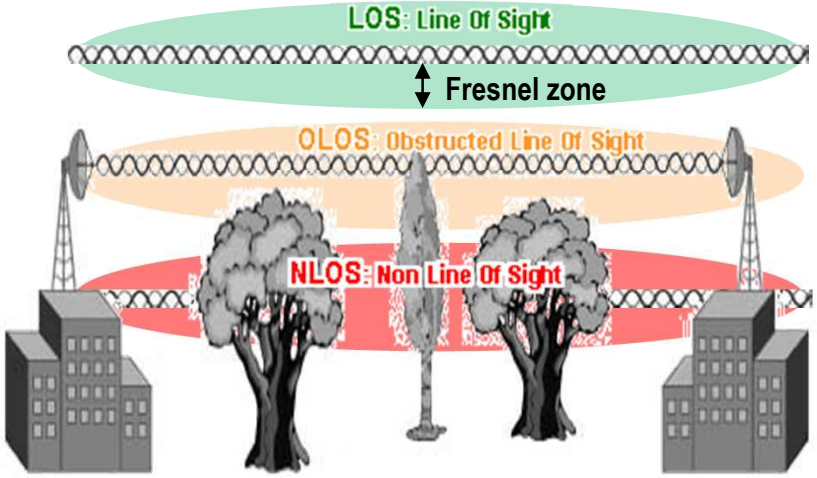
- First responders' equipment
  - ☹ Weight (impede mobility)
  - ☹ Breathing apparatus (stress)
- Wearable antenna
  - ☹ Limited power for Tx (effects of EMW)
  - ☹ Small size (low / no gain)
  - ☹ Body obstruction
- Battery carried by the first responders
  - ☹ Limited power
  - ☹ Limited autonomy
  - ☹ Weight
- Sensors, display and telecom integration
  - ☹ Robustness, reliability
  - ☹ Ergonomic (simple to use)
  - ☹ Helmet certification
  - ☹ Weight
- Indoor or dense urban transmission
  - ☹ Multipath propagation
  - ☹ Frequency fading
- L.O.S. almost never exists
  - ☹ Obstructions in 1st Fresnel zone
- De-Polarization of RF
  - ☹ By multipath propagation
  - ☹ By inclement weather
- Building infrastructure
  - ☹ Steel framework
  - ☹ Reinforced concrete
  - ☹ Frequency selective
  - ☹ Severe propagation attenuation

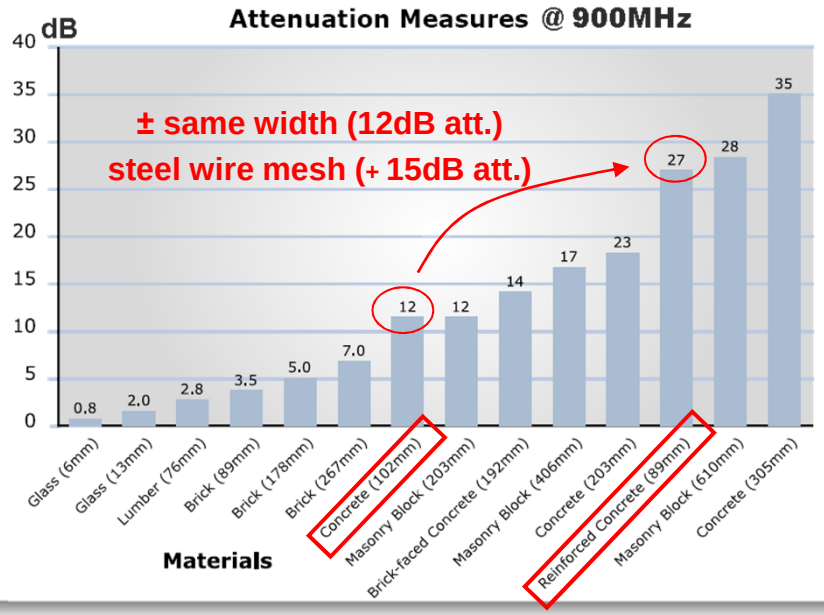
Reinforced concrete wall

Steel framework

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
- Gain
- Efficiency
- Adaptation

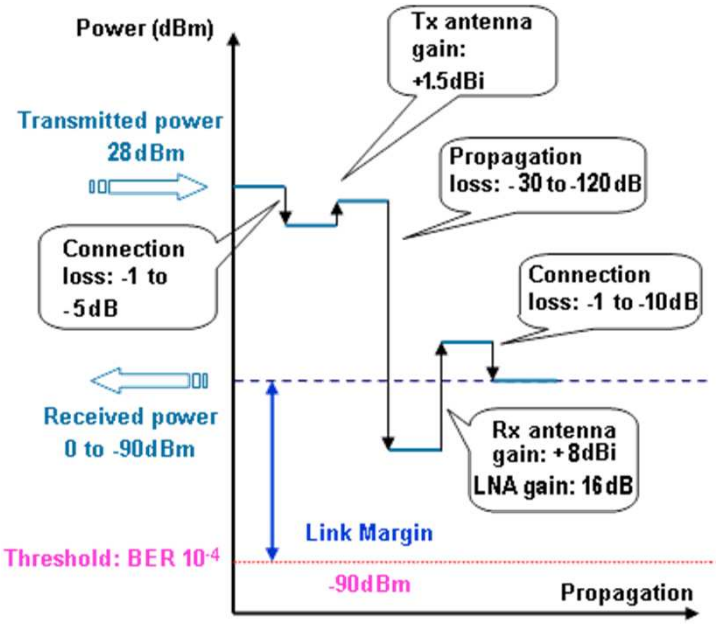
Rx antenna
- Gain
- Efficiency
- Adaptation

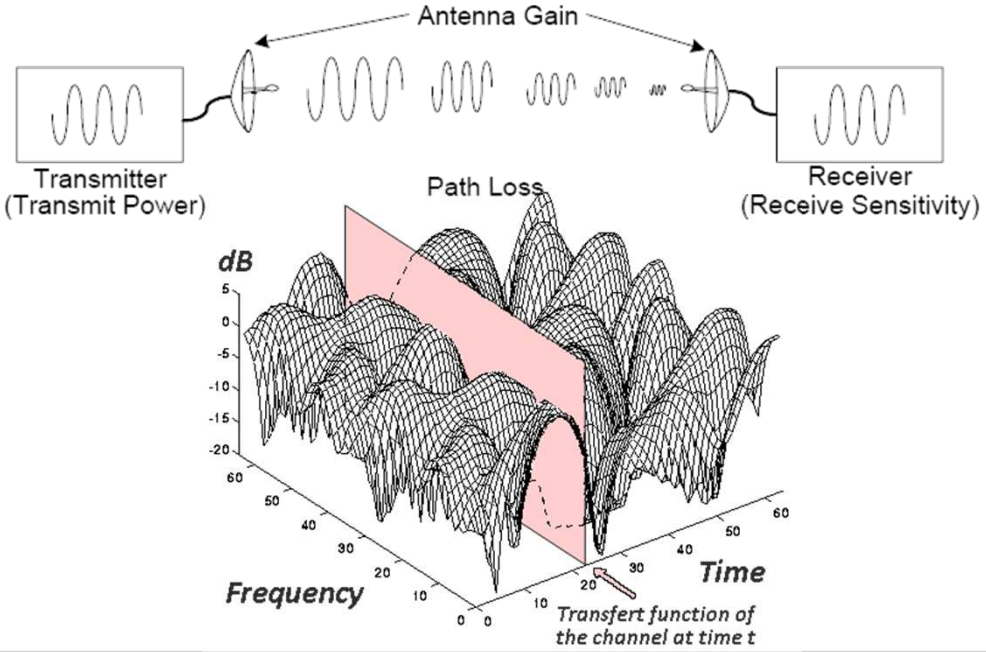
Polarization
- Wave
- Rx antenna

Attenuation
- Wavelength
- Distance

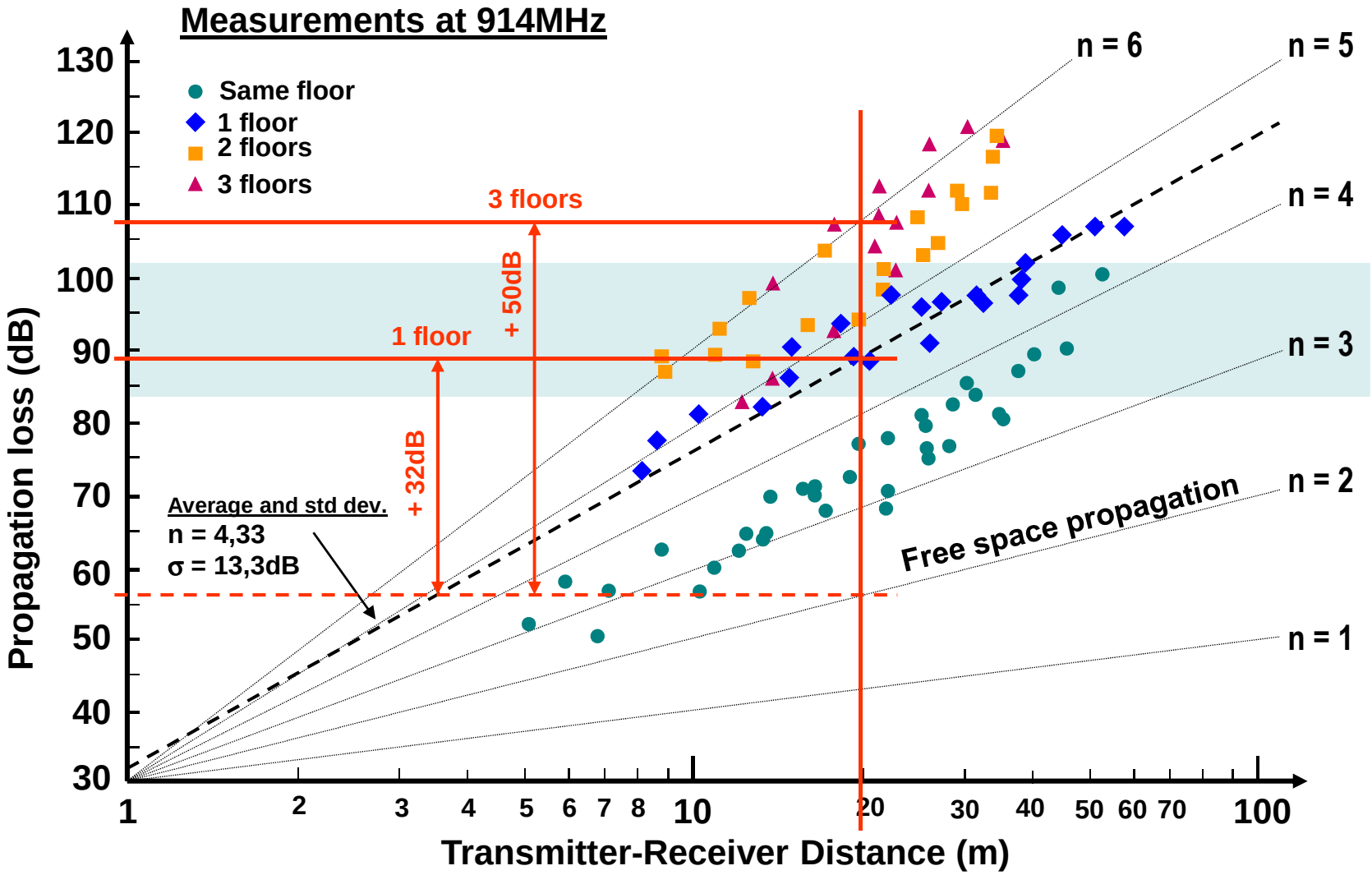
Multipath
- Ricean channel
- Rayleigh channel

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

- The steel structure of the buildings and the wire mesh in reinforced concrete is harmful for long waves propagation, short waves are less affected by this problem but suffer more free space loss.

- The propagation in the lower part of UHF band (300 to 800Mhz) is a good compromise for FRs' environments (indoor and dense urban).

- Selection of TVWS frequencies as candidate for this indoor/outdoor propagation channel

RF band	Frequency	Channel	GRENOBLE	GRENOBLE	AUXERRE
			Tour sans venin	Chamrousse	Molesme
V	602	37	DVB-T - R1	DVB-T - R1	TF1
V	610	38			
V	618	39			
V	626	40			
V	634	41			
V	642	42			
V	650	43			
V	658	44			
V	666	45			
V	674	46			
V	682	47			
V	690	48			
V	698	49			M6
V	706	50		France 2	

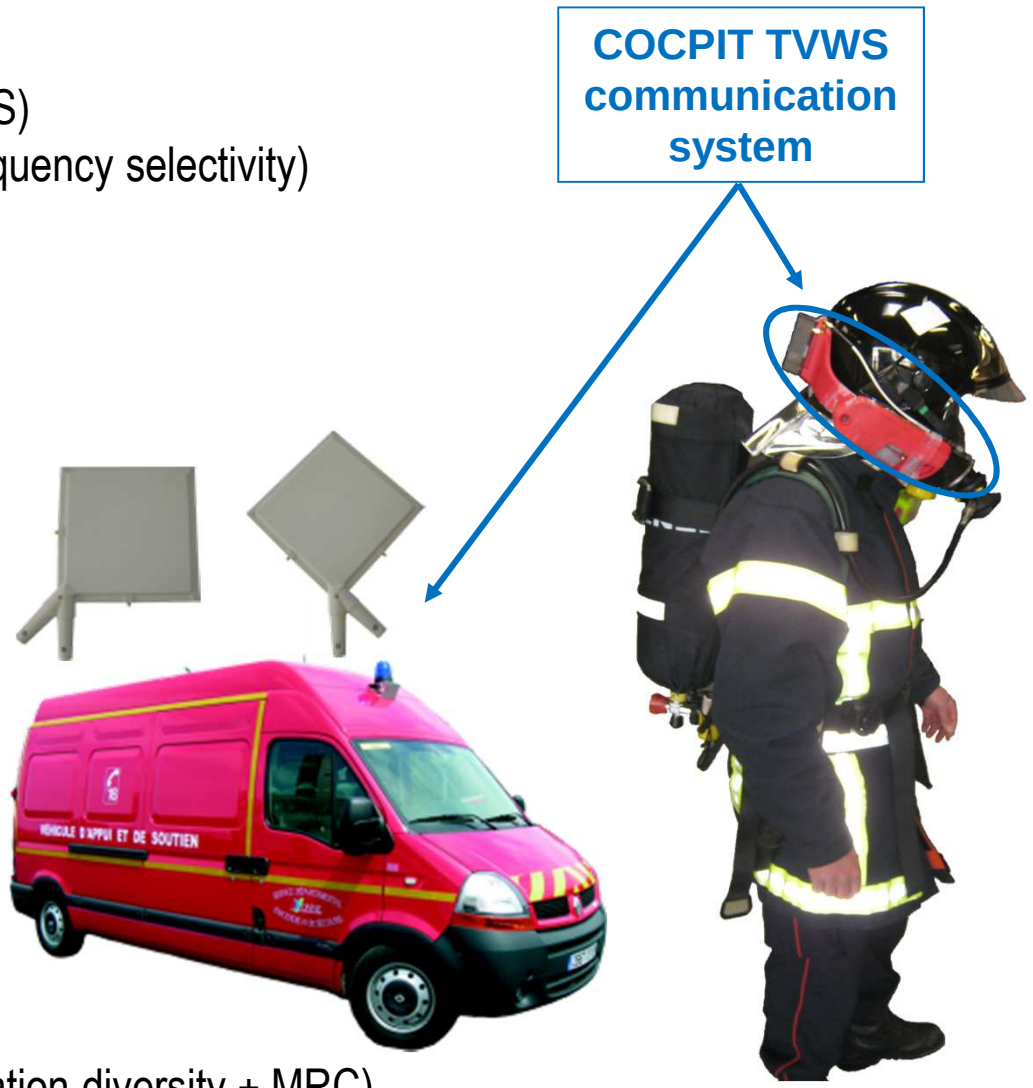
Opportunistic use of TVWS

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

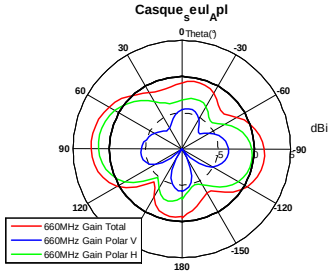
System specification

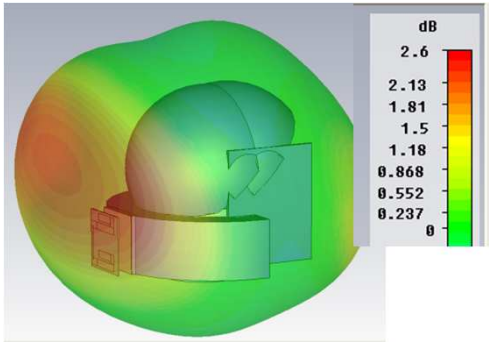
- Antenna
  - fo = 650MHz (BW: 35MHz)
  - Gain: 1.5dB (Omni)
- RF Tx
  - Frequency agile: 610-690MHz
  - BW: 12MHz
  - Electrical power = 28dBm
- Baseband
  - COFDM 1024 sub-carriers
  - Effective data rate: 8Mbps
  - 1 ➔ 4 SIMO (spacial and polarization diversity + MRC)

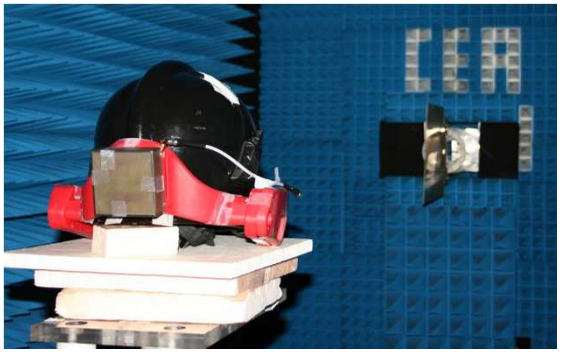


Transmission from First Responders to crisis HQ

- Public safety testbed at CEA Grenoble
  - Real-time bi-spectral video
  - Audio
  - Sensors







Indoor to outdoor using TVWS technology

- 1x4 SIMO architecture improves SNR and coverage

100m

First Responders

Mobile Command Center

Outdoor hop using COTS WiMAX technology

> 1000m

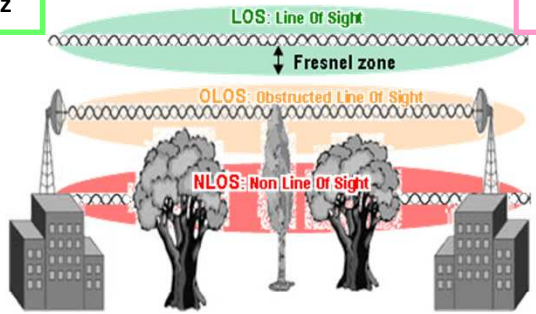
- Full coverage of CEA-G site
- Data rate varies from 2 to 11Mbps

Crisis HeadQuarter

WiMAX vs. Wi-Fi evaluation at CEA-G

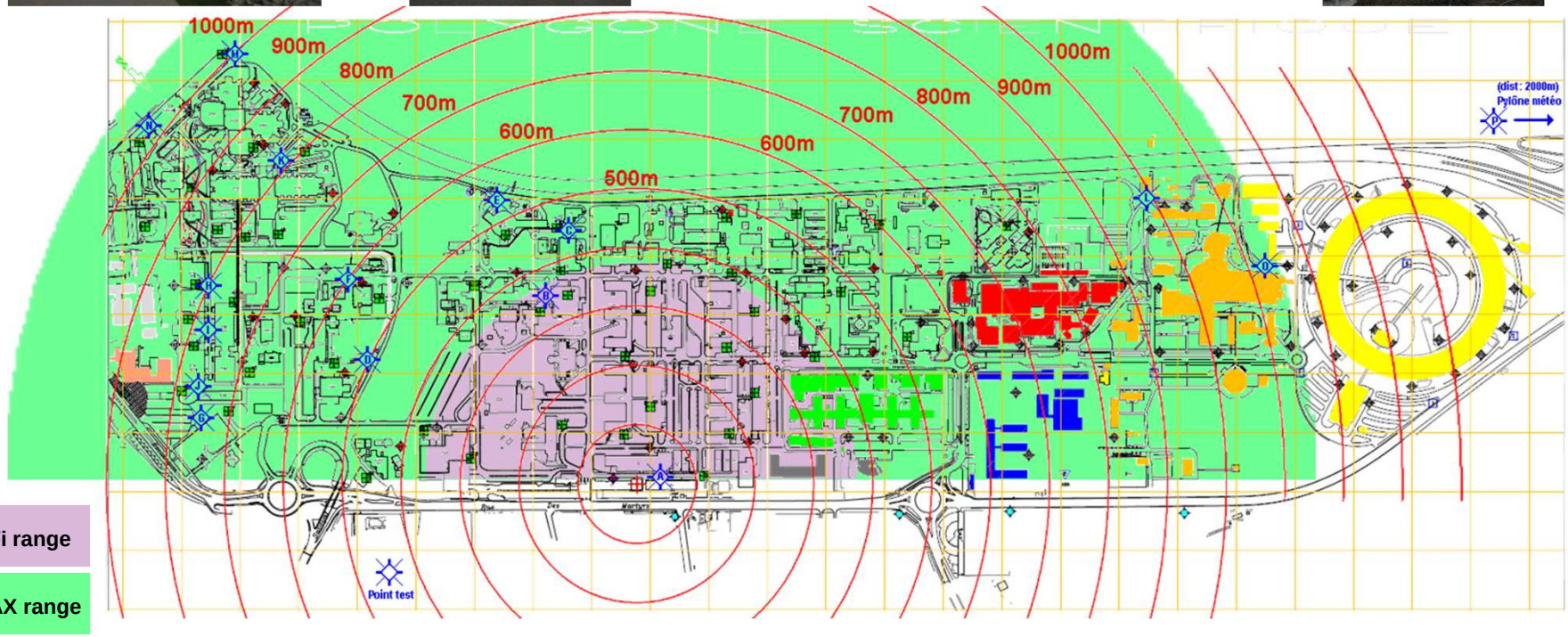
Wi-Fi 802.11h
- Antenna: 20dBi
- Power: 14dBm
- Freq: 5700MHz

WiMAX 802.16e
- Antenna: 16dBi
- Power: 14dBm
- Freq: 5520MHz



Wi-Fi 802.11h
- Antenna: 16dBi
- Power: 14dBm
- Freq: 5700MHz

WiMAX 802.16e
- Antenna: 16dBi
- Power: 14dBm
- Freq: 5520MHz



Wi-Fi range

WiMAX range

Conclusion

- **Public safety communication systems have limited functionality (not broadband)**
- **Video communication with current system is not possible**
- **FR operate in harsh environments and face complex channel conditions**
- **TX power must be limited (wearable equipment's) + other constraints**
- **UHF bands offer a good opportunity for this use case**
- **CEA has developed a two hop wireless system for FR ➔ HQ com.**
- **TVWS is a major enabler for such applications**
- **Technology was specified to cope with harsh channel conditions**
- **Field trial results to come soon…**

Acknowledgement

The COCPIT project received the support from the **French National Research Agency**

Agence Nationale de la Recherche

Leti

LABORATOIRE D'ÉLECTRONIQUE
ET DE TECHNOLOGIES
DE L'INFORMATION

CEA-Leti
MINATEC Campus, 17 rue des Martyrs
38054 GRENOBLE Cedex 9
Tel. +33 4 38 78 36 25

www.leti.fr

Thanks for attention

LLOYD'S REGISTER QUALITY ASSURANCE ISO9001

cea

MINATEC

INSTITUT CARNOT CEA LETI