http://www.ic1004.org

# NEWSLETTER

## Cooperative Radio Communications for Green Smart Environments

**Number 5, July 2013**

**Newsletter Editor:** Alain Sibille, Telecom ParisTech, France

**COST IC1004 Chairman:** Narcis Cardona, Univ. Politecnica Valencia, Spain



## Editorial

Dear readers,

Mobile communications remain an extremely vivid area of research and of promising technological and industrial developments. If we look back into the past, we see that the GSM story started in the early nineties, 3G at the turn of the century and 4G is gently starting now. This gives about a decade between two generations. 5G is the next one, which is starting to be approached in research projects under this acronym. Each new generation brings very substantial improvements over the previous and it is our role, as academic and company/industry researchers to make this true also for the next leap. Of course, we can't progress indefinitely, but Moore's law in silicon taught us that predicted slowdown were often contradicted by reality, thanks to human imagination to solve apparently un-surmountable difficulties. We have our Edholm law, claiming that data rates also follow an exponential trend. The challenge is to verify it over the next decade, towards 5G. This is both a very ambitious and a very exciting goal, which will keep our laboratories and our young and experienced researchers boiling of energy to reach it.

At the last management committee meeting in Ilmenau, we had three invited presentations addressing the wireless challenges along 3 different angles: Werner Mohr gave a wide and holistic overview of future mobile and wireless communications towards 2020 (see also the virtual interview in this issue), Thomas Kaiser provided keys and statements for the success of cognitive and software defined radio paradigms and Oliver Klemp focused on vehicular centric communications, one of the "smart environments" at the heart of our IC1004 COST Action.

Please have a look at this newsletter, hoping you will be easily convinced of the relevance and value of our efforts, and think of joining. The more, the richer... scientifically speaking !

*Alain Sibille*

## Chairman's Address

Dear Colleagues,

It is my pleasure to open the fifth issue of our Newsletter after having completed the second year term of our Action with excellent results on research activities, dissemination and training. In the recent previous months some successful events have been organised by COST IC1004, like the Training School on Tools for Cooperative Communications, in Prague, the Workshop on Self Organising Networks for Energy Efficiency, in Ilmenau, and a special session at the Future Network Mobile Summit, in Lisbon. Many of our dissemination and training activities are joint with European projects and other COST actions, and in some weeks IC1004 is organising a joint workshop on Terminal Antenna Systems for 4G and Beyond, in cooperation with COST IC1102 (VISTA) Action, Ghent, 25th of September.

Plans for the third year of IC1004 are to keep impacting the EU Wireless Communications Area with some contributions to models, standards and position papers on future research challenges in cooperative and efficient wireless communications, while the Action continues growing in quality and outcomes, and we keep receiving many fresh ideas and novel initiatives from participants at every IC1004 meeting. Recently, I went through a popular citation search tool in Internet, and what I found is that COST IC1004 is cited in almost 300 publications so far, which for sure is a key indicator of success for the action and for the COST framework. This is -and will only be- possible with the volunteer contribution from the IC1004 participants. Thank you all for your selfless commitment.

Enjoy the reading and be welcome to join us at any of our coming events.

*Narcis Cardona*

## Highlights

Fruitful discussions took place in SWG1.1 during the Ilmenau meeting. Ideas for possibility joint activities ahead include more STSMs, short course at a conference and even the writing of a white paper on the group's vision on future handset antenna systems. The group will also be mainly responsible for organizing the upcoming Joint COST IC1004-COST VISTA Workshop in Ghent on 25 Sep 2013, as well as for possible publication of workshop papers in a special cluster of IEEE Antennas and Wireless Propagation Letters.

