28 Septembre 2022

Séminaire COP – Communications Ferroviaires

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Chercheure COSYS/ LEOST
Campus de Lille

Nouvelles antennes embarquées intégrées à la structure du matériel roulant : des spécifications aux prototypes

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COSYS/LEOST

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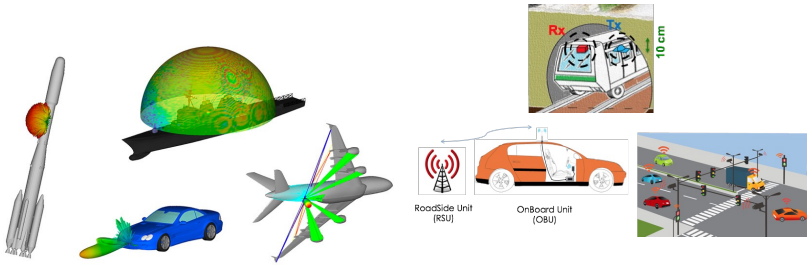
Antennes dans systems de transports

Villes intélligentes, véhicules autonomes, ...



2

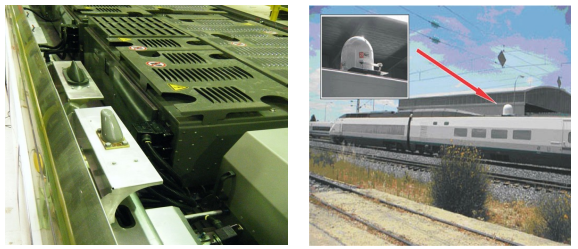
Défi :
La diversité des scenarios : infrastructures, environnements et véhicules...

... à prendre en compte lors d'un seul dépioiement.

Ces défis sont identiques pour le déploiement de l'IoT au sein d'infrastructures intélligentes.

3

Vue de près de l'intégration d'une antenne ferroviaire à bord



Thornton, J., White, A., & Long, G. (2009). Multi-beam scanning lens antenna for satellite communications to trains. Microwave Journal, 52(8), 56-70.

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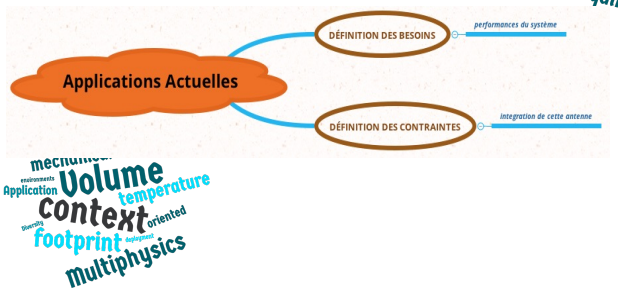
Les antennes dans les applications de télécommunications actuelles…



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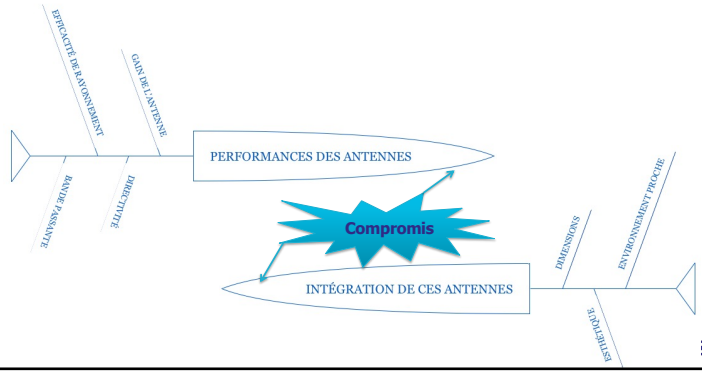
Compromis à trouver entre les performances et le contexte d'intégration des antennes



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Antennes pour des différentes générations de systèmes de communications…

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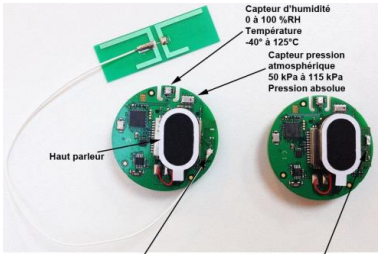
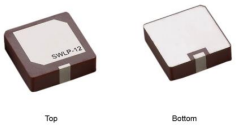
Choix d'antennes à intégrer : exemple d'un capteur communicant

Vers la miniaturisation…





Antenne on Ceramic Substrate

https://www.taoglas.com/product/swlp-2450-12-4-b-02-2-4ghz-smd-patch-antenna-12mm/

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Antennas for Railway Applications

Single Band Antennas (Antonics)

Multiport Antenna (Antonics)

Multiband Antennas (Huber & Suhner)

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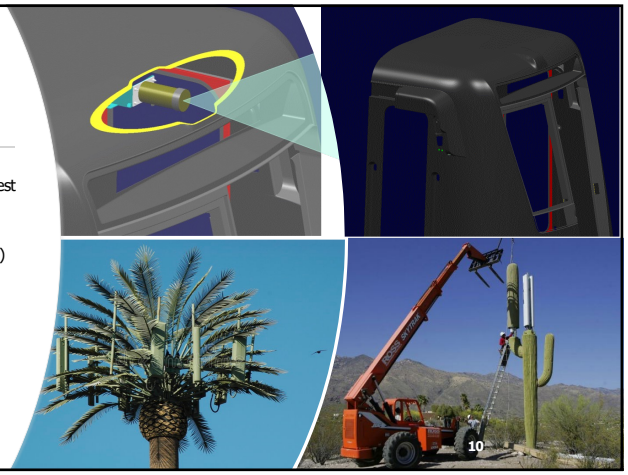
Considération esthétique

- Exemple du Métro Budapest
- Palmier station de base antenne (Mauritius Island)
- Cactus shaped station de base (USA)



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Intégration d'antennes en environnement ferroviaire

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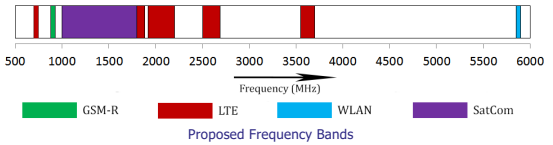
Antenna specifications for Next Generation Railway Communication Projects

Next Generation Train Control (NGTC) [2013-2016]

- Proposed a mutli-vector or multi-standard approach
- Use of multiple radio technologies for railway environment
- Discussion on SatCom as a bearer in railways

((NGTC))
Next Generation oF Train Control systems
www.ngtc.eu



Proposed Frequency Bands

Conclusion of the study: LTE should be the common bearer for both mainline/high speed and urban/metro railway scenarios

NGTC, WP6 D6.3 "Choice of Technologies to study", 2014.

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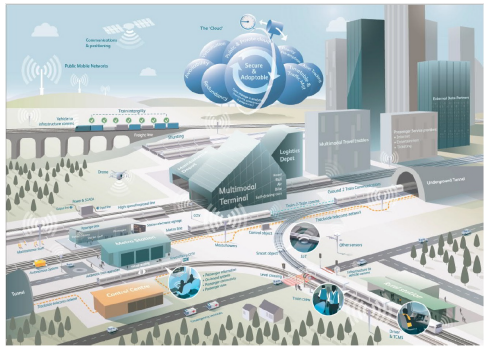
Antenna specifications for Next Generation Railway Communication Projects

Shift2Rail [Ongoing]

- R&D of innovative solutions for railways
- Adaptable Communication System (ACS) which supports multiple bearers simultaneously
- Identifying suitable bearers (standards) for mainline/highspeed, urban/metro and regional/freight.



Shift2Rail
www.shift2rail.org

X2Rail-1, Deliverable 3.1, "User & System Requirements (Telecommunications)", 2017.

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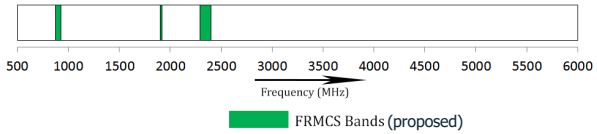
Antenna specifications for Next Generation Railway Communication Projects

Future Railway Mobile Communication System (FRMCS) [Ongoing]

- Successor of GSM-R
- Bearer flexibility
- Internetworking
- First edition to be ready by 2025

FRMCS
Future Railway Mobile Communication System
www.uicfrmcs.org



- 3GPP, 'Study on Future Railway Mobile Communication System (FRMCS)', Technical report 22.889, Release 17.2.0.
- https://www.uic.org/com/enews/article/5grail-the-frmcs-demonstrator-officially-launched?page=modal_enews

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From an antenna perspective…

- Support of multiple standard simultaneously
- Need for multi-port antenna with good port isolation.
- Dimensions (reasonable and might require specific miniaturisation techniques)

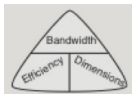
Isolation and cohabitation
– Several antennas (same frequency or different frequencies)
– FDD (beamforming and MIMO systems)

- Hardware implementation

– Avoid several complex RF devices/circuits (filters, power divider, diplexer)

- Requires trade-off in antenna parameters…

– Physical limitations of antennas…



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Ongoing research

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Illustration of ongoing research on antenna integration for complex platforms, for railways, ...

