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Power Line Communications:

A Technology with Application from Smart Grids to In-vehicle Scenarios

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IEEE Vehicular Technology Society (VTS)

HISTORY

The Institute of Radio Engineers (IRE) Professional Group on Vehicular Communications (PGVC) was formed in 1949, marking what we consider the birth year of the IEEE Vehicular Society. In 1963 the IRE merged with the American Insitute of Electrical Engineers (AIEE) to form the Institute of Electrical and Electronics Engineers (IEEE). At the time of the merger the AIEE had a Land Transportation Committee (LTC) substantially devoted to the rail industry. After a few years, the LTC joined with the vehicular communications engineers and vehicular electronics engineers in a new society called the Vehicular Technology Society (VTS) devoted to all aspects of electrical and electronics engineering in all forms of transportation and vehicular communications.

Organizational Focus

The IEEE Vehicular Technology Society focuses on the theoretical, experimental and operational aspects of electrical and electronics engineering in mobile radio, motor vehicles and land transportation. Mobile radio shall include all forms of wireless and wired vehicular communications. Motor vehicles shall include the components and systems and motive power for propulsion and auxiliary functions. Land transportation shall include the components and systems used in both automated and non-automated facets of ground transport technology.

Fields of Interest

The Society concerns itself with land, airborne and maritime mobile services; wireless mobile and portable communications, inter- and intra-vehicle communications; vehicular electrotechnology, equipment and systems of the automotive industry; traction power, signals, communications and control systems for mass transit and railroads.

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LEARN ABOUT THESE TECHNICAL FIELDS OF INTEREST

Mobile & Portable Communications

Mobile & Portable Communications includes all aspects of personal, mobile and vehicular communications using radio propagation media. Included in this field are Internet wireless, dual-mode fixed wireless, cellular telephony, two-way radio, and radiodispatch. Mobile & Portable Communications in today's 2G technologies, 3GPP Long Term Evolution (LTE), 3GPP2, ITU, WiMAX Forum, WiGig, IEEE 802.15.3.c and 4G are

Land Transportation

This field of interest includes electro-technology for such applications as land and marine transportation. Included in this field are mass transit systems, guideway and magnetic levitation systems, high-speed rail, dual-mode and inter-modal transportation and technologies related to vehicle power and propulsion.

Applications include system control, electric power conversion and control, electric propulsion, intelligent highway control and related communication and control systems.

Vehicle Propulsion and Power

Including [illegible], pollution control and vehicle safety. Vehicle Electronics and Power Technology also includes vehicle power and propulsion, hybrid vehicles, power conversion and control, fuel cell power source applications, vehicle guidance control systems and telematics applications involving both information and communications.

Also included are vehicle tracking and mapping for monitoring and fleet management. In-vehicle road side services, entertainment, security and control are all parts of Vehicle Electronics and Power Technology.

Membership

Benefits of [illegible] membership in the Society and the IEEE include the opportunity to advance your professional career by encouraging association with colleagues; learning the most recent developments in technology; of seeing your technical achievements published; of earning recognition from your peers for your professional accomplishments; and of making other worthwhile contributions to the objectives of the Society and the IEEE.

Benefits Include:

- Network with other society members
- Participate in local chapter meetings and events
- Attend presentations by our Distinguished Lecturers
- Receive the society's monthly newsletter

CONFERENCES

The IEEE VTS sponsors various conferences throughout the year, the highlight of which is the IEEE Vehicular Technology Conference (VTC). Noted for the quality of technical papers and speakers represented, the VTC is innovative in breaking of new engineering developments. While covering all areas of the Society's activities, the conference focuses on mobile radio technologies in its various forms.

The IEEE Vehicle Power and Propulsion Conference (VPPC) is co-sponsored with the IEEE Power Electronics Society (PELS). The conference covers the technology of vehicle power and propulsion, in particular new developments such as hybrid traction. With an end goal of developing and promoting "clean technology", many advances originally presented at VPPC are currently implemented in transportation systems worldwide.

The Joint Rail Conference (JRC) is co-sponsored with the ASME Rail Transportation Division, ACSE T&DI Rail Transportation Committee, American Railway Engineering & Maintenance of Way Association – High Speed Rail Committee and the Transportation Research Board – Rail Group. JRC provides a forum for passenger and freight rail transportation, covering management, planning in addition to engineering topics.

Publications

The IEEE Vehicular Technology Magazine, a membership benefit of the IEEE Vehicular Technology Society whose subscription is included in the Society fee, is published quarterly. The magazine contains additional information of interest to members. The annual subscription fee is $22 to VTS non-members.

The IEEE Transactions on Vehicular Technology is dedicated to vehicular technology and mobile communications. This scholarly journal consists of high-quality technical manuscripts on advances in the state-of-the-art of vehicular technology in the areas of: land, airborne and maritime mobile services; portable commercial and citizen's communications services; vehicular electrotechnology, equipment and systems of the automotive industry; traction power, signals, communications and control systems for mass transit and railroads. The Transactions has nine issues per year, with special sections, averaging over 400 pages per issue. According to data from the Journal Citation Reports, the TVT ranks among the top journals in the field of electrical and electronics engineering.

Wireless and Power Line Communication Lab

Andrea M. Tonello
Aggregate professor at Univ. of Udine
Vice-chair IEEE TC-PLC
Steering committee member IEEE ISPLC

- University of Udine: 17.000 students (*in the top-ten in 2011*)
- 15 Members – part of the Department of Electrical, Mechanical and Management Eng. (150+ members)
- Activities: Wireless and Power Line Communications
  - Communication theory and signal processing
  - Measurements and emulation
  - RF and base band prototyping
  - *Home networking, smart grid, infomobility and vehicular technology*
- Projects: several national and EU FP5-FP7 projects

Outline

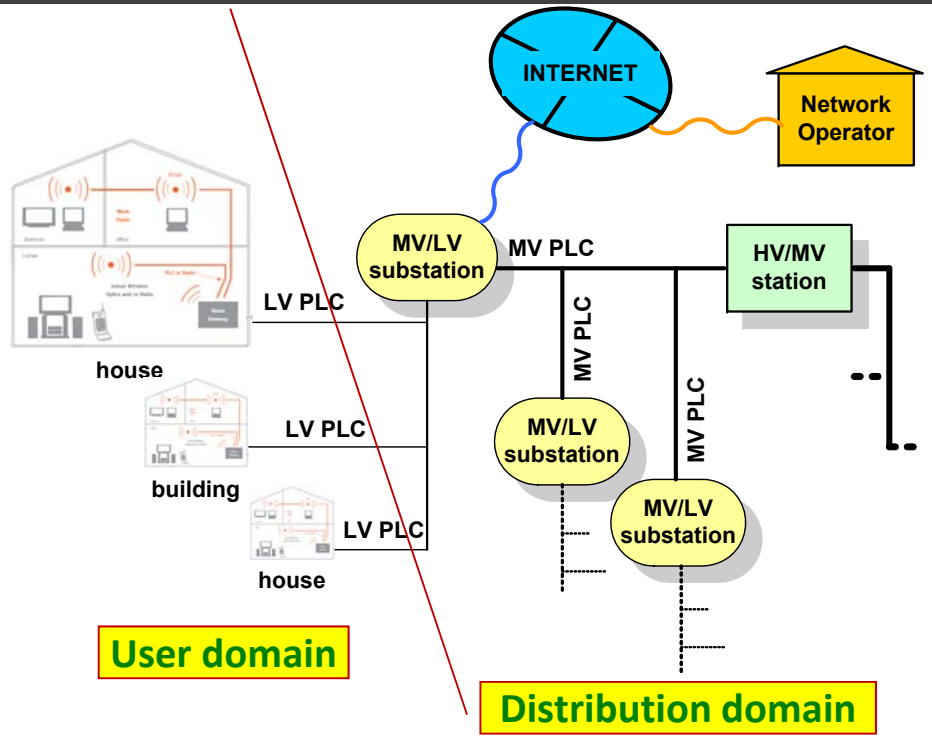
- Applications of PLC
- A look at the standards
- Key issues for the successful development of PLC systems:
  - Channel and noise characterization
  - Physical layer techniques: existing solutions and what next
- Final remarks

Application Scenarios

- Power lines are pervasively deployed
- Application of power line communications can be ubiquitous

  - Broad band internet access
  - In-Home networking
  - Smart grid applications
  - In-Vehicle application

PLC in the Distribution Grid



- PLC provides an easy to install two way communication infrastructure
- The user domain is very important for the penetration of SG services

Distribution Domain

- **Monitoring and control**
  - Fault detection, monitoring of power quality and islanding effects
- **Energy management**
  - Decentralized production and storage control
  - Charging of electrical vehicles
- **Smart meter reading**
  - Demand side management
  - Demand response
  - Dynamic pricing
  - Acquisition of user behavior