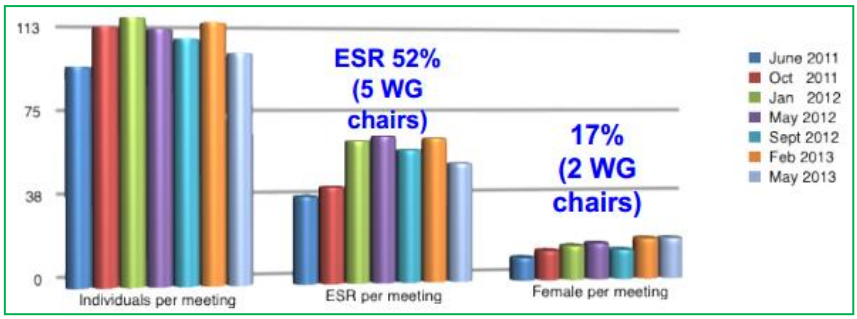
The MIMO OTA TWG commits itself to developing Over-the-Air testing techniques for reproducibly and reliably assessing the performance of (small) MIMO user equipment. During the Ilmenau meeting, two variations on familiar themes were presented. The first is channel sounding in live mobile radio networks with so-called scanners, in contrast to campaigns in carefully arranged scenarios with channel sounders, TD(13)07053. The lack of calibration possibilities limits absolute accuracy and because of the incoherence, antennas de-embedding and high-resolution estimations are not possible. On the other hand, the scenarios are really realistic, the scanner is considerably smaller than the usual channel sounders and much easier to operate, consequently more data can be measured. The second unconventional paper is on determining the Total Isotropic Sensitivity of user equipment not in anechoic but in (stirred-mode) reverberant chambers, TD(13)07008. The results still differed from anechoic chambers and the use of fading signals for the measurements was criticized but the measurements are potentially faster than in anechoic chambers. Other papers continued more specific MIMO OTA themes. Results of a first measurement campaign in TD(13)07041, trying to quantify how much background interference not related to communication systems exists between 500 and 2700 MHz in 4 different environments in Denmark. Especially the angular distribution was of interest, but, generally, the noise was around or under the threshold set at 92 dBm. This relates to the on-going discussion in CTIA MIMO OTA Special Group on noise and interference injection. Two other presentations discussed improvements on a candidate OTA method for standardization, the two-stage method, and system simulations for optimising the method, respectively, TD(13)07047 and TD(13)07049. Calibration accuracy for accurate wave field synthesis was the topic of TD(13)07054.

The activities of WG2/SWG2.1 focused on the preparation of the COST-IC1004/FP7-DIWINE Training School **"Tools for cooperative communications (TSCC 2013)"**, which took place in Prague, Czech Republic (May 20-22, 2013). Cooperative communications are increasingly the focus of much research in wireless communications, since wireless networks increasingly involve interactions between larger and larger numbers of nodes, which must cooperate to enable efficient communication. Together with the DIWINE project (FP7), COST IC1004 considers several techniques for designing and optimizing cooperative wireless networks, including Wireless Network Coding, distributed signal processing and interference management. the program is shown on the right.

| | | |
|---|---|---|
| Monday 20.5.2013 | 9:00-10:30 | **Frank Fitzek: "Green Mobile Clouds: Network Coding and User C Energy Efficiency"** |
| | 11:00-12:30 | |
| | 13:30-15:00 | **Umberto Spagnolini: "Distributed signal processing and synchronization"** |
| | 15:30-17:00 | |
| Tuesday 21.5.2013 | 9:00-10:30 | **Eduard Jorswieck: "Distributed Interference Processing in Single- and Multi-hop Interference Channels"** |
| | 11:00-12:30 | |
| | 13:30-15:00 | **Jan Sykora and Alister Burr: "Advances in Wireless Network Coding** |
| | 15:30-17:00 | |
| Wednesday 22.5.2013 | 9:00-10:30 | **Daniel Calabuig: "The limits of cooperation. The Gaussian broadcast channel and Gaussian multiple access channel."** |
| | 11:00-12:30 | **Michal Wodczak: "Autonomic management of cooperative networking"** |
| | 13:30-14:30 | **Russell Haines "Cooperative Communications in Standards and Industry"** |

COST IC1004 and the FP7 GREENETS project also organized the Joint Workshop on "SON Algorithms for Energy Efficiency" (May 28th, 2013 - Ilmenau, Germany). The presentations (available under the Member's Area of the website or by request to the authors) were the following:

- Alister Burr "Energy Efficiency in Wireless Network Coded Cooperative Communications"
- Renato Cavalcante "Energy Savings in Cellular Networks with the Majorization-Minimization Algorithm"
- Zoran Utkovski "Emergence of Cooperation in Decentralized Wireless Networks"
- Johannes Baumgarten "Energy Consumption Model for Multiple RATs Based on Network Measurements"
- Maria Lema "Enhanced Scheduling Techniques for Efficient Uplink Communications with Carrier Aggregation"
- Renato Cavalcante "Voice and Traffic Prediction in GSM and UMTS Cells Based on Real Network Measurements"
- Margot Deruyck "Taking user capacity demands into account to reduce power consumption in wireless networks"




***COST IC1004 keeps growing !***

**Interview:** Werner Mohr, Head of Research Alliances, Nokia Siemens Networks

[IC1004]: You have been an actor in the history of wireless networks for many years now, starting from 2G to 4G after crossing "fractional G" generations. Would you say that the future of mobile networks at the 2020 horizon will be "beyond 4G" or 5G?

[Werner Mohr]: We will see significant further developments. Future mobile and wireless communications systems have to provide much higher system capacity per area unit, more flexibility in data rate allocation, lower latency and significantly reduced energy consumption. In addition, new frequency bands will be used in heterogeneous networks.

[IC1004]: 1000 times more capacity is a highly challenging target for 2020. It seems we are very close to reaching fundamental performance limits at least in point to point links. What is the main driver of such a progress? Is, basically, something like 1000 smaller cells traded against 1000 more spectrum?

[Werner Mohr]: The factor of 1000 means an increase of system capacity per area unit. Different frequency bands in heterogeneous networks with common network management, additional frequency bands including millimeter wave frequency bands for nomadic and indoor applications and smaller cells are means to achieve this. On link level we basically reached the Shannon limit. However, there is still potential on system level by interference management, Comp, interference cancellation, dynamic spectrum use for opportunistic spectrum access by means of cognitive radio and advanced antenna concepts.

[IC1004]: Spectrum is both a fundamental and an expensive resource in wireless communications. It will be difficult to reach the target traffic levels without enough bandwidth, however this is at a price since spectrum is a commercial quantity now. Is the economic equation favorable? How to find the balance between more spectrum and more base stations?

[Werner Mohr]: The expected growth in data traffic cannot be solved only by additional frequency spectrum. Lower frequency bands (e.g. in the Digital Dividend) are beneficial for broadband services from an economic perspective for full area coverage and high mobility in particular in low densely populated areas. However, the available frequency bands at lower frequencies limit the system capacity. Many subscribers are using broadband applications in nomadic and/or indoor scenarios (low mobility), where traffic can be offloaded from cellular systems to short-range systems even in much higher frequency bands as part of heterogeneous networks. Such concepts can also combine licensed and unlicensed frequency bands.

[IC1004]: It seems that, in the future, humans will be embedded in a large variety of networks and of cell layers. If we want both high availability, low latency and high QoS, this means very flexible devices, able to operate over many bands and switch from a RAT to another quasi instantaneously. Is that feasible? What about technology cost, energy efficiency for devices?

[Werner Mohr]: The switch-over between RATs should be seamless. Instantaneously switching is not necessary. The support of several RATs requires flexible radios. Moore's law is still supporting the necessary signal processing. An energy management system in devices is necessary, because not all radios have to be active simultaneously. Already today smart phones are supporting several radio systems in different frequency bands. Therefore, it is expected that this will be feasible.

[IC1004]: Self operation will be one of the enablers to develop dense heterogeneous networks at a reasonable deployment cost and with the freedom required by an agile society. Is the technology mature, will the performance be sufficient to limit interference to an acceptable level and achieve scalability?

[Werner Mohr]: First SON (self-organizing network) concepts are already introduced into the market. However, further research is needed to manage the increasing complexity and interference. Accurate channel estimation is a pre-condition for many interference management algorithms, which may limit mobility of users and may require a new radio interface (shorter frames).

[IC1004]: Many concepts have been investigated in research in the last or not so recent years, such as multi-user interference cancellation, cooperative communications, cognitive radio, smart antennas and many others. Do you foresee any one to contribute significantly to performance/capacity gains of networks in 2020?

[Werner Mohr]: Most probably, all these concepts will be needed to improve system performance by addressing different effects. An optimal integrated combination of the different building blocks is needed to exploit physical limits.

[IC1004]: Millimeter waves are now considered by some manufacturers as a truly promising way to ensure high data rate provision towards the user, even the mobile user, or within the network (backhauling). Do you believe in that? Is the semiconductor industry ready? Can the physics based limitations, essentially propagation related, be mitigated at the 2020 horizon? Will we need sophisticated techniques, such as electronic beam forming to achieve the needed link budgets?

[Werner Mohr]: Millimeter wave systems will mainly be used for point-to point nomadic and/or indoor applications or back- and front-hauling due to their propagation conditions (mainly LOS possible, higher path loss and atmospheric attenuation) and not for full area coverage. There are potentially wider frequency bands available. The basic technology is available from microwave and satellite links. However, advanced antenna technologies are necessary to mitigate the higher path loss.

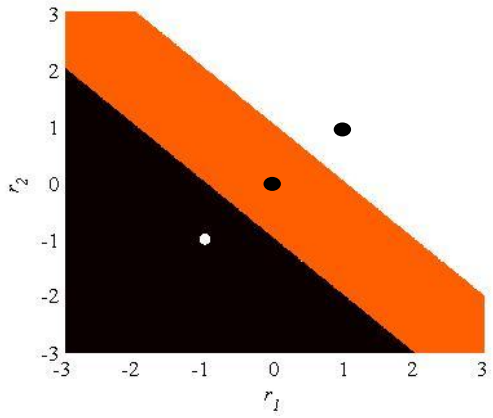
[IC1004]: Thank you!

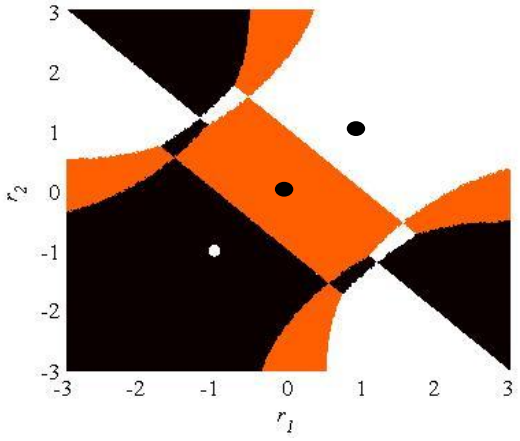
**Werner Mohr** was graduated from the University of Hannover, Germany, with the Master Degree in electrical engineering in 1981 and with the Ph.D. degree in 1987. Dr. Werner Mohr joined Siemens AG, Mobile Network Division, in Munich, Germany in 1991. He was project manager of the EU FRAMES Project, which developed the basic concepts of the UMTS radio interface. Since April 2007 he is with Nokia Siemens Networks in Munich, Germany, where he is Head of Research Alliances. He was coordinator of the EU WINNER Project, chairman of WWI (Wireless World Initiative) and of the Eureka Celtic project WINNER+, which laid the foundation for the IMT-Advanced radio interface and provided the starting point for the 3GPP LTE standardization. Werner Mohr was founding chair of the "Wireless World Research Forum – WWRF" from 2001 to 2003. Currently, he is chair of the European Technology Platform Net!Works. Werner Mohr is co-author of three books on mobile communications.

**Selected scientific topic:** "Robust receivers in impulsive noise", *by Wei Gu, Gareth W. Peters, Laurent Clavier, François Septier, Ido Nevat* (TD(13)07026)

In wireless communications, both the network interference and the thermal noise should be considered in receiver design, due to the strong impairments each may cause on the quality of the reception. It has been shown in many situations (ad hoc networks, cognitive radio, impulse radio ultra wide band...) that a Gaussian approximation is not adequate for interference, which exhibits an impulsive behavior. The challenge we address is to define robust receivers in different noise configuration, especially when the impulsiveness of the observed interference varies.

Suppose a single symbol $X \in \{-1,0,1\}$ is transmitted twice. $r_1$ and $r_2$ are the received values. The two figures represent the decision regions for a purely Gaussian noise (left) and an $\varepsilon$-contaminated noise (right) which represents an impulsive case. It is clearly seen that the linear receiver will not work very well in impulsive situation due to important mismatch between the decision regions.




