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Mobile Communications Group (MCG) Annual Research Report 2016/2017

Head of the Group research report

The Mobile Communications Group of the ITEAM is currently involved in different research projects, which are divided in three main research areas: Wireless In-body Devices, Broadcast Technologies and Wireless Technologies.

In the framework of Wireless In-body Devices, the MCG has been working towards three different fields. Firstly, accurate characterization of the UWB in-body propagation channel which implies the design of novel in-body antennas taking into account the particular characteristics of the surrounding environment. Secondly, the development of tissue characterization tools that allow either measure biological tissues in wideband as well as the characterization of chemical compounds for laboratory use. And thirdly, the investigation of new phantom formulas for the emulation of different body tissues in wideband that can be used for testing wireless communications signals and algorithms. These tasks are currently undertaken with the support of the Hospital Universitario y Politécnico La Fe of Valencia, and the Centre for Biomaterials and Tissue Engineering of the UPV.

The MCG has extensive knowledge and experience in multimedia broadcasting in general, an in particular in the optimization of DVB (Digital Video Broadcasting), ATSC (Advanced Television Systems Committee) and 3GPP MBMS (Multimedia Broadcast Multicast Service) systems. Within this field, the MCG has been actively contributing to the standardization of the DVB-T2, DVB-NGH and ATSC 3.0 standards and has established fruitful collaborations with leading companies in the broadcasting industry. Moreover, the group has participated in the design and network planning of the DVB-T2 network in Colombia and has evaluated the spectrum compatibility between 4G cellular technologies and analog and digital TV broadcast systems.

In the framework of Wireless Technologies, the MCG focuses its researches in two different fields. On the one hand, there is a clear research line devoted to the new generation of mobile and wireless communications, known as 5G. This area focuses on radio aspects for future communication networks. On the other hand, the group is working on vehicular communications with the aim of guaranteeing the optimum operation of each vehicle communication equipment and its interconnection in a 5G technology use scenario, and thereby contribute to reduce the number of traffic crashes and to increase the levels of road safety.

The flagship projects of the MCG during the last years have been METIS and METIS-II, which have placed the MCG among the most important research groups in the development of 5G technology. Recently, the MCG has secured funding for two European projects. One of them is called 5G-Xcast, with a budget of around 8 million euros and coordinated by the MCG, that started on June 2017. The other is an MSCA-ITN Action about mmW MIMO and massive MIMO antennas, and the starting date is October 2017.

1.- Project activities

1.1.- Ongoing projects

1. Developing Future Architectures and Technologies towards 5G Networks (DEFINE-5G)

This project deals with the integration of mmW and small-cells into current and future wireless communication systems. The proposal is to research on some particular aspects related to the integration in V2X communications.

This project has been funded by the Spanish Government.

2. Technologías de Radiodifusión Digital Extra-Terrestre (E.T. Broadcast)

The main scientific objective of the E.T.Broadcast project is to investigate and validate new technological solutions for the next generation of standards of Digital Terrestrial Television (DTT), which intend to redefine the DTT of the future allowing the efficient transmission of ultra-high definition (UHD) fixed services and high definition mobile services (HD) to mobile devices, especially tablets, using much less spectrum.

This project has been funded by the Spanish Government.

3. Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society-II (METIS-II)

https://5g-ppp.eu/metis-ii/

METIS-II is a project with 23 partners co-funded in the European H2020 research programme with a budget of 8 M€. Ericsson is the project coordinator and Nokia Networks is the technical coordinator. Further partners are Alcatel Lucent, Deutsche Telekom, Huawei, iDate, Intel, ITRI, Janmedia Interactive, KTH, NTT DOCOMO, NYU, Orange, Samsung, Telecom Italia, Telefónica, University of Kaiserslautern, Universitat Politècnica de València and WINLAB. The main objective of METIS-II is the development of the necessary means to integrate the new technology, as well as the evolution of the already existing ones, in an efficient, scalable and versatile 5G radio system design.

This project has been funded by the European Commission

4. Wireless In-Body Environment Communications (WIBEC)

https://www.ntnu.edu/wibec

This project is an Innovative Training Network that aims to train excellent researchers in the field of wireless communications inside the body. In particular, the two main application areas are Wireless Capsule Endoscopy (WCE) and pacemakers. WIBEC project will have a duration of 4 years during which 16 researchers will be trained in 8 European institutions, among them. WIBEC consortium is coordinated by Oslo University Hospital from Norway and is composed of 3 universities (Norges Tekninsk-Naturvitenskapelige Universitet, Norway; Universitat Politècnica de València, Spain; and Technische Universität Dresden, Germany); 3 companies (Sorin CRM, France; Ovesco AG, Germany; and ValoTec, France); and 2 university hospitals (Hospital Universitario y Politécnico La Fe, Spain; and Oslo University Hospital, Norway).

This project has been funded by the European Commission

5. Early Stage Colon Tumour Diagnosis by Electromagnetic Reflection (STuDER)

This is a joint collaborative project with Hospital La Fe, jointly funded by both public institutions. This project is devoted to the investigation of the potential applications for early stage colon tumour detection and diagnosis based on the different electromagnetic properties of healthy and malignant colon tissues. The first trials of the project took place during Spring 2017.

This project has been funded by the Hospital Universitario y Politécnico La Fe and the Universitat Politècnica de València.

6. Multiple Antenna Schemes for LDM

This project is a collaboration with the Electronics and Communications Research Institute (ETRI) from Korea in the disruptive non-orthogonal multiplexing mode, known as Layered Division Multiplexing (LDM), adopted on the new U.S. DTT standard, ATSC 3.0.

This project has been funded by ETRI.

7. Broadcast and Multicast Communication Enablers for the Fifth Generation of Wireless Systems (5G-Xcast)

It is a new project of the 5GPPP's second phase and involves researchers from Spain, Finland, Germany, United Kingdom, France, Hungary, Israel, Netherlands, Italy and Switzerland, being coordinated by the MCG of the hand of Dr. David Gómez Barquero. The 5G-Xcast is a two-years' project, that started in June 2017 and is funded with a budget of around 8 million euros. The main objective of the project is to design the point-to-point multicast and broadcast components of the 5G.

This project has been funded by the European Commission.

A complete list of research projects can be found at http://www.iteam.upv.es/group/mcg.html

2.- Research results

2.1.- Featured publications

1. **Interference Analysis Between Digital Terrestrial Television (DTT) and 4G LTE Mobile Networks in the Digital Dividend Bands**. Jefferson Ribadeneira, Gerardo Martínez, David Gómez Barquero, Narcís Cardona. IEEE Transactions on Broadcasting, pp.24-34, 2015.

DOI: 10.1109/TBC.2015.2492465

With the introduction of digital terrestrial television (DTT) and the analogue television switch-off, terrestrial broadcast spectrum in the UHF band is being released for mobile communications, in particular for fourth generation (4G) long term evolution (LTE) mobile services. This spectrum is known as digital dividend. an impending problem when deploying 4G LTE mobile networks in the digital dividend bands is that interferences may appear in the adjacent radio frequency channels used for DTT. In this paper, we analyze the adjacent coexistence of DTT and 4G LTE networks in the digital dividend bands at 700 MHz and 800 MHz.

2. **An Overview of the ATSC 3.0 Physical Layer Specification**. Luke Fay, Lachlan Michael, David Gómez-Barquero, Nejib Ammar, and M. Winston Caldwell. IEEE Transactions on Broadcasting, pp 159-171, 2016.

   DOI: 10.1109/TBC.2015.2505417

   This paper provides an overview of the physical layer specification of Advanced Television Systems Committee (ATSC) 3.0, the next-generation digital terrestrial broadcasting standard.

3. **Bit-Interleaved Coded Modulation (BICM) for ATSC 3.0**. Lachlan Michael and David Gómez-Barquero. IEEE Transactions on Broadcasting, pp 181-188, 2016.

   DOI: 10.1109/TBC.2015.2505414

   In this paper, we summarize and expound upon the choices made for the bit-interleaved coded modulation (BICM) part of the next-generation terrestrial broadcast standard known as ATSC 3.0.

4. **Cooperative Radio Communications for Green Smart Environments**. Narcís Cardona. River Publishers 2016.

   DOI: 10.13052/rp-9788793379145

   The demand for mobile connectivity is continuously increasing, and by 2020 Mobile and Wireless Communications will serve not only very dense populations of mobile phones and nomadic computers, but also the expected multiplicity of devices and sensors located in machines, vehicles, health systems and city infrastructures. This book addresses both the techniques to model, analyse and optimise the radio links and transmission systems in many new scenarios, together with the most advanced radio access, resource management and mobile networking technologies.

5. **5G Mobile and Wireless Communications Technology**. Afif Osseiran, Jose F. Monserrat, Patrick Marsch. Cambridge University Press, June 2016.

   DOI: 10.1017/CBO9781316417744

   Written by leading experts in 5G research, this book is a comprehensive overview of the current state of 5G. Covering everything from the most likely use cases, spectrum aspects, and a wide range of technology options to potential 5G system architectures, it is an indispensable reference for academics and professionals involved in wireless and mobile communications.

6. **Spectrum Sharing for LTE-A and DTT: Field Trials of an Indoor LTE-A Femtocell in DVB-T2 Service Area**. Gerardo Martínez-Pinzón, Narcís Cardona, Concepción García-Pardo, Alejandro Fornés-Leal, Jefferson Ribadeneira. IEEE Transactions on Broadcasting, pp. 552-561, 2016.

   DOI: 10.1109/TBC.2016.2582338

   In the near future, many applications such as environmental sensors, smart objects, health sensors, and personal devices will be connected to mobile networks requiring additional spectrum. Studies have been made to demonstrate a low occupancy time and locations on the digital terrestrial television (DTT) band. In this paper, we study a particular case which goes a step beyond the previous ones, as it aims at sharing the same frequency band in the same area between long term evolution-advance (LTE-A) and digital video broadcasting-terrestrial second generation (DVB-T2) technologies.

7. **Spatial In-Body Channel Characterization Using an Accurate UWB Phantom**. Carlos Andreu, Sergio Castelló-Palacios, Concepción García-Pardo, Alejandro Fornés-Leal, Ana Vallés-Lluch, Narcís Cardona. IEEE Transactions on Microwave Theory and Techniques, pp 3995-4002, 2016.

   DOI: 10.1109/TMTT.2016.2609409

   UWB systems have emerged as a possible solution for future wireless in-body communications. However, in-body channel characterization is complex. Animal experimentation is usually restricted. Electromagnetic software tools are expensive and imply a high computational cost. Chemical solutions, known as phantoms, can solve this issue. However, achieving a reliable UWB phantom is challenging since UWB systems use a large bandwidth and the permittivity of human tissues are frequency-dependent. In this work, a measurement campaign within 3.1-8.5 GHz by using an UWB phantom is performed. This phantom achieves the best known approximation to the permittivity of human muscle within UWB band. Measurements were performed in different spatial positions, to investigate also the diversity of the in-body channel in the spatial domain.

8. **Tailor-Made Tissue Phantoms Based on Acetonitrile Solutions for Microwave Applications up to 18 GHz**. Sergio Castelló-Palacios, Concepción García-Pardo, Alejandro Fornés-Leal, Narcís Cardona, Ana Vallés-Lluch. IEEE Transactions on Microwave Theory and Techniques, pp. 3987-3994, 2016.

   DOI: 10.1109/TMTT.2016.2608890

   Tissue-equivalent phantoms are a key issue in the development of wireless devices that are tested on them before their commercialization.

However, existing phantoms cover a few tissues and do not reproduce them accurately within wide frequency bands. This paper aims at enlarging the number of tissues as well as their working frequency band.

9. **Performance Evaluation of Analog Beamforming with Hardware Impairments for mmW Massive MIMO Communication in an Urban Scenario**. Sonia Gimenez, Sandra Roger, Paolo Baracca, David Martín-Sacristán, Jose F. Monserrat, Volker Braun and Hardy Halbauer. Sensors 16 (10), 1555, 2016.

   DOI: 10.3390/s16101555

   The use of massive multiple-input multiple-output (MIMO) techniques for communication at millimeter-Wave (mmW) frequency bands has become a key enabler to meet the data rate demands of the upcoming fifth generation (5G) cellular systems. In particular, analog and hybrid beamforming solutions are receiving increasing attention as less expensive and more power efficient alternatives to fully digital precoding schemes. Despite their proven good performance in simple setups, their suitability for realistic cellular systems with many interfering base stations and users is still unclear. Furthermore, the performance of massive MIMO beamforming and precoding methods are in practice also affected by practical limitations and hardware constraints. In this sense, this paper assesses the performance of digital precoding and analog beamforming in an urban cellular system with an accurate mmW channel model under both ideal and realistic assumptions.

10. **Dielectric characterization of healthy and malignant colon tissues in the 0.5–18 GHz frequency band**. Alejandro Fornés-Leal, Concepción Garcia-Pardo, Matteo Frasson, Vicente Pons Beltrán and Narcís Cardona. Physics in Medicine and Biology, pp 7334-7346, 2016.

    DOI: 10.1088/0031-9155/61/20/7334

    Several reports of last decades show that the electromagnetic properties of healthy and malignant tissues of the same body organ usually have different values. However, there are not large studies of human colon tissue, despite being one of the most common types of cancer worldwide. In order to provide information regarding this matter, a dielectric characterization of healthy and malignant colon tissues is presented.

11. **The METIS 5G System Concept: Meeting the 5G Requirements**. Hugo Tullberg, Petar Popovsky, Zexian Li, Mikko A. Uusitalo, Andreas Hoglund, Omer Bulakci, Mikael Fallgren, Jose F. Monserrat. IEEE Communications Magazine, pp 132-139, 2016.

    DOI: 10.1109/MCOM.2016.1500799CM

    The development of every new generation of wireless communication systems starts with bold, high-level requirements and predictions of its capabilities. The 5G system will not only have to surpass previous generations with respect to rate and capacity, but also address new usage scenarios with very diverse requirements, including various kinds of machine-type communication. Following this, the METIS project has developed a 5G system concept consisting of three generic 5G services: extreme mobile broadband, massive machine-type communication, and ultra-reliable MTC, supported by four main enablers: a lean system control plane, a dynamic radio access network, localized contents and traffic flows, and a spectrum toolbox. This article describes the most important system-level 5G features, enabled by the concept, necessary to meet the very diverse 5G requirements.

2.2.- Patents

1. **Modelo sintético de tejidos biológicos para la evaluación de la transmisión inalámbrica de ondas electromagnéticas**. Cardona Marcet Narciso; Castelló-Palacios Sergio; Fornés Leal Alejandro; Concepcion Garcia-Pardo; Vallés Lluch Ana. Spanish Patent Office PCT/ES2016/070912. Granted

2. **Interleaving for Layer-Aware Forward Error Correction**. Hellge Cornelius; Thomas Schierl; Thomas Wiegand; David Gomez-Barquero. US Patent 9473174. Granted

3. **Mobile reception of digital video broadcasting - terrestrial services**. T. Stockhammer; David Gomez-Barquero; Gozálvