

Wireless with Strong Industrial Noise: Solving the Power Substation Case



Le génie pour l'industrie

IEEE WISEE Conference

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Content

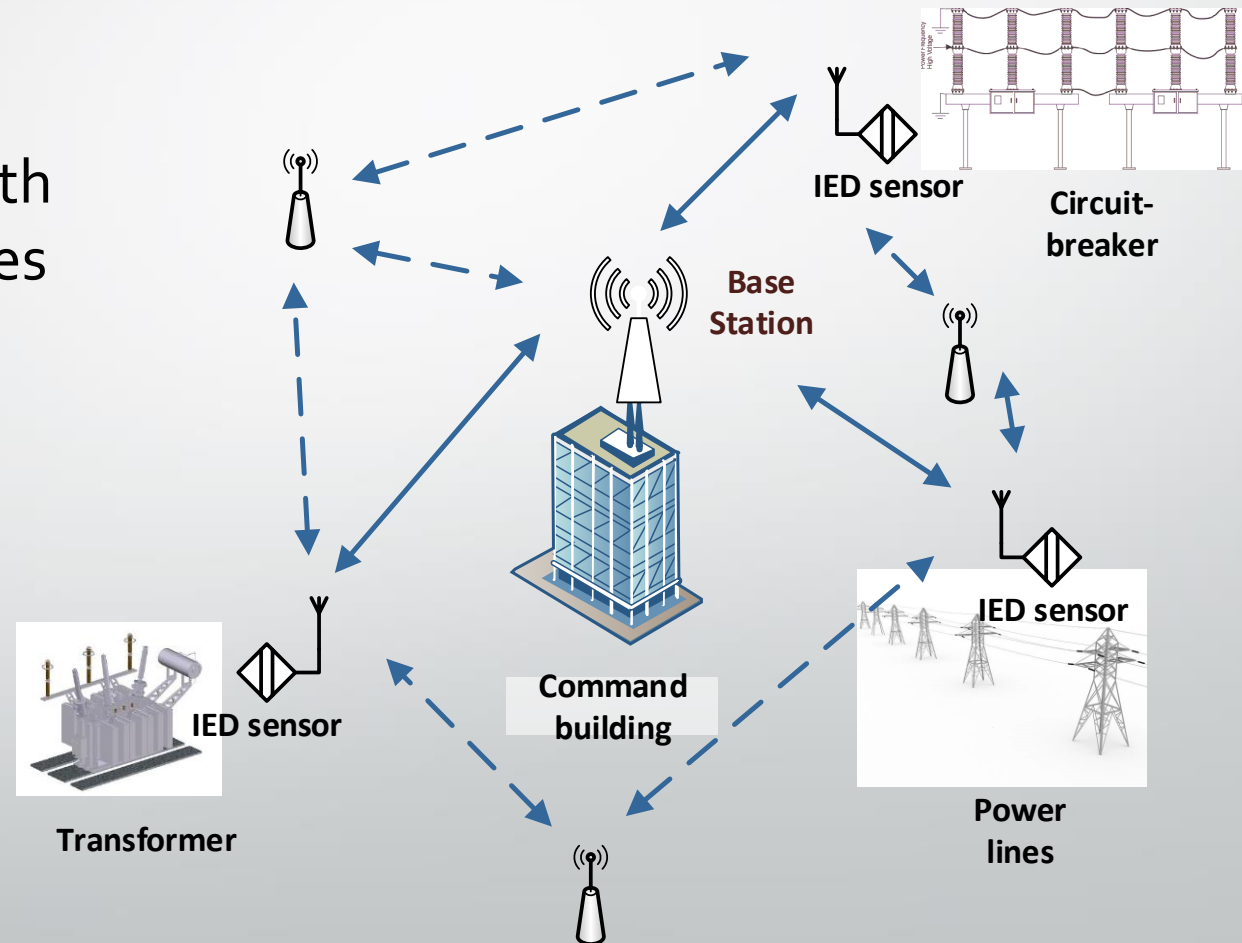
- Smart grid context
- Industrial challenge: Power substations
- Academic and industrial collaboration
- Projects
- Contributions
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Smart Grid Context