*For more details please contact: laurent.clavier@telecom-lille1.eu*

**Selected scientific topic:** "Radio channel measurements in live LTE networks", by Pekka Kyösti and Pasi Kemppainen (TD(13) 07053)

Radio channel measurements have been conducted for several decades to capture different radio channel parameters. There have been a high variety of targets for the measurements. Among others the purpose may have been either to collect site specific information for, e.g., network planning or network problem solving, or to gather channel parameters for more general channel modelling use. Typically either self-made, by research institutions, or commercial channel sounders of different kinds have been utilized in measurements.

A good side of multi-dimensional channel sounders is their high accuracy and resolution. In the best case a sounder may resolve propagation paths in time, frequency/delay, polarization, and azimuth & elevation direction at both link ends. A down side of sounder measurements is, e.g., the cost and weight of devices, and a need of separate Tx and Rx units. Typically sounder measurements are laborious and difficult to repeat, and thus require very good planning beforehand.

A scanner measurement in a live network gives a simpler, but less accurate and less versatile, alternative for sounder measurements. By scanner we mean a portable device capable of receiving downlink broadcasting signals of a network, decoding them, and recording them. Base stations of a network act as transmitters, so there is need neither for a separate transmitter of a sounding signal nor to get any license to utilize a frequency. In this paper we discuss measurements for getting insight to site specific or route specific radio channel characteristics for cable (conducted) or over-the-air radio channel emulations. The channel measurement system is capable of capturing the dynamic received signal level (Fig. 1), channel power delay profile, received polarization power ratio, Ricean K-factor (Fig. 2) and antenna signal correlations.

*For more details please contact: pekka.kyosti@anite.com*

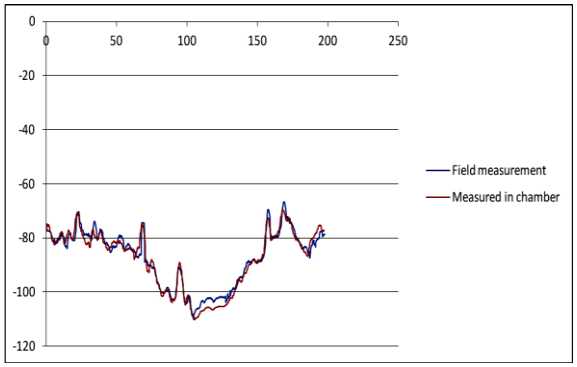



Fig. 1: Measured and approximated Rx power level from a live LTE network.

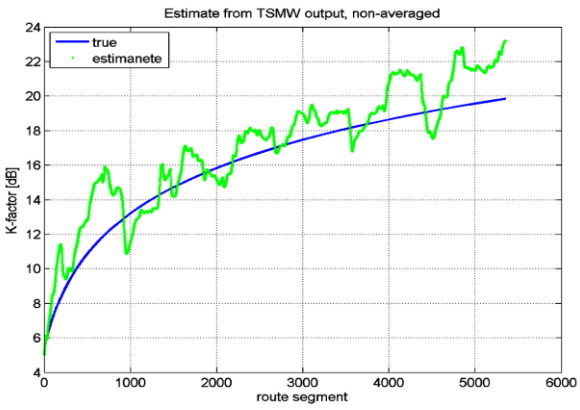



Fig. 2: Dynamic Ricean K-factor measurements with K-factor linear in linear scale.

## Selected scientific topic: "Analysis and Modeling of the Polarization Characteristics of Diffuse Scattering in Indoor and Outdoor Radio Propagation", by Enrico M. Vitucci, Francesco Mani, Claude Oestges, Vittorio Degli-Esposti (TD(13)07052)