- Antenna integration through a modal approach: Cubesat and Aircrafts
- Multiple standard antenna for next generation railway communication systems
- Antennas for confined environments: tunnels, ...
- Antenna integration through miniaturisation while accounting for reduced performances
- Reducing antenna blocking during integration through cloaking

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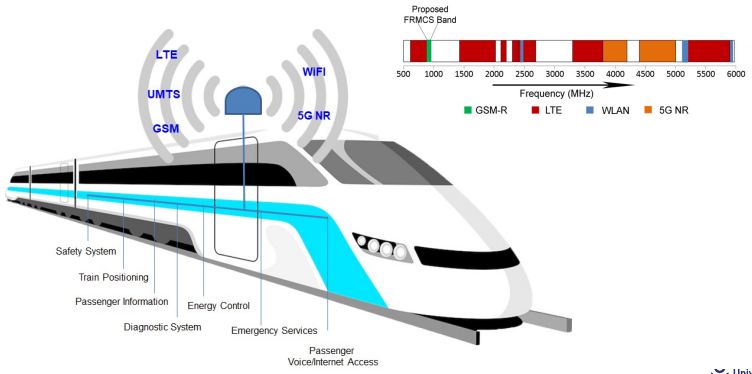
Multiple standards to be hosted simultaneously on single platforms...



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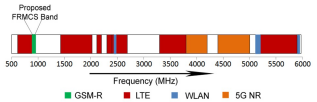
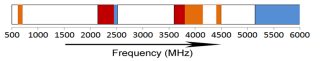
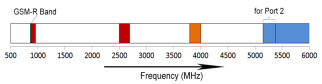
A new antenna concept based on modal analysis



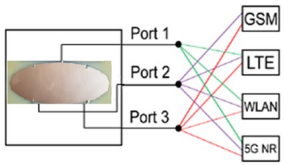
Frequency Spectrum



Port 1



Port 2 and 3



Standard	Isolation (Between Port 1 and 2)	Isolation (Between Port 1 and 3)
4G LTE	2500 MHz – 2690 MHz: < -19 dB	2500 MHz – 2690 MHz: < -20 dB
WLAN	2.4 GHz: < -18.4 dB	5.30 GHz – 5.50 GHz: < -22.5 dB 5.85 GHz – 6 GHz: < -31 dB
5G NR	3.6 GHz – 4.5 GHz: < -25 dB	--

D. Seetharamdoo and N. Kumar, "Antenne multimode, multiport et multi standard pour système de communication adaptable," French Patent Application Number FR2006115, University Gustave Eiffel, filed on 11 June 2020.

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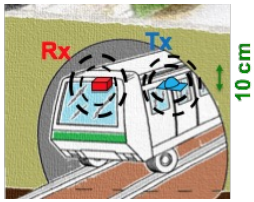
Antenna design and spefications for tunnel environments?

Focus on tunnel environment



Google images, French ANR project METAPHORT

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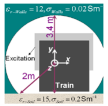
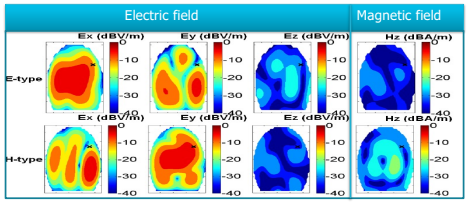
Modal propagation inside tunnels gives insight into antenna specifications



→ Exciting Ez

→ Exciting Hz

French ANR project METAPHORT



Observations:

Either the z-component of the E or H field predominates.

This depolarization phenomena was also observed loaded tunnels.

This modeling approach (accounting for modes) shows the depolarization of the waves.
Thus giving insight for antenna specifications...

Ph.D. Jorge Avella Castiblanco, University Gustave Eiffel (previously IFSTTAR), 2013.

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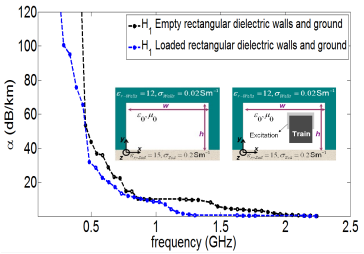
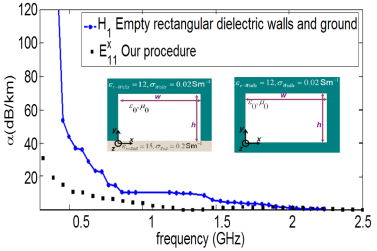
How scenarios and material parameters impact propagation in tunnels?

Rectangular tunnel **with** a metallic train and **without** a metallic train



Rectangular tunnel with **metallic** and **non-metallic** walls



The presence of conductors, in these case the trains, improves the wave propagation.
The conductivity of the soil and walls cannot be neglected.

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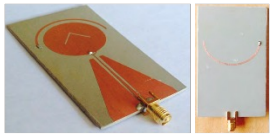
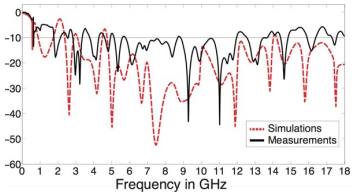
Antenna miniaturisation is an important parameter for antenna integration...

How to restore performances while miniaturising?



(a) Top (b) Bottom



Design	Peak Directivity		Peak Realized Gain		Radiation Efficiency
	Linear	dB scale	Linear	dB scale	
EWB Antenna alone	0.14	-8.53	0.021	-16.7	15 %
MTM Inspired EWB Antenna (+LOOP)	0.85	-0.7	0.482	-3.16	56.4 %

Systematic methodology for increasing the efficiency of electrically small antennas.

Ph. D.. of H. Rabah, University Gustave Eiffel, 2015.

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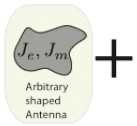
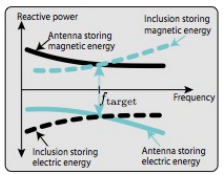
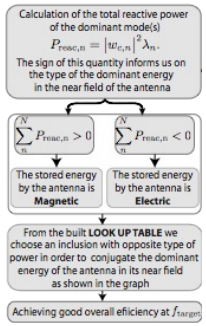
Systematic methodology for preserving the performances of electrically small antennas







D. Seetharamdoo, H. Rabah, et al., Method for improving the efficiency of an electrically small antenna, US Patent App. 16/311,474, 2019.

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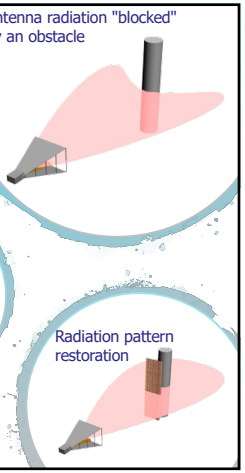
Antenna radiation patterns are affected by obstacles...

Could cloaking be a potential solution?

- **Cloaking** has been a hot research topic in several field of physics: seismic waves, electromagnetic waves, … using **metamaterials** (structured metal dielectric composites)
- How can this approach be considered for antenna integration, for instance, in Railway?
- From obstacle to antenna cloacking



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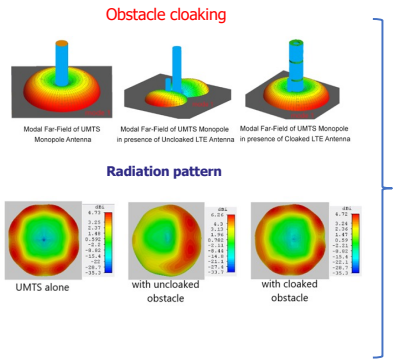
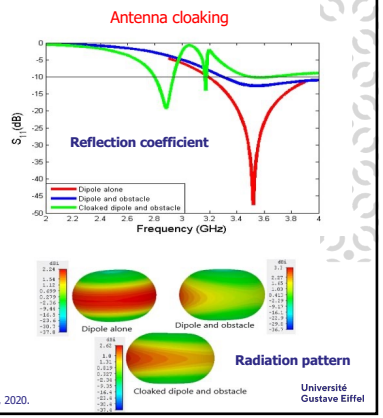
From obstacle cloaking to antenna cloaking





Ongoing research in the context of Ph.D. of Ozuem Chukwuka at University Gustave Eiffel, 2020.

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Conclusion

- Integration d'antennes sur les plateformes de transport
- Description de l'intégration d'antennes avec un focus sur l'environnement ferroviaire
- Illustrations de résultats de recherches en courssur l'integration d'antennes...

… de la recherche appliquée à des sujets exploratoires tel que le cloaking/ingénierie de l'invisibilité.

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