- Evolution of electrical networks toward digitalization of electrical operations
- Automation operations: Monitoring, protection, control, and maintenance
- Wireless communications : A great asset
 - Easy installation and network configuration
 - Low cost compared to other communication media
 - Constantly improving (5G, IoT,...)
 - **Number of base stations is such that it is also becoming more resilient than optical communications!**

Smart Grid Context

- Wireless sensor network with Intelligent Electronic Devices (IED)
- Two possible configuration scenarios:
 - mesh network
 - point-to-multipoint



Industrial challenge: power substations

- Critical operations : Low latency, secure protocols, reliable throughput
- Power substations: A hostile RF environment
 - High-voltage: up to 735 kV
 - Power equipment: transformers, circuit-breakers, switch gears, filters, converters...
 - Partial discharges, Corona effect, electric arcs
 - RF Impulsive noise on ISM band : -30 dBm to -60 dBm
- Interference sources are localised: Spatially-sensitive techniques (e.g. MIMO) simplify the problem and provide smarter solutions.

Academic and Industrial collaboration

- Academia
 - École de technologie supérieure (ÉTS), Montréal
 - Prof. François Gagnon
 - McGill University, Montréal
 - Prof. Fabrice Labeau (Research chair 3I with Hydro-Québec)
- Industry
 - Institut de Recherche d'Hydro-Québec (IREQ), Varennes
 - Dr. Basile L. Agba
 - Hydro-Québec Transport (TransÉnergie), Montréal
 - Media5, Sherbrooke
 - Axsera, Montréal



Academic and Industrial collaboration

Hydro-Québec contribution

- Collaboration with HQ people: researchers, engineers, and technicians
- In a very diverse and industrial environment:
 - High-voltage laboratory at IREQ
 - Power substations all across Québec (transport and distribution)
 - Offices for professors, students and postdocs at IREQ and TransÉnergie
- Communication and information – HQ provides:
 - Technical documents
 - Equipment (telecommunication and power)
 - Symposium 3I, conferences (CIGRE, IEEE)



Academic and Industrial collaboration

IT ALL STARTED WITH...

Richard J. Marceau research chair on Wireless IP Technology for developing Countries

"60% of world population doesn't have internet access"

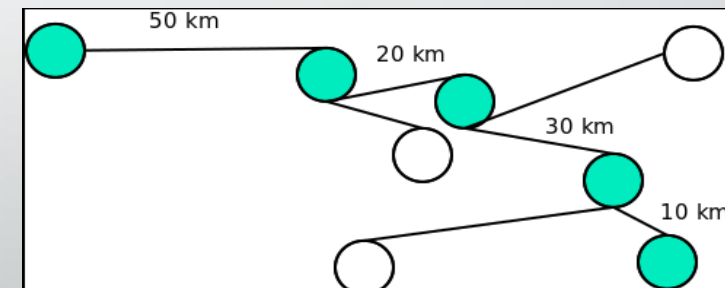
LONGSTANDING UNSOLVED CHALLENGES

- Large number of analog telephony subscribers
- Existing remote stations and broadcast licenses
- Migration to IP wireless systems associated with:
 - Unacceptable latency (IP routing)
 - Security issues (internet access)

THE CHAIR'S GOALS

- Upgrade legacy telecommunications equipment in developing countries at a reasonable cost
- Migrate synchronous digital wireless systems to IP

LATENCY IN IP NETWORKS



- Propagation time: 367 μ s (110 km at c m/s)
- Routing time: 40 ms (4 hops at 10 ms/hop)

Academic and Industrial collaboration

BUT... This research will tackle issues that matter to all users of modern wireless systems

CURRENT STATE OF THE ART

- Early detection of OFDM symbols
- High-performance short codes for ECC
- M2M channel reservation for 5G
- High-capacity HetNets
- Flexible software defined networking

OUTSIDE SUPPORT



Researchers and living laboratory



State of the art VoIP platforms



Wireless expertise

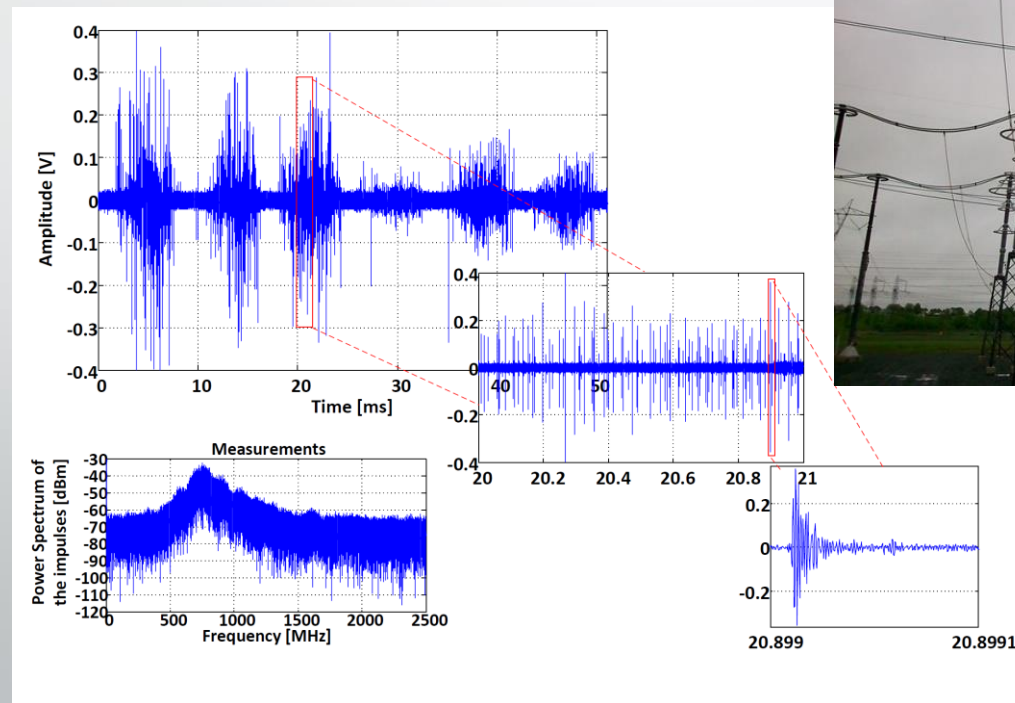
NSERC PROMPT COLLABORATIVE R&D GRANTS (3.5 M\$ on 5 years)

- Increase the Chair's reach and impact
- Form a mutually beneficial relationship with our partners
- Train highly-qualified personnel
- Make technological transfer to industry a core objective

Projects

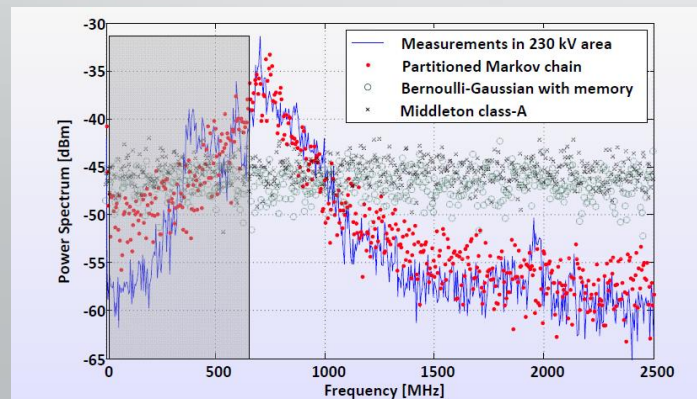
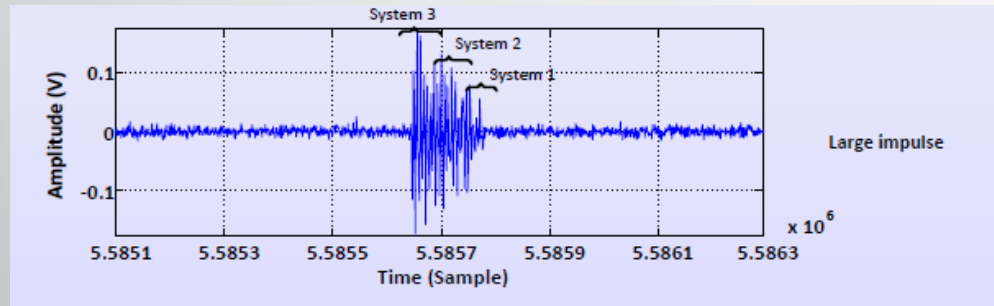
- **Project 1** (Bineta Sarr, PhD student 2016-present)
Communication protocols for sensor networks in hostile environments
- **Project 2** (Azzouz Zayen Master student 2016-2017)
Wireless transmission with low latency for machine-to-machine communications
- **Project 3** (Minh Au, PhD student, Postdoc 2011-2016)
Analysis and modelling of radio frequency interferences induced by electric arc discharges in high voltage substations
- **Project 4** (Fabien Sacuto, PhD student, Postdoc, and research professional 2010-2015)
Modeling of the impulsive noise in the power substation environment and its application to receiver design
- **Project 5** (Fabien Sacuto, Master student 2008-2010)
Characterization of high-voltage environments for wireless sensor network

Contributions: Measurements

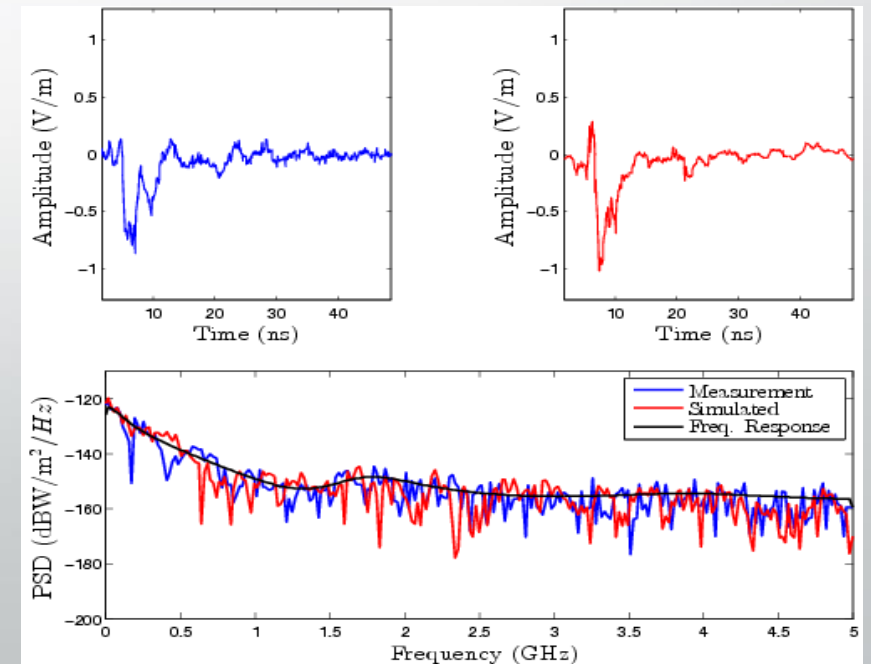


Contributions: Modeling

Statistical modeling

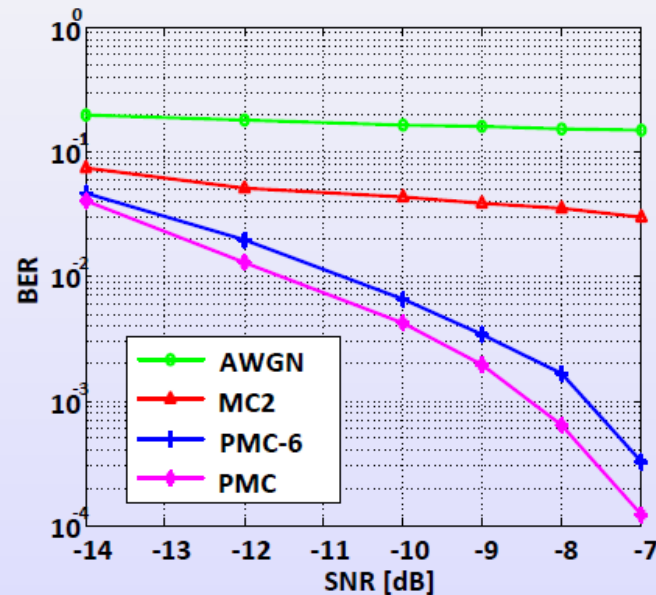
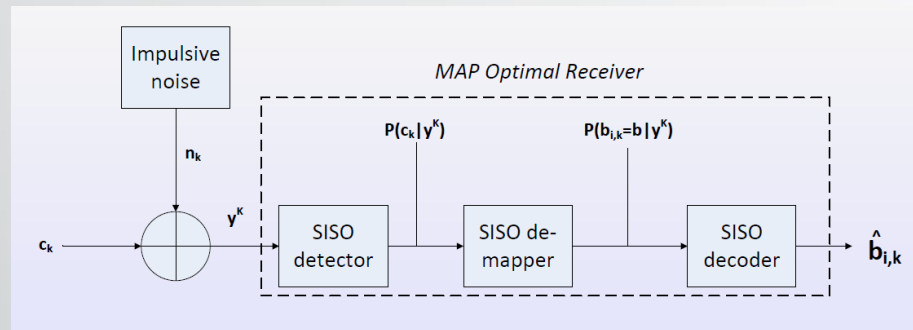


Physical modeling

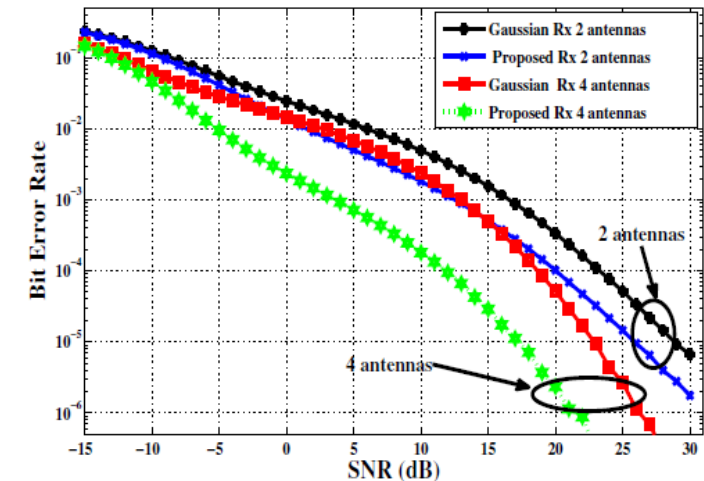
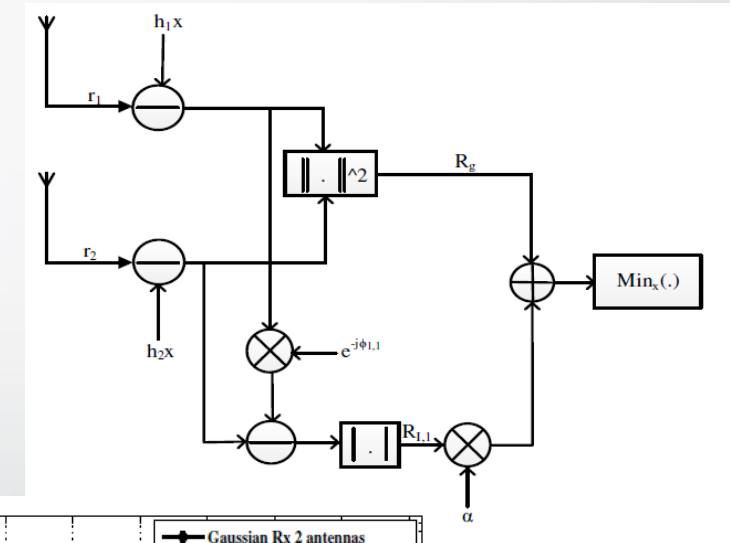


Contributions: Robust receiver and MIMO solutions

Robust receiver

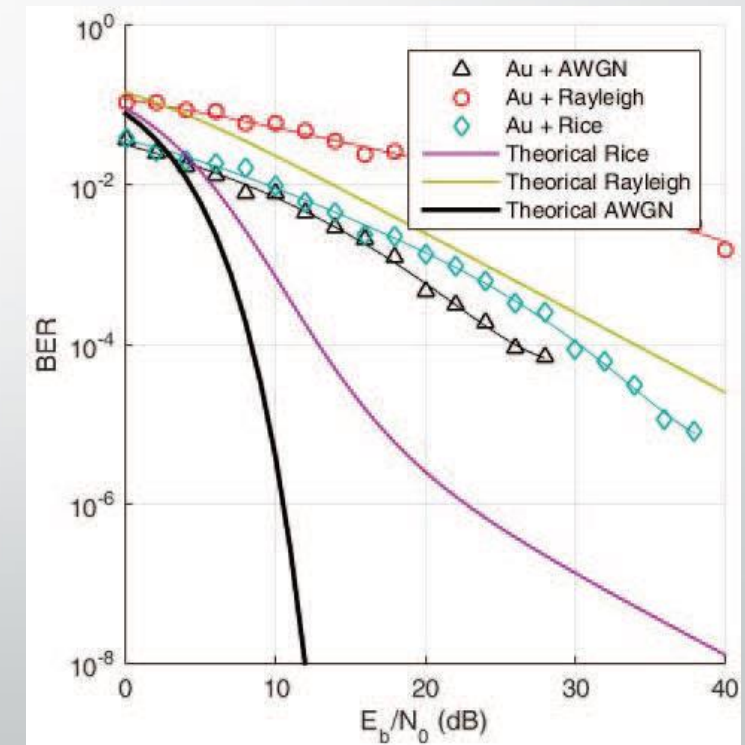
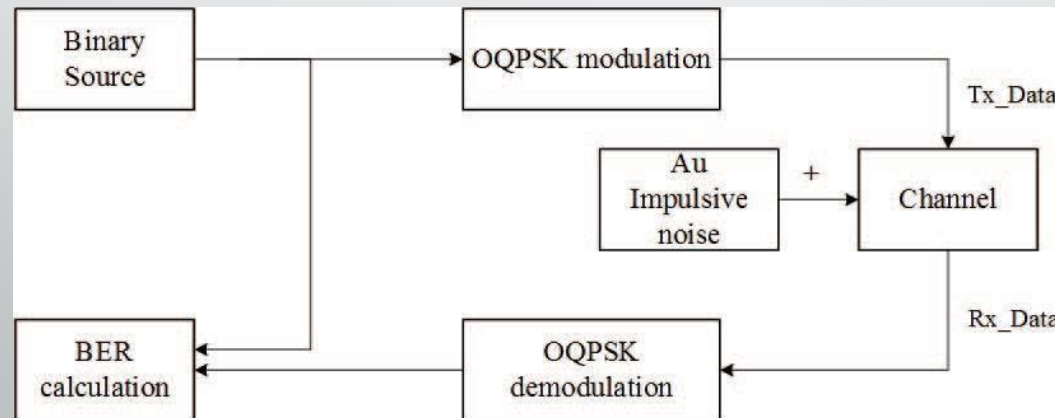