User Domain

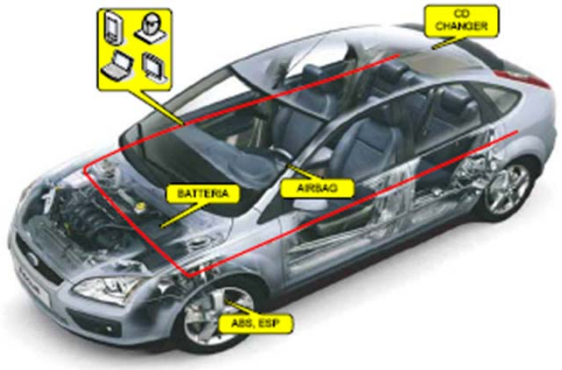
- **Internet access**
- **Smart home**
  - Home networking
  - Automation and control

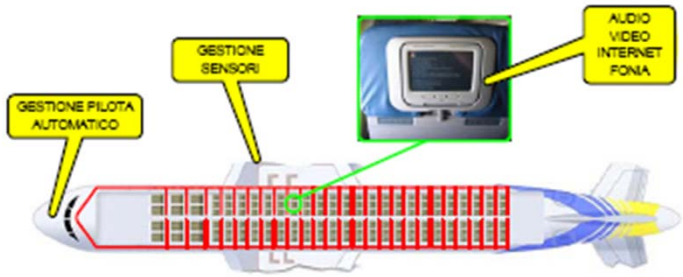
Broad Band and Narrow Band PLC

- All these services and applications have different requirements:
  - *Data rate, latency, robustness, energy efficiency*
- Both Narrow Band and Broad band PLC have a role
  - NB-PLC: **3-148.5 kHz** (Cenelec band) and **3-500 kHz** (FCC/ARIB band)
  - BB-PLC: **2-30 MHz** and beyond
- It is believed that NB PLC is the right choice for SG applications.

  This is because:
  - Low data rates are required
  - Longer distances are covered by NB PLC signals
  - Cheap modems have to be deployed
- BB PLC has been designed for internet access and home networking

In-Vehicle PLC





Wipli Lab team in a cruise ship measurement campaign

- In-vehicle communications via DC/AC power lines:
  - Alternative or redundant communication channel (e.g., to CAN bus)
  - Command and control of devices and sensors
  - Multimedia services distribution (music, video, games, etc.)
  - **Controlling the charging status of e-cars**
- Benefits
  - Weight reduction
  - Lower the costs

REF. A. B. Vallejo-Mora, J. J. Sánchez-Martínez, F. J. Cañete, J. A. Cortés, L. Díez, "**Characterization and Evaluation of In-Vehicle Power Line Channels**", *Proc. of the IEEE Global Telecommunications Conference (GLOBECOM) 2010*, Dec. 2010.

REF. M. Antoniali, A. M. Tonello, M. Lenardon, A. Qualizza, "**Measurements and Analysis of PLC Channels in a Cruise Ship**," in *Proc. Int. Symp. on Power Line Commun. and Its App. (ISPLC'11)*, Udine, Italy, April 3-6, 2011.

REF. M. Antoniali, A. M. Tonello, "**In-car PLC Advanced Transmission Techniques**," in *Proc. of the 5th Biennial Workshop on Digital Signal Processing for In-Vehicle Systems*, Kiel, Germany, September 2011.

Existing Systems and Standards

Narrow Band PLC Systems and Standards

	Insteon	Konnex	X10	CEBus	UPB Universal PLC bus	HomePlug C&C	Meters & More (Enel, Endesa)	G3-PLC	PRIME PowerLine Intelligent Metering	G.Hnem ITU-T 9955	IEEE P1901.2
	Home Automation					*Command and Control*	*Automatic Meter Reading*			*NB standard*	*NB standard*
Standard body	**Single carrier Low data rate: some kbits/s**							**Multicarrier data rate: hundred of kbits/s**			
Spectrum	CENELEC C	CENELEC B	CENELEC B	CENELEC FCC ARIB	CENELEC A	CENELEC A C FCC ARIB	CENELEC	CENELEC A FCC	CENELEC A	A, B,C,D FCC	A, B,C,D FCC
Modulation	BPSK	S-FSK	PPM	Spread Spectrum	PPM	DCSK *differential code shift keying*	BPSK	OFDM DQPSK DBPSK	OFDM D8PSK DQPSK DBPSK	OFDM QPSK 16-QAM	-
Bit-rate	2.4 kbps	1.2 kbps	50 or 60 bps	8.5 kbps	240 bps	0.6 to 7.5 kbps	Up to 4800 bps	34 to 240 kbps	128 kbps	up to 1 Mbps	-
MAC	ND	CSMA	CSMA/CD	CSMA/CD	-	CSMA/CA	-	CSMA/CA	CSMA/CA TDMA	CSMA/CA	-

Broadband PLC Systems and Standards

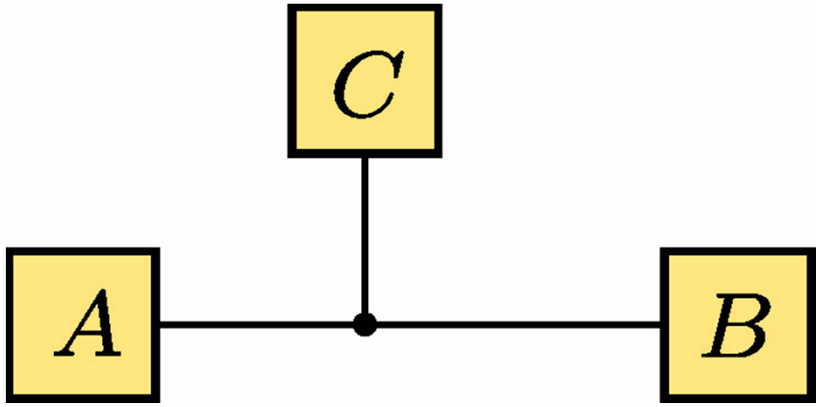
	HomePlug AV	HP Green PHY	HD-PLC	IEEE P1901	ITU-T G.hn ITU-T G.9960
Standard body	HomePlug Consortium	HomePlug Consortium	High Definition PLC Alliance	IEEE	ITU
Multicarrier data rate: Over 200 Mbits/s					
Modulation & Coding	OFDM (1536 tones) Bit-loading Up to 1024-QAM Convolutional, Turbo codes	OFDM (1536 tones) QPSK	Wavelet OFDM (512 tones) Bit-loading Up to 16-PAM RS, Convolutional, LDPC	OFDM (HP AV) (3072 tones) Bit-loading Up to 4096-QAM W-OFDM (HD-PLC) (1024 tones) Bit-loading Up to 32-PAM	OFDM (up to 4096 tones) Bit-loading Up to 4096-QAM LDPC
Bit-rate	200 Mbit/s	3.8-9.8 Mbit/s	190 Mbit/s	540 Mbit/s	>200 Mbps Up to 1Gbps
MAC	TDMA-CSMA/CA	CSMA/CA	TDMA-CSMA/CA	TDMA-CSMA/CA	TDMA-CSMA/CA

Channel Characteristics

The knowledge of the channel is important to design and test PLC systems

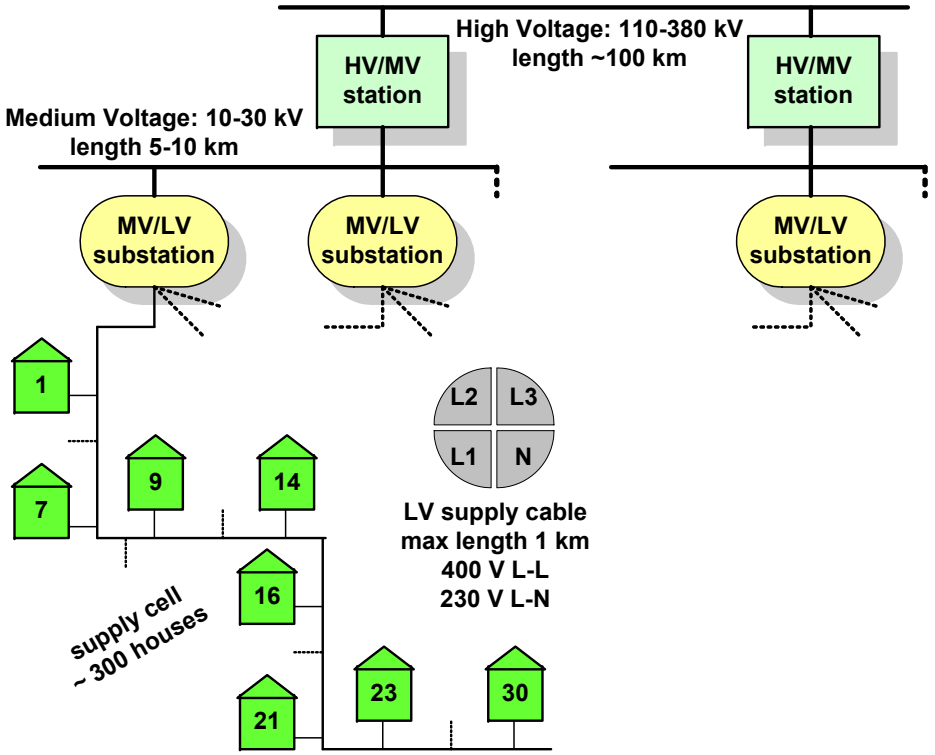
Channel Characteristics

- In general the channel exhibits
  - Multipath propagation due to discontinuites and unmatched loads
  - Frequency Selective Fading
  - Cyclic time variations due to periodic change of the loads with the mains frequency (*mostly bistatic behaviour in home networks*)



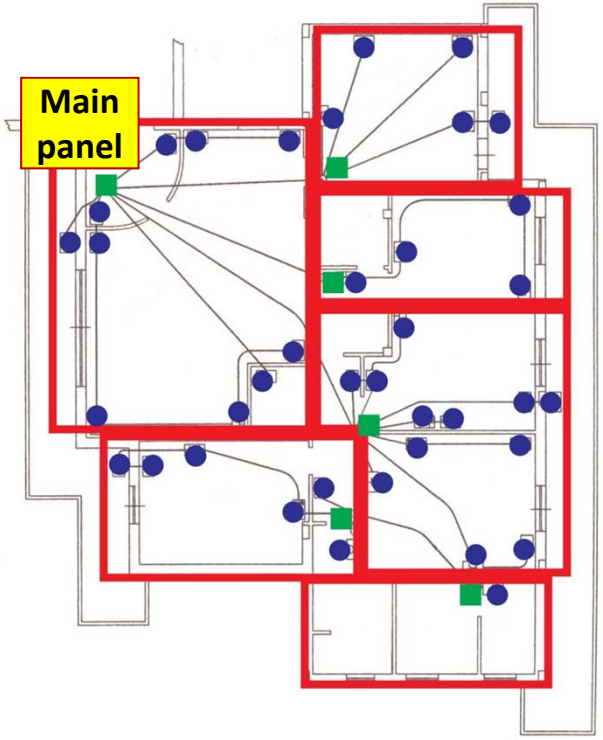
A Look at the Topologies

Distribution Grid



- The distribution system is divided in supply cells with a number of houses connected to a MV/LV substation.
- Structure depends on the country

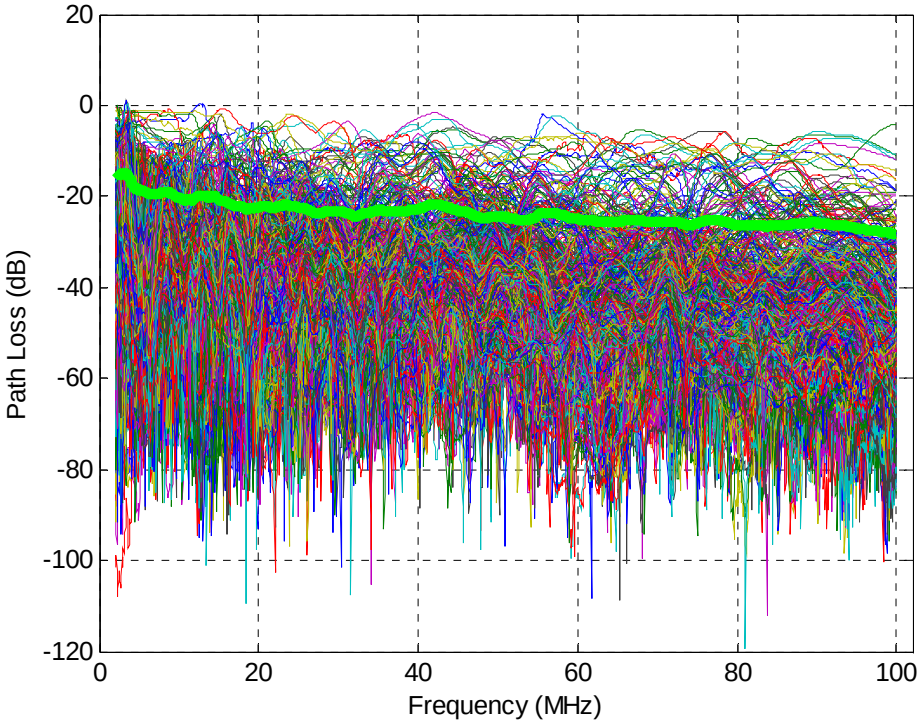
In-home Grid



- Layered tree structure from the main panel with many branches and outlets fed by derivation boxes

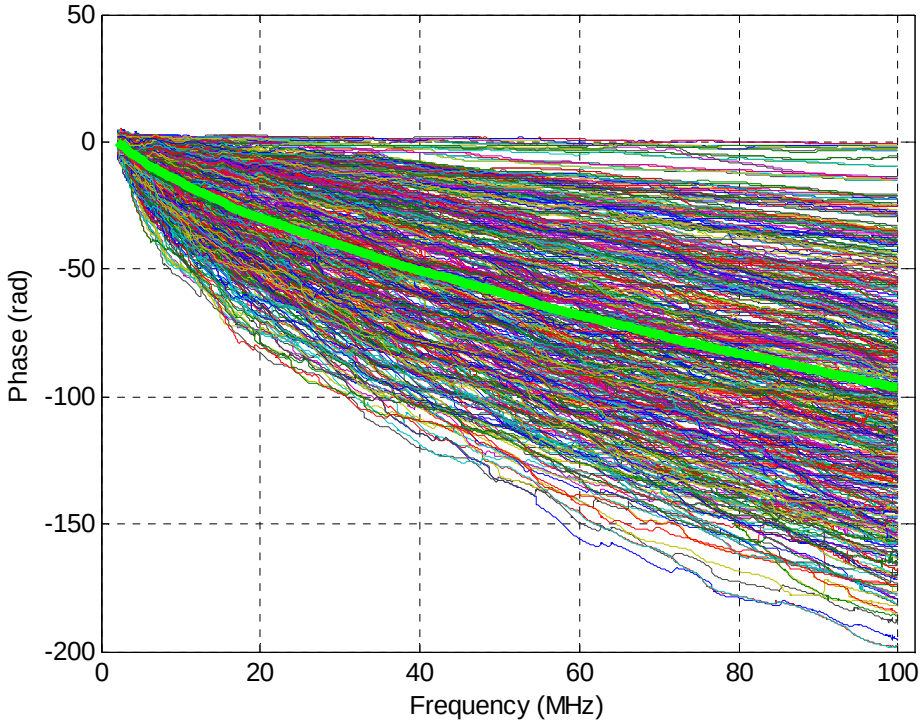
In-Home Channel from Measurements

Path Loss



- On average
  - Frequency increasing attenuation
- Strong fading effects
  - Average channel gain is log-normal

Phase

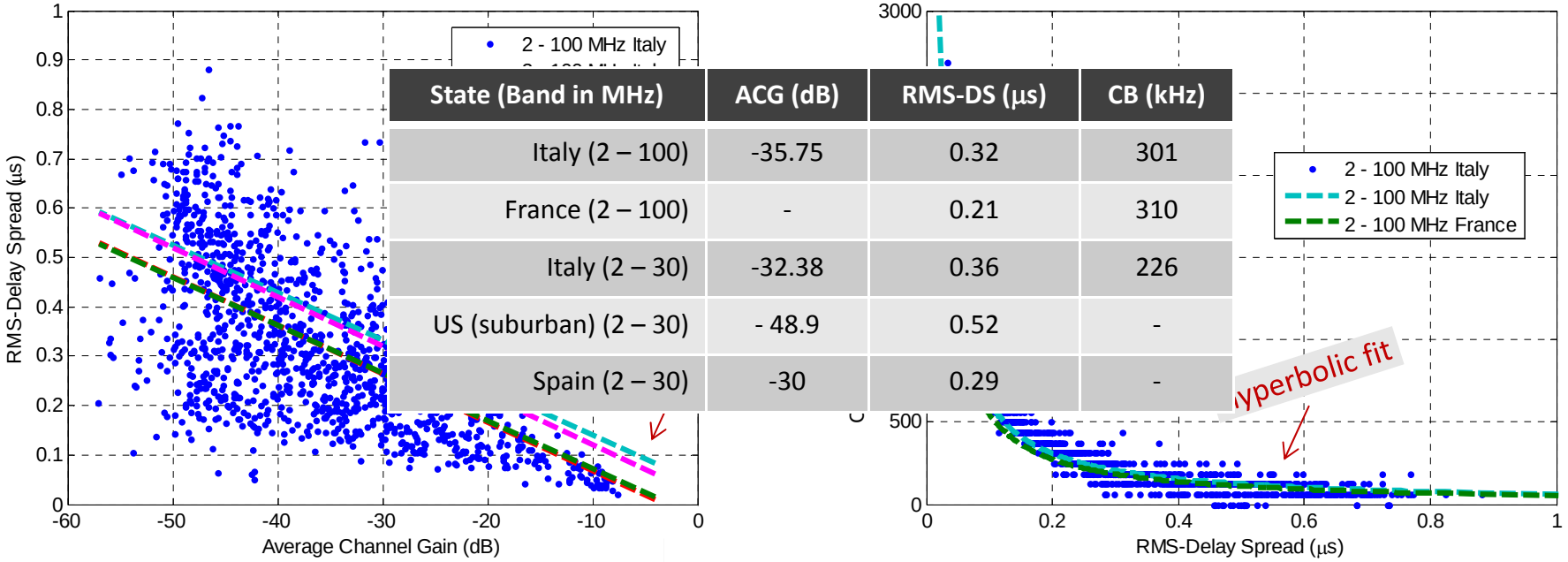


- The phase is uniformly distributed
- The average phase is not linear at low frequencies

Relations between Metrics (In-Home)

- The higher the channel attenuation, the higher the delay spread
- Coherence bandwidth is an hyperbolic function of the delay spread
- Data from campaigns in Italy, in France, in USA, and in Spain

State (Band in MHz)	ACG (dB)	RMS-DS (μs)	CB (kHz)
Italy (2 – 100)	-35.75	0.32	301
France (2 – 100)	-	0.21	310
Italy (2 – 30)	-32.38	0.36	226
US (suburban) (2 – 30)	- 48.9	0.52	-
Spain (2 – 30)	-30	0.29	-



REF. M. Tlich, A. Zeddam, F. Moulin, F. Gauthier, "**Indoor Power-Line Communications Channel Characterization Up to 100 MHz – Part II: Time Frequency Analysis**," *IEEE Trans. Power Del.*, 2008.

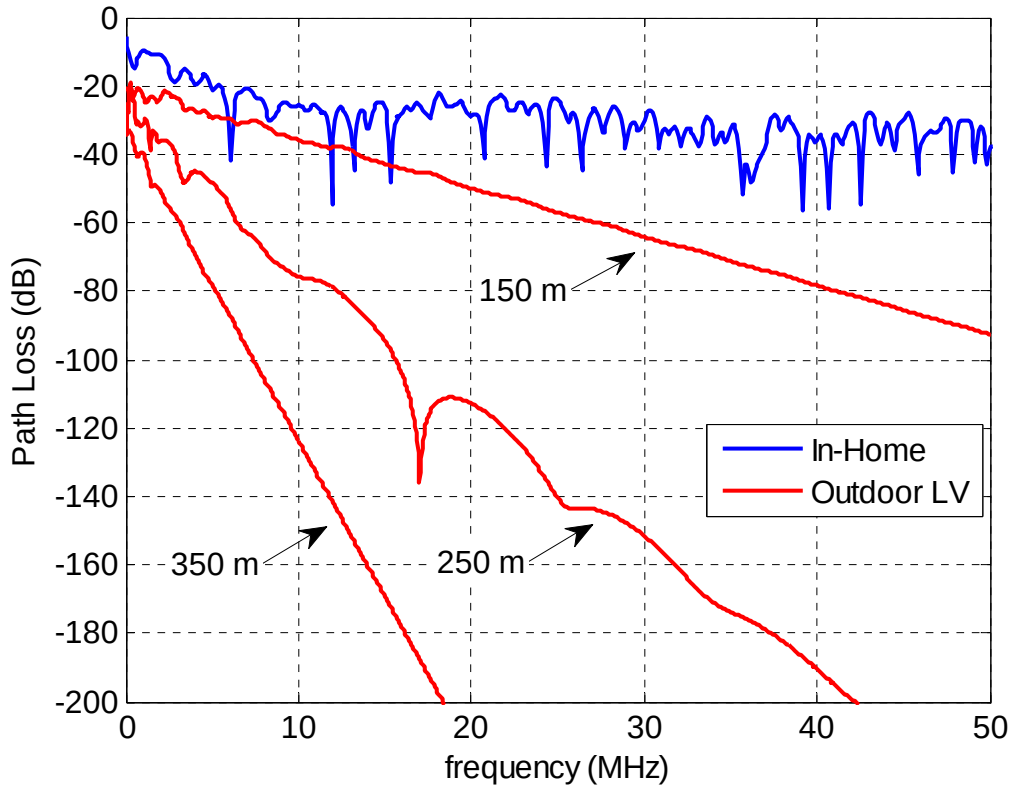
REF. S. Galli, "**A Simple Two-Tap Statistical Model for the Power Line Channel**," *in Proc. of ISPLC 2010.*

REF. F. J. Cañete, J. A. Cortés, L. Díez, J. L. G. Moreno, "**On the Statistical Properties of Indoor Power Line Channels: Measurements and Models**," in Proc. *of ISPLC 2011*.

REF. F. Versolatto, A. Tonello, "**On the Relation Between Geometrical Distance and Channel Statistics in In-Home PLC Nets.**," in Proc. of *IEEE ISPLC 2012*

Outdoor LV vs. In-Home PLC Channel

- Comparison between OPERA (Open PLC European Research Alliance) reference channels and a typical In-Home channel



- **In-Home** channels have high frequency selectivity and low attenuation
  - Very high number of branches, discontinuities and unmatched loads
  - Short cables
- **Outdoor LV** channels have high attenuation but negligible fading
  - Cable attenuation dominates

REF. M. Babic et al., "**OPERA Deliverable D5. Pathloss as a Function of Frequency, Distance and Network Topology for Various LV and MV European Powerline Networks**," 2005.

Outdoor MV Channel

- MV channels exhibit in general (but not always) **lower attenuation than Outdoor LV PLC**
  - Further investigations have to be done
- Coupling effects have also to be considered

- *Size is an issue if used in MV/HV lines*

Capacitive coupling in MV lines, courtesy of RSE

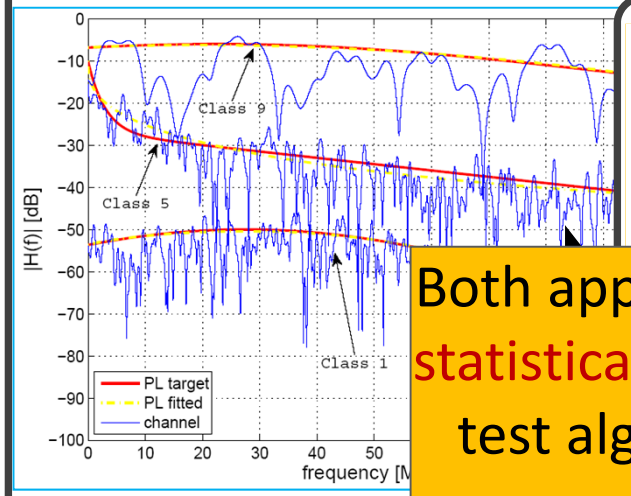
- *Inductive coupling simplifies installation but has lower pass behavior*

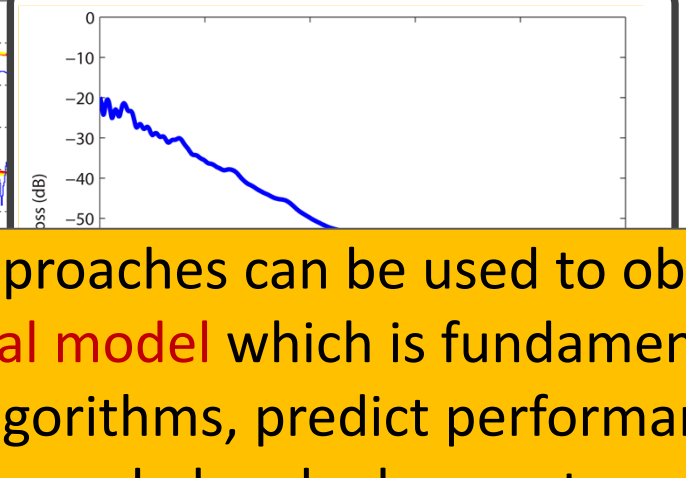
Inductive coupling in MV lines, courtesy of RSE

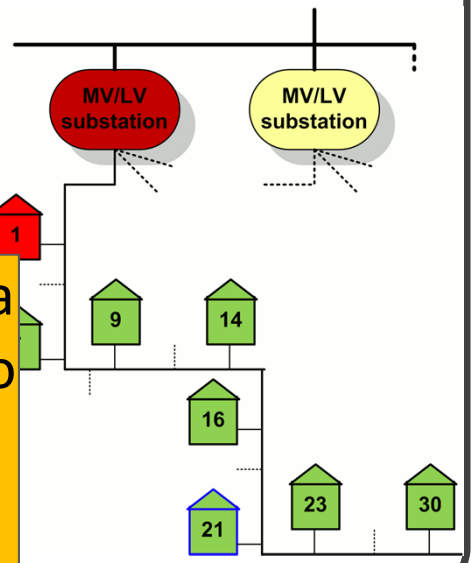
REF. A. Tonello, et al. "**Analysis of Impulsive UWB Modulation on a Real MV Test Network,**" in Proc. *IEEE Int. Symp. on Power Line Commun. and Its App. ISPLC'11*, Apr. 2011.

Is it Possible to Model the Channel ?

- The channel can be accurately modeled with two approaches:
  - **Top-down:**
    analytic model fitted with data from measurements
  - **Bottom-up:**
    from topology to channel response using transmission line theory







Both approaches can be used to obtain a statistical model which is fundamental to test algorithms, predict performance, and plan deployment

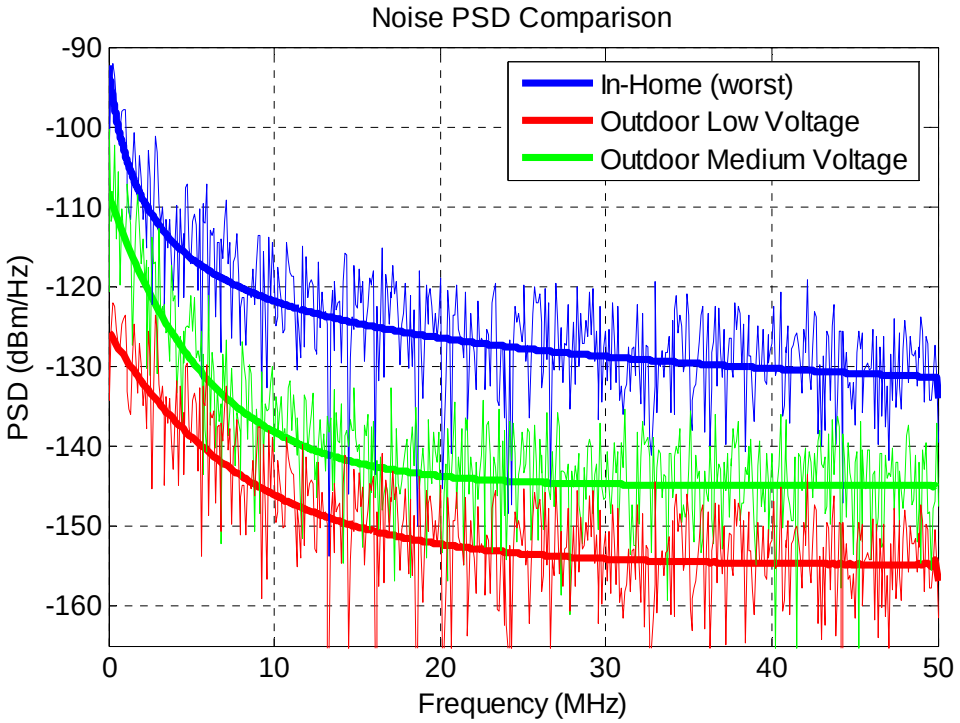
Top-down in-home model available at *www.diegm.uniud/tonello*

REF. A. Tonello, F. Versolatto et … *wer Del.* 2012.

REF. A. Tonello, F. Versolatto, "**…del and Efficient Transfer Function Computation**," *IEEE Trans. Power Del.*, Apr. 2011.

REF. A. Tonello, F. Versolatto, "**Bottom-up Statistical PLC Channel Modeling – Part II: Inferring the Statistics**," *IEEE Trans. Power Del.*, Oct. 2010.

Background Noise Comparison



- In-Home PLCs experience the highest level of noise
- Noise is much higher at low frequencies

NB PLC exhibits higher noise than BB PLC

- Background noise has an exponential PSD
- Narrowband interference
  - FM disturbances (> 87.5 MHz), AM (< 1.6 MHz), Radio amateur (from 1.9 MHz)
- Impulsive noise, noise introduced by devices (inverters, switching power supplies, fluorescent lamps, motors, etc.)

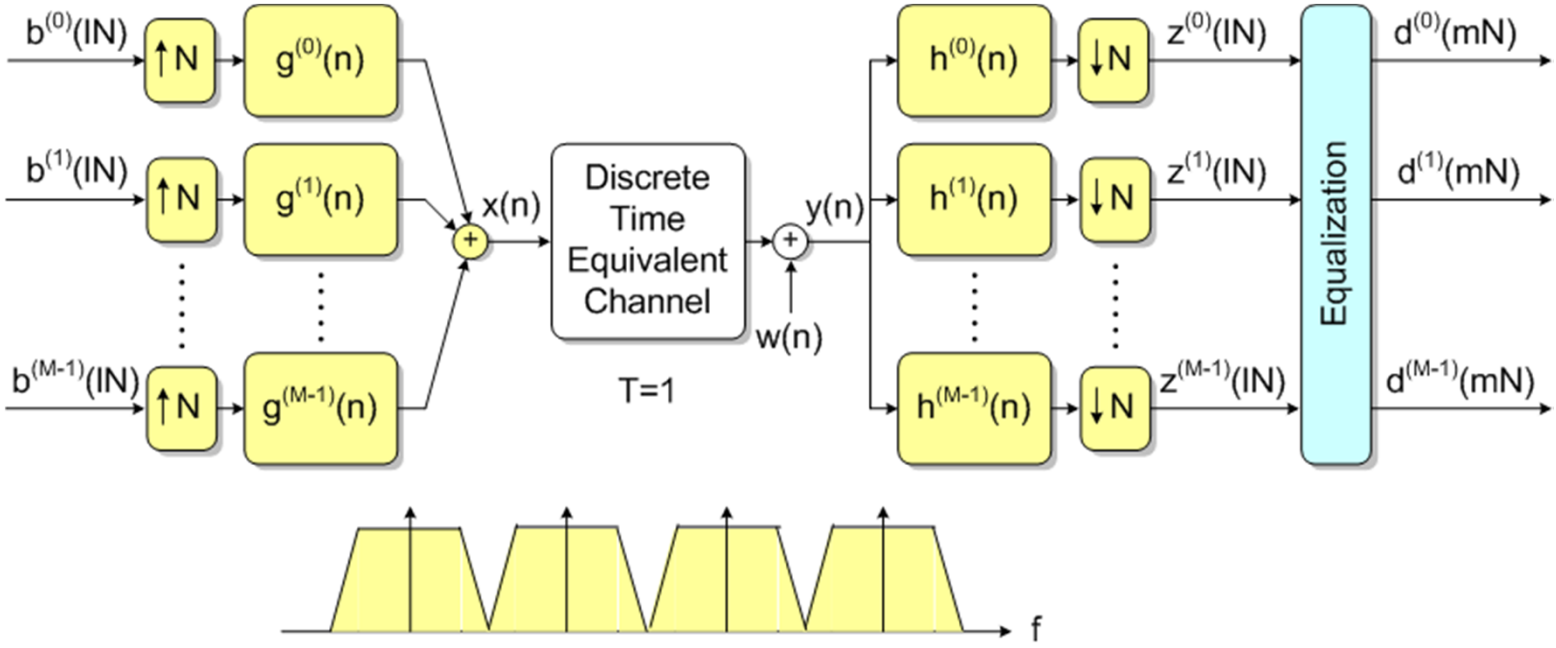
Relations/Differences with Wireless

- The channel is a **shared medium** both in PLC and Wireless
- The channel is **low pass** with pass band below 300 MHz in PLC
- **Multipath** propagation in both PLC and Wireless
- Frequency response is approximately **log-normal** in PLC as for path-loss in wireless
- **Time variations are cyclic** in PLC (no mobility)
- **Colored background** and **impulsive noise** are present in PLC

Physical Layer

Signal processing algorithms are fundamental to overcome the channel impairments

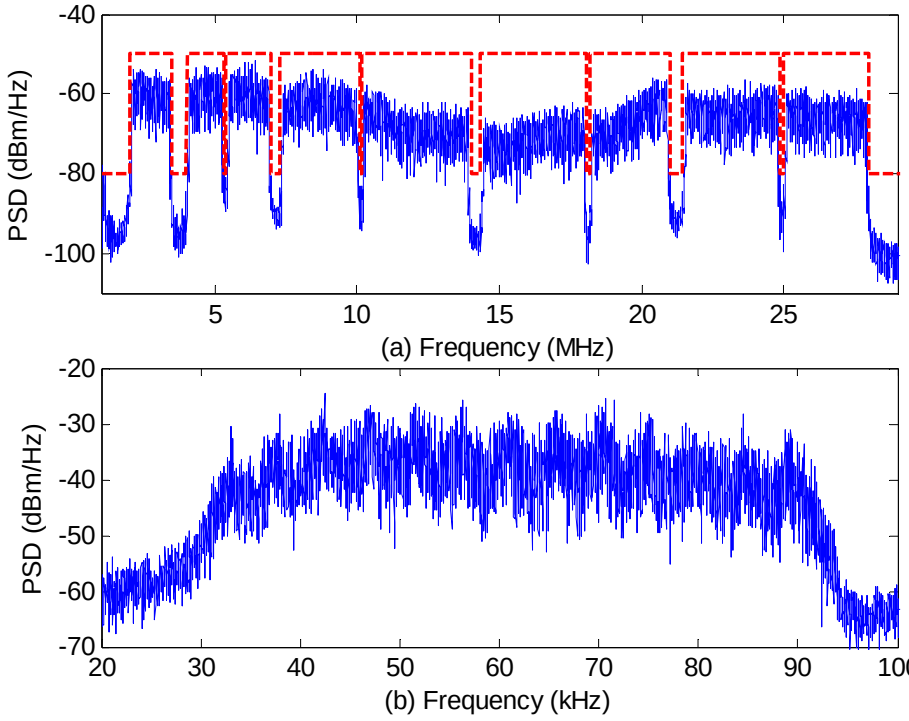
State-of-the-art PLC Deploys Multicarrier Modulation



- $b^{(k)}(mN)$: QAM data symbols
- $g^{(k)}(n)$: sub-channel pulses, obtained from the modulation of a prototype pulse
- N: interpolation factor $N \geq M$ number of sub-channels

Notching

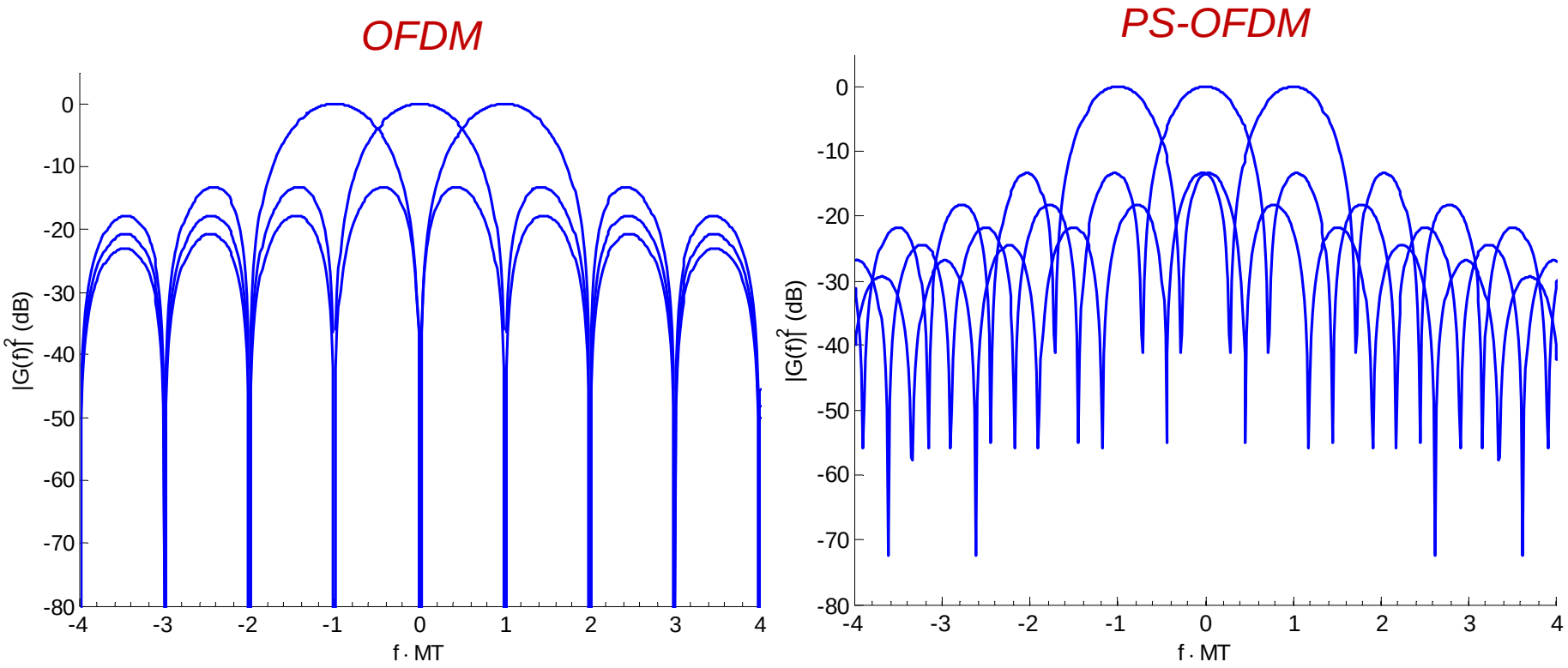
- It is important to:
  - Transmit with low power so that the common mode currents that generate radiated fields are limited
  - Notch the spectrum to grant coexistence with other systems



HPAV spectrum

G3 spectrum

Spectrum of OFDM and PS-OFDM

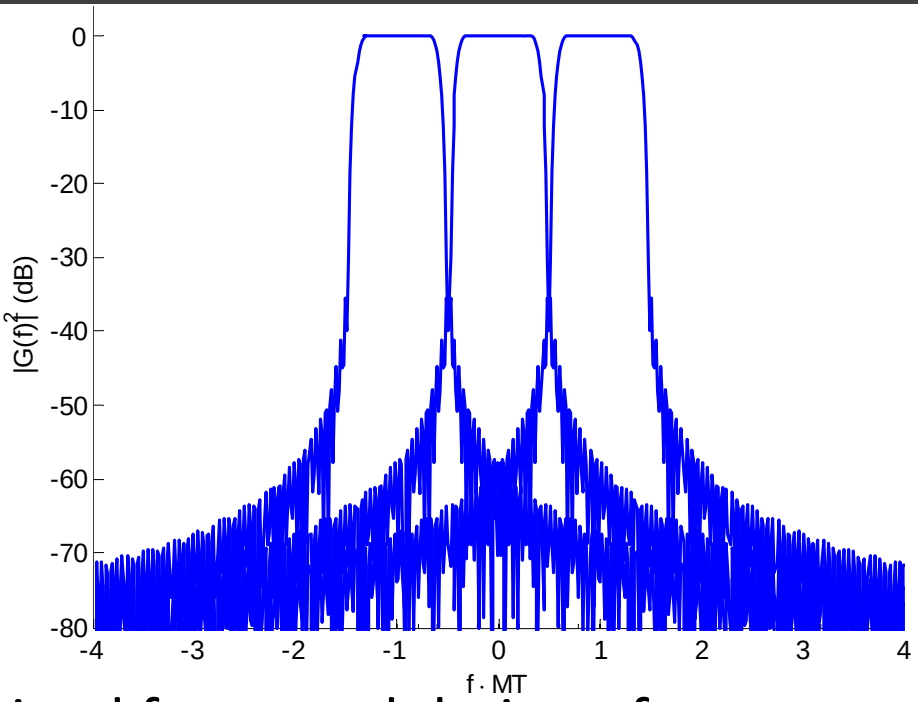


- OFDM uses a rectangular pulse (poor sub-channel frequency confinement)
- PS-OFDM uses a window, e.g., raised-cosine, to fulfill the notching mask with a larger number of active tones

Filter Bank Approaches

- Can we increase the sub-channel frequency selectivity ?
  - Yes, by privileging the frequency confinement
- What schemes are available ?
  - Wavelet OFDM (one solution adopted by IEEE P1901)
  - Filtered Multitone Modulation (FMT)
  - Other filter bank modulation approaches are also possible

FMT Basics



- Pulses obtained from modulation of a prototype pulse
  - Time/Frequency confined pulses
  - Perfect reconctruction solutions provided that $N > M$

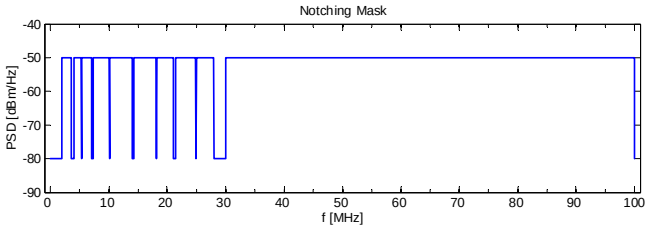
REF. G. Cherubini, E. Eleftheriou, S. Olcer, "**Filtered multitone modulation for very high-speed digital subscriber lines**," *IEEE J. Select. Areas Comm. 2002.*

REF. A. Tonello, F. Pecile, "**Efficient Architectures for Multiuser FMT Systems and Application to Power Line Communications**," *IEEE Trans. on Comm. 2009.*

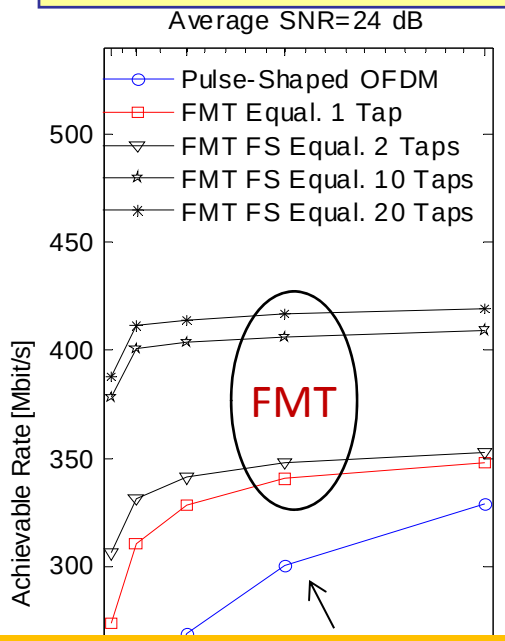
REF. N. Moret, A. Tonello, "**Design of Orthogonal Filtered Multitone Modulation Systems and Comparison among Efficient Realizations**," *EURASIP Journal on Advances in Signal Processing, 2010*.

Achievable Rate as a Function of N. of Tones

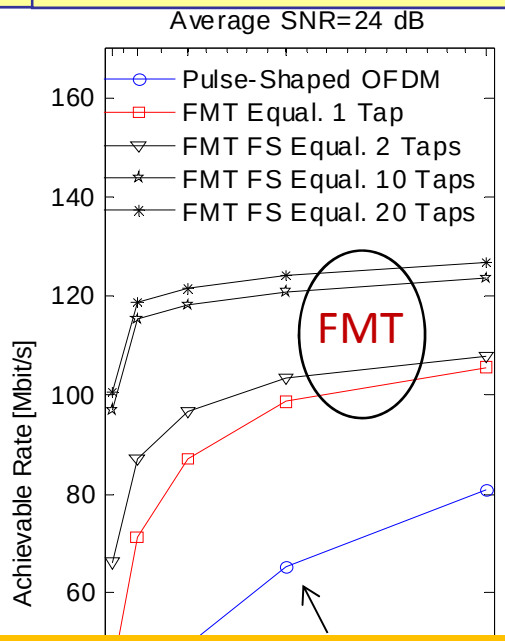
Target notching mask below 30 MHz: HPAV



Masked 2-100 MHz



Masked 2-28 MHz



- FMT outperforms PS-OFDM
- The lower the SNR the higher is the advantage of FMT w.r.t. PS-OFDM
- FMT has better notching capability

REF. "**Chapter 5: Digital Transmission Techniques**," Power Line Communications, Theory and Applications for Narrowband and Broadband Communications over Power Line, L. Lampe, E. Ferreira, J. Newbury, (ed.s), 2010, John Wiley & Sons

How Can We Increase Performance ?

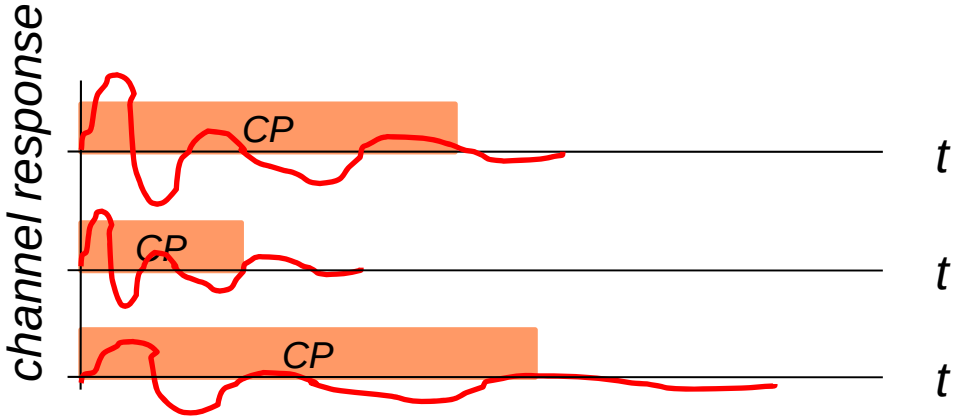
- Increase bandwidth
  - *up to 100 MHz or even above for BB PLC*
  - *up to 500 kHz for NB PLC*
- Use powerful channel coding
- Perform adaptation of the transmitter parameters:
  - bit and power loading
  - adaptive scheduling (exploiting cyclic SNR variations)
  - cognitive use of spectrum
- Use MIMO transmission

Adaptive OFDM and FMT

- We can adapt the pulse shape and the overhead $\beta = N\text{-}M$ such that capacity is maximized

$$R(\beta) = \frac{1}{(M+\beta)T} \sum_{k \in K_{ON}} \log_2 \left(1 + \frac{SINR^{(k)}(\beta)}{\Gamma} \right) \quad [bit/s]$$

- For example, in CP-OFDM we adapt the CP to the channel response



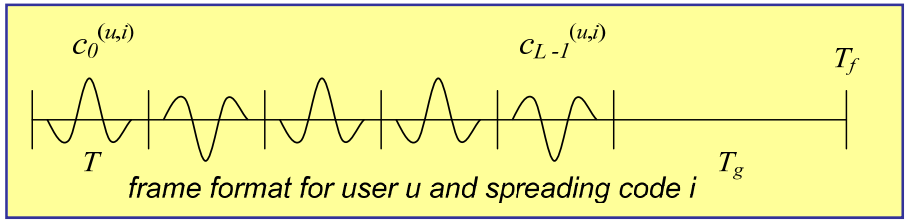
REF. A. Tonello, S. D'Alessandro, L. Lampe, "**Cyclic Prefix Design and Allocation in Bit-Loaded OFDM over Power Line Communication Channels**," *IEEE Trans. on Communications, Nov. 2010.*

Physical Layer Techniques

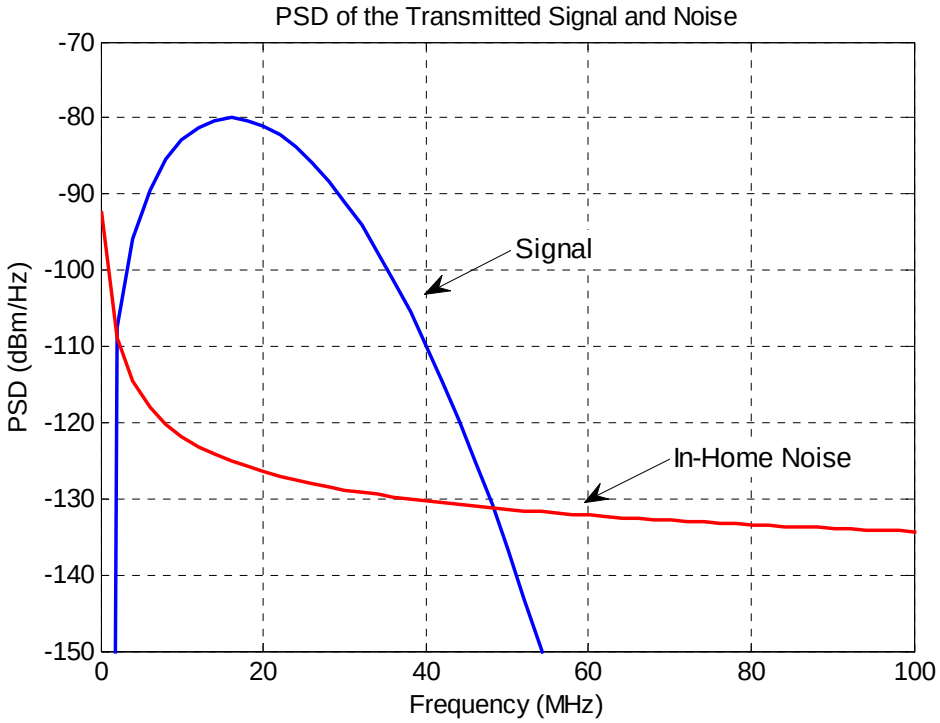
Can we use other modulation techniques ?

Impulsive UWB: I-UWB

- **For low data rate:** Impulsive UWB



- Gaussian monocycle D=50-200 ns, T_f = 2 us, R = 0.5 Mpulses/s.
- Symbol energy is spread in frequency by the monocycle (*frequency diversity*)
- The *monocycle* is spread in time via a binary code (*time diversity*)
- Coexistence with broadband systems is possible due to the low PSD and high processing gain

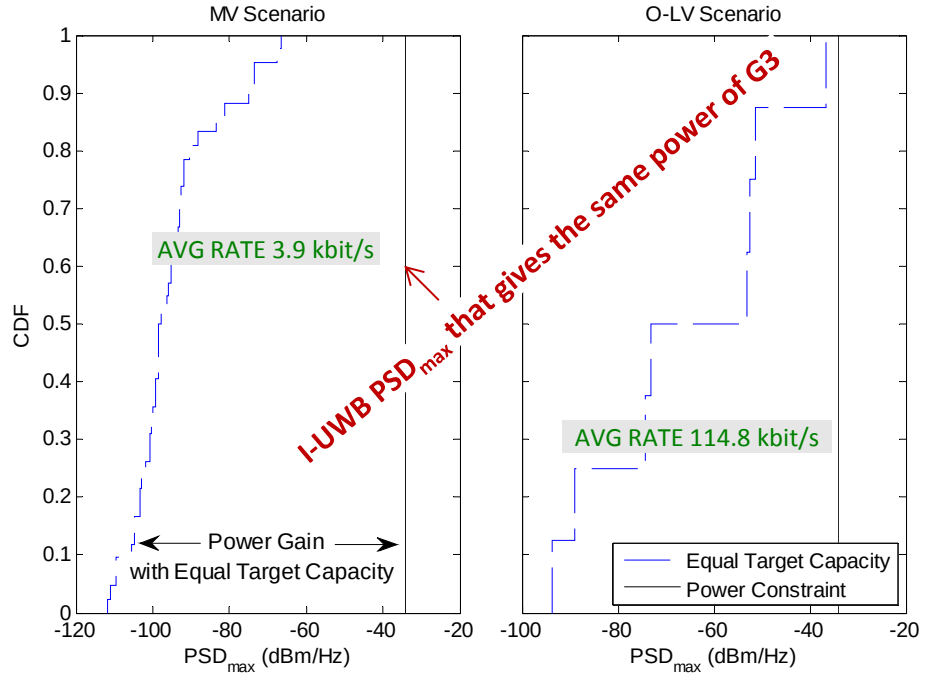


REF. A. Tonello, **"Wideband Impulse Modulation and Receiver Algorithms for Multiuser Power Line Communications,"** *EURASIP Journal on Advances in Signal Processing*, vol. 2007, pp. 1-14.

Comparison of I-UWB with NB-OFDM

- I-UWB may be suitable also for outdoor communications
  - Same transmitted power: higher data rates with I-UWB w.r.t. NB-OFDM
  - Same data rate: very low transmitted PSD with I-UWB

G3 Bandwidth = 54.7 kHz, PRIME Bandwidth = 46.9 kHz
(here, only G3 because they perform similarly)



REF. A. Tonello, et al. "**Comparison of Narrow-Band OFDM PLC Solutions and I-UWB Modulation over Distribution Grids,**" *in Proc. IEEE Smart Grid Communications Conference,* Oct. 2011.

Relations/Differences with Wireless

- **Filter bank modulation** is a solution for high speed communications both in PLC and wireless
- **UWB** is a wireless technology but it may have some application also in PLC with smaller bands and data rate, though
- **Chanel coding** solutions developed for wireless are applied also in PLC, e.g., convolutional, turbo and LDPC codes
- **Adaptation and cognitive techniques** are important in PLC
- **MIMO** is not clear yet whether it has a role in PLC

Conclusions and Evolution of PLC

Conclusions

- PLC technology has reached a certain maturity
  - The in-home BB market is significantly increasing
  - PLC will play an important role in the SG (both NB and BB PLC)
  - PLC for in-vehicle has many benefits but little work done so far
- Importance of definition of applications and requirements in the SG (many domains)
  - Is AMR/Smart metering the killer application ?
- Coexistence of technologies is fundamental
- Harmonization of standards needs to be completed for mass deployment

Evolution

- EMC, coexistence/interoperability mechanisms also with other technologies
- Advances at the PHY, e.g.,
  - filter bank modulation, MIMO, *optimal* channel coding, mitigation of interference and impulsive noise….
- Advances at the MAC, e.g.,
  - adaptation and *applicable* resource al
    cooperative techniques, …
- New grid topologies, new cables, and pos
  might come out

- It is important to perform channel characterization and modeling … *and I enjoy doing that !*

Dissemination Opportunities

Journal of Electrical and Computer Engineering

Special Issue on

Power-Line Communications: Smart Grid, Transmission, and Propagation

Call for Papers

Power-line networks are gaining popularity in various service provisions such as in houses/offices, access networks, ships, aircrafts, trains, vehicles, industry systems control, and advanced metering infrastructure. This popularity is also striding towards smart grid implementations. However, the network structure affects the channel response which exhibits frequency selectivity and time-variant behavior. These effects are due to different terminal loads connected to such systems, number of branches, and different branched line lengths. In addition, different types of cables and signal injection methods used (i.e., with respect to adjacent lines/grounds and the grounding systems implemented in different countries) for such systems render the propagation difficult. Furthermore, electromagnetic compatibility (EMC) issues and more especially electromagnetic interference (EMI) occurring at different frequencies of operations still need more investigations. We are interested in articles which explore various aspects related to the provision of communications services over power-line networks, especially for (but not limited to) the smart grid, as antenna mode and signal propagation in power-line networks for both single-input single-output (SISO), single-input multiple-output (SIMO), and multiple-input multiple-output (MIMO) channel modeling and estimation, noise modeling and mitigation techniques, EMC, EMI, modulation and coding techniques for SISO and MIMO, and capacity analysis and coupling mechanics for power-line communication (PLC) systems.

Potential topics include, but are not limited to:

- The influence of grounding system implementations in various countries
- Signal propagation, EMF, and EMC analysis for indoor/outdoor systems, in-ship systems, aircrafts systems, train systems, in-vehicle systems, industry control and application systems, and so forth
- Signal propagation aspects in monitoring energy generation systems using power-line techniques
- Modelling and analysis of power-line networks as a wave guide
- Signal propagation and network infrastructure modeling for advanced metering and smart grid/smart meter infrastructures
- Common-mode current propagation in broadband power-line communication networks
- Channel estimation and capacity analysis for MIMO and SIMO power PLC systems
- Ultrawideband power-line signal propagation
- Spectrum monitoring and sensing techniques and methods for cognitive PLC systems

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Manuscript Due	Friday, 3 August 2012
First Round of Reviews	Friday, 26 October 2012
Publication Date	Friday, 21 December 2012

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Call for Papers (Preliminary)

With a great pleasure we announce the **17th IEEE International Symposium on Power Line Communications and its Applications** to be held at the University of Johannesburg's School of Tourism and Hospitality (Kerzner Building), from March 24 to March 27, 2013. Johannesburg is a world class African city, the hub of the South African economy and also known as "The City of Gold".

IMPORTANT DATES
Full Paper Submission:
16 November 2012
Notification of Acceptance:
18 January 2013
Camera-ready Paper Submission:
15 February 2013

The symposium focuses on research, application and commercialization aspects of the power line communications technology, in both broadband and narrowband fields. Prospective authors are cordially invited to submit contributions describing completed or on-going research related to the power line communication area. Papers should be original, do not exceed 6 pages and should not have been presented in other conferences or journals. The contributions should address one of the following aspects related to PLC field including but not limited to:

- PLC in Smart Grid
- Channel characterization and modelling
- Electro-magnetic compatibility/interference and coupling
- Modulation and coding techniques
- Signal processing
- Cognitive and cooperative algorithms and approaches
- Error control
- Multiple access techniques and MAC protocols
- Duplex and repeater techniques, routing and autonomous network functions
- Network planning and optimization
- Cross-layer optimization and service integration
- Green communications
- Coexistence and interoperability
- Modern and LSI design
- Security in PLC
- Network and service management
- System architectures and solutions
- Broadband and multimedia applications
- Experimental systems, field trials and commercial networks
- Standardization and regulation
- Access, in-home and in-vehicle power line networks

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Ευχαριστω !