The polarimetric characteristics of the radio channel are of notable importance for modern MIMO radio transmission techniques, where the polarization domain can be exploited to implement diversity or multiplexing schemes and therefore increase transmission performance. The adoption of dual-polarized antenna elements is very attractive as it allows in theory a doubling in the number of input/outputs of the MIMO link with a less than proportional increase of the antenna-array size. The analysis and the modeling of the polarimetric properties of the radio channel is quite difficult as traditional empirical-statistical propagation models do not account for them, and there is a relative scarcity of specific models addressing polarization. It has been proven that in deterministic propagation models, as ray-tracing, diffuse scattering (or Dense Multipath Component, DMC) has a major role in determining the polarimetric behavior of the radio channel. For this reason, in this paper we present the summary of a comprehensive work of derivation, parametrization and validation of a polarimetric model for ray-based diffuse scattering, both in outdoor and indoor scenarios with the help of several measurement campaigns. One of the characteristics of this model is its simplicity. As a matter of fact it relies on a single parameter: $K_{xpol}$. Results show that $K_{xpol}$ increases - and therefore depolarization of the diffuse component increases - with the increase of complexity in the scenario. It ranges from a minimum of ≈0 considering backscattering from an isolated rural building (low depolarization), to a maximum of about 0.5 in indoor scenarios (full depolarization). In urban scenarios values of $K_{xpol}$≈0.3 are found.

*For more details please contact: enricomaria.vitucci@unibo.it*

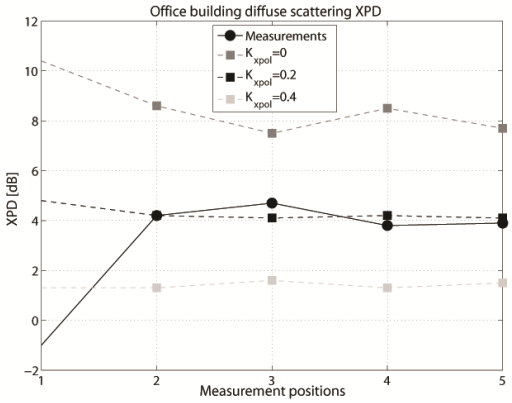



Fig. 1: Cross-polar Discrimination (XPD) of DMC in office scenario for different values of $K_{xpol}$.

TABLE I
Best-fit $K_{xpol}$ values in the different scenarios

| *Environment type* | $K_{xpol}$ |
|---|---|
| Rural Building | 0.05 |
| Office Building | 0.2 |
| Campus Scenario | 0.2 ÷ 0.3 |
| Street-Canyon Scenario | 0.3 |
| Indoor Office Scenario | 0.5 |
| Indoor Lab Scenario | 0.55 |

## Selected scientific topic: "Potential Games for Distributed Coordination of Wireless Network Coding Based Cloud", by Tomas Hynek and Jan Sykora (TD(13)07031)

This paper provides a game theoretical analysis of self-organization algorithm for complex relay networks based on wireless network coding (WNC), see Fig.1. Recent approaches assume mainly a centralized control of the network or are based on a random selection of WNC operation at the relay. The former needs an "omnipotent" control entity and intensive communication overhead the latter does not always guarantee decodability of WNC at the destinations.

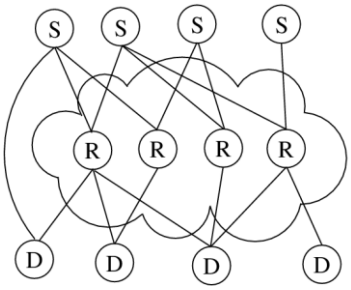



Fig. 1: Example of network topology

To improve the network performance (minimize flows inside the network) a repeated myopic learning process for selecting of proper Hierarchical Network Code (HNC) – a combining function of incoming streams (note that the XOR is not the only one possibility) – is analysed. In several steps of the algorithm each relay is offered a chance to improve its local utility function – output cardinality in presented case - while the decodability of WNC is definitely always ensured. We show that this learning process has promising game theoretical properties, such as existence of the Nash equilibrium and inherent convergence to it, see Fig.2 for 2-source 2-relay network example. Although this paper assumes a Hierarchical Decode and Forward strategy the proposed algorithm is suitable also for Compute/Amplify/Joint Decode/… and Forward strategy in wireless as well as in wire-line networks.

*For more details please contact: hynetom@fel.cvut.cz*

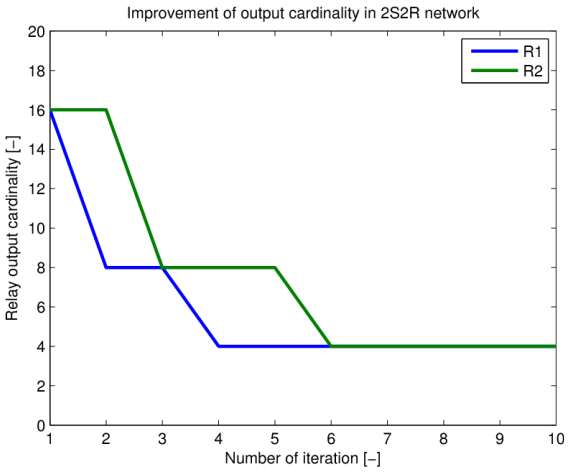



Fig. 2: Progress of learning process in two source two relay network

**Next Training School** (open to anyone, see here for updated information)

**"FUNDAMENTAL RESEARCH THROUGH EXPERIMENTATION"** (Barcelona, Spain, end of November 2013)

Organized jointly with the NEWCOM# Network of Excellence

Topics: channel characterisation, PHY layer, Flexible interfaces, IoT applications.

Organizer: Dr. Miquel Payaro (CTTC)

**Short course at Eucap 2014** (open to anyone, see here for updated information)

**"PROPAGATION AND CHANNEL MODELLING FOR 4G"** (The Hague, Netherlands, April 5/6, 2014)

Organized jointly with the NEWCOM# Network of Excellence

Topics: channel characterisation, PHY layer, Flexible interfaces, IoT applications.

Organizers: Claude Oestges (UCL, Louvain, BE)
Thomas Kürner (T.U. Braunschweig, DE)

**Next Management Committee meeting:** the 8th MC meeting (Sept 25-27, 2013, Ghent, Belgium) will be accompanied on Sept. 25 by a joint Workshop with the IC1102 VISTA COST Action. The topic will be "Terminal Antenna Systems for 4G and Beyond". The deadline for submitting abstracts is July 21. see the CFP here.

Following the workshop, a "special cluster" of **IEEE Antennas and Wireless Propagation Letters** has been accepted in order to host journal papers on this topic.

Guest Editors: Buon Kiong Lau, Lund University, SE)
Marta Martinez Vazquez (IMST, DE)

**9th Management Committee meeting:** the 9th MC meeting will take place in Ferrara, Italy (5-7 Feb. 2014).

## COST IC1004 White Paper to H2020: "Scientific challenges towards 5G mobile communications"

This white paper is currently being prepared for dissemination towards the EU Commission and the general public, in order to provide inputs for the preparation of the future R&D programs on "beyond 4G".

EURACON
European Association of Communications and Networking

**EURACON** is a non-profit Association of Communications & Networking, aiming at:

- Organise and endorse European Conferences, European workshops, and all associated events in the field of Communications and Networking (hereinafter, C&N);
- Support European Schools, as well as M.Sc. & PhD programmes on C&N;
- Create or endorse (on-line) scientific publications (books, periodicals) with the highest scientific standards in C&N
- Create a European web portal about research and education in C&N based also on the former European ViCe-WiCom (Virtual Centre of Excellence in Wireless Communications);
- Circulate and exchange information among European scientists and engineers in C&N, and promoting standardisation;
- Facilitate contacts between, on the one hand, the academic and scientific milieu and, on the other hand, industry, services and Institutions at the European level in C&N;
- Promote European research on C&N;
- Promote and harmonize co-operation across national C&N communities and Societies;
- Support the EC in the definition of the research agenda in C&N;
- Coordinate and manage large-scale C&N research and formation initiatives

WILEY ONLINE LIBRARY AGU American Geophysical Union
RADIO SCIENCE

## Radio Science
## Opened Special Issue:
## Green Radio Communications

Associate Editor: Sana Salous

Guest Editor: Alain Sibille

Papers accepted from May 1, 2013

Submission deadline: August 31, 2013

See the Radio Science Web Site for further details and access to the CFP

A special section on, "Green Radio Communications", to be published in the Journal of Radio Science, has been approved. The Special Section will open for submissions in GEMS on May 1, 2013 and close to submissions on July 31, 2013. The special section will include invited papers and we are pleased to announce that three invited authors have already accepted our invitation to submit review papers. The special section is also open to all members of the COST IC1004 Action and to radio scientists. Please submit your contribution after the 1st of May to ensure that it is included in the special section and we look forward to a successful issue on Green Radio Communication.

An **invited session has been organized by IC1004** in the Future Networks & Mobile Summit (FUNEMS 2013), in Lisbon. In addition to a global presentation of IC1004 activities and results, three highlights of original research goals were shown.

Future Network & Mobile Summit 2013
3 - 5 July 2013, Lisbon, Portugal

**COST IC1004 Activities: Cooperative Radio Communications for Spectrum and Energy Efficiency in coming Traffic Scenarios**
Narcis Cardona, Universidad Politecnica de Valencia, Spain

**Impact of Realistic Mobility Modelling in the Context of Propagation Modelling on the User and Network Experience**
Dennis Rose, Technische Universität Braunschweig, Germany

**Statistical Modelling of Antennas Applied to Realistic Use Cases in Wireless Networks**
Alain Sibille, Telecom ParisTech, France

**Traffic Steering by Self-tuning Controllers in Enterprise LTE Femtocells**
Salvador Luna-Ramirez, University of Málaga, Spain

**Designing Advanced Energy-efficient Wireless Access Networks by a Capacity based Deployment Tool**
Margot Deruyck, Ghent University/iMinds, Belgium

*The presentations can be obtained from the authors*

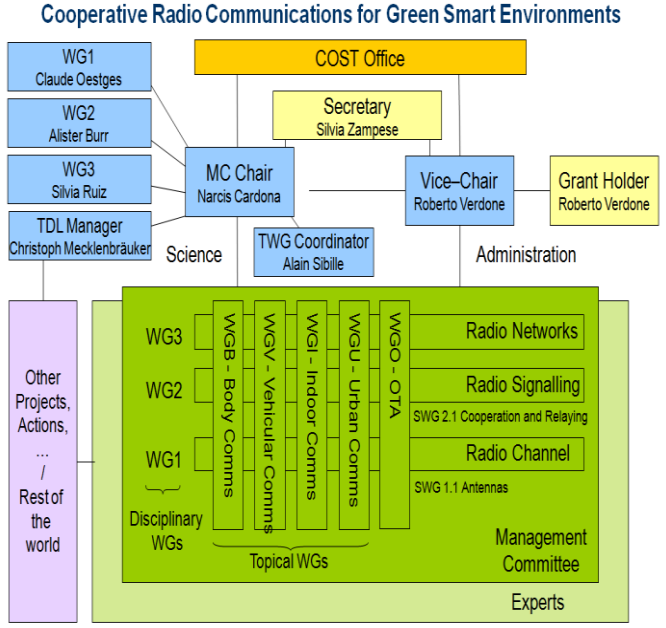
## About COST IC1004

COST IC1004 is the Action on **"Cooperative Radio Communications for Green Smart Environments"**, belonging to the ICT Domain of the COST framework (see www.cost.eu). This Action addresses research issues in the field of cooperative radio communications to make our society cleaner, safer and more energy efficient. It started on January 2011 and will end on May 2015. Among many activities, 3 meetings and at least one training school are organized per year.

The Action goals are:

- to increase knowledge of cooperative communications applied to Green SEs (GSEs), by exploring and developing new methods, models, techniques, strategies and tools, in a context enriched by deep industry-academia links
- to play a supporting role to European industry through the focused interest of Working Groups
- to train young researchers in the field of cooperative radio communications for GSEs

The MoU and all information can be found at http://www.ic1004.org or by contacting the secretariat at secretary@ic1004.org




## Facts & Figures

Number of signatory countries: **28**
*Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom.*

Number of non-COST countries: **7**
*Australia, Canada, China, Colombia, Japan, Montenegro, USA*

Number of COST country entities (institutes, etc.) currently participating: **129**

Number of non-COST entities (institutes, etc.) currently participating: **13**

Number of MC Members: **52** (+ Chair)

Number of registered experts: **461**

Number of meetings / year: **3**

Number of training schools / year: **≥1**

Number of completed STSM: **17**

Number of presented TD/workshop papers: **470**

Average number of participants / meeting: **120**