MIMO



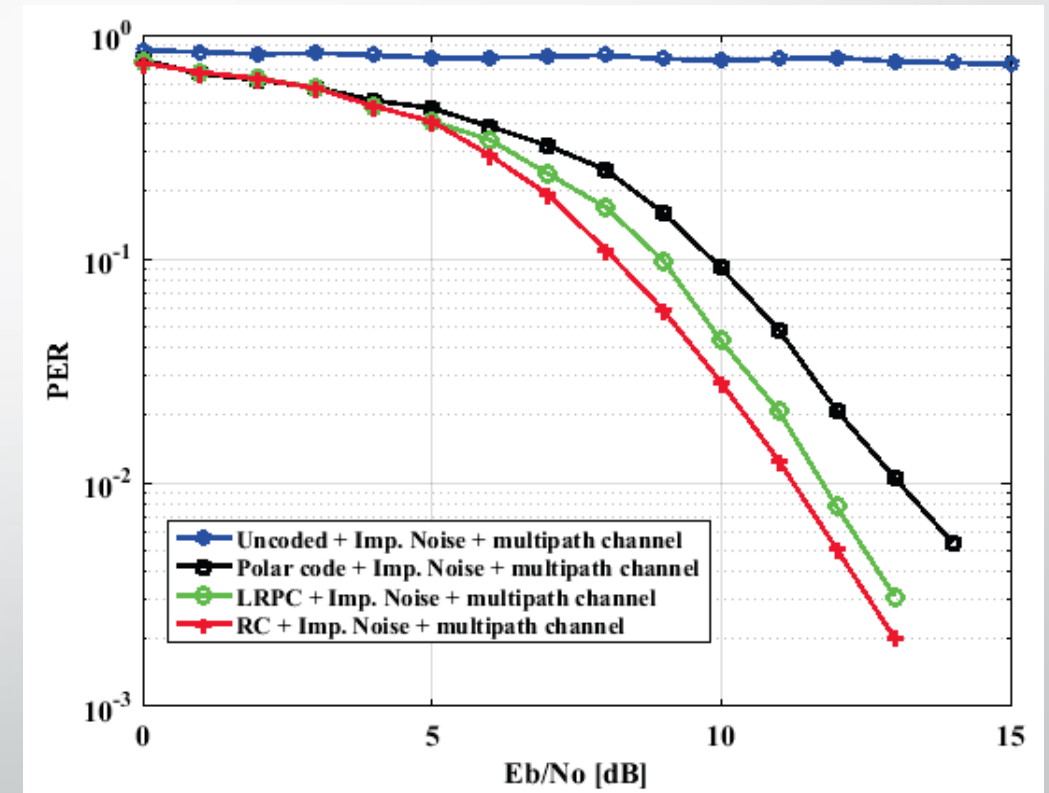
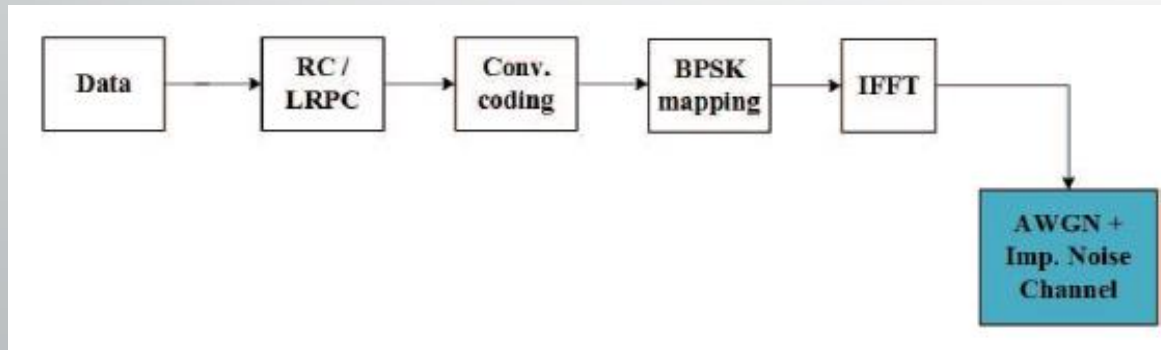
Contributions : communication protocols on the physical layer

- State of the art of communication protocols: sensor networks and impulsive noise models
- Physical layer protocols (ZigBee, WirelessHart, ISA100) impaired by substation impulsive noise



Contributions: Coding schemes

- Polar codes
- Low Rank Parity Check (LRPC)
- Rank metric Code (RC)



Contributions

Publications

Journals

- M. Au, B. L. Agba and F. Gagnon "A Model of Electromagnetic Interferences Induced by Corona Discharges for Wireless Channels in Substation Environments", in *IEEE Transactions on Electromagnetic Compatibility*, Vol. 57, no3, pp 522-531, 2015
- F. Sacuto, F. Labeau, and B.L. Agba, "Wide Band Time-Correlated Model for Wireless Communications under Impulsive Noise within Power Substation", in *IEEE Transactions on Wireless Communications*, vol.13, no.3, pp.1449-1461, March 2014
- G. Madi, F. Sacuto, B. Vrigneau, B. L. Agba, Y. Pousset, R. Vauzelle, and F. Gagnon, "Impacts of impulsive noise from partial discharges on wireless systems performance: application to MIMO precoders", in *EURASIP Journal on Wireless Communications and Networking*, 2011

Conferences

- N. B. Sarr, A. K. Yazbek, H. Boeglen, J. P. Cances, R. Vauzelle and F. Gagnon, "An impulsive noise resistant physical layer for smart grid communications", in *IEEE International Conference on Communications (ICC)*, Paris, pp. 1-7, 2017
- N. B. Sarr, H. Boeglen, B. L. Agba, F. Gagnon and R. Vauzelle, "Partial discharge impulsive noise in 735 kV electricity substations and its impacts on 2.4 GHz ZigBee communications," in *International Conference on Selected Topics in Mobile & Wireless Networking (MoWNeT)*, Cairo, pp. 1-7, 2016

Contributions

Conferences

- F. Sacuto, F. Labeau and B. L. Agba, "RF characterization of substations: Parameters for impulsive noise models based on the equipment voltage," in *IEEE Electrical Power and Energy Conference (EPEC)*, Ottawa, ON, pp. 1-6 2016
- F. Sacuto, G. Ndo, F. Labeau and B. L. Agba, "MAP optimum receiver mitigating correlated impulsive noise," in *IEEE Wireless Communications and Networking Conference (WCNC)*, Doha, pp. 1-6, 2016
- M. Au, B. L. Agba and F. Gagnon "A Fast Identification of Partial Discharge Sources Using Blind Source Separation and Kurtosi", in *Electronic Letters*, Vol. 51, Issue25, pp 2132-2134, 2015
- I Ben Sik Ali, M. Au, B. L. Agba and F. Gagnon "Mitigation of Impulsive Interference in Power Substation with Multi-Antenna Systems", in *IEEE International Conference on Ubiquitous Wireless Broadband*, 2015
- M. Au, B. L. Agba and F. Gagnon "An Experimental Characterization of Substation Impulsive Noise for an RF Channel Model", in *Progress in Electromagnetics Research Symposium (PIER)*, 2013
- F. Sacuto, F. Labeau, and B.L. Agba, "Fuzzy C-means algorithm for parameter estimation of partitioned Markov chain impulsive noise model", *IEEE International Conference on Smart Grid Communications (SmartGridComm)*, pp.348,353, 21-24 October 2013F. Sacuto, F. Labeau, J. Béland, M. Kassouf, S. Morin, S. Poirier, and B. Agba, "Impulsive Noise Measurement in Power Substations for Channel Modeling in ISM Band", *CIGRE Canada Conference*, September 2012
- F. Sacuto, B.L. Agba, F. Gagnon, and F. Labeau, "Evolution of the RF characteristics of the impulsive noise in high voltage environment", *IEEE Third International Conference on Smart Grid Communications (SmartGridComm)*, pp.686-691, 5-8 November 2012

Conclusions

- We have reliable physical solutions for wireless communications within power substations:
 - Statistical and physical models of power substation environments
 - Designs of robust receivers
 - Coding schemes to mitigate impulsive noise
- The spatially-sensitive solutions (MIMO) is the key for an optimal and reliable solution

Conclusions

- The future of wireless communications within power substations:
 - We can ensure low latency communications for critical operations in high-voltage environments (e.g. substation automation)
 - Next step: implementation of our solutions and application to hostile industrial environments
 - Possibility to enhance wireless systems to even more harsh and hostile environments



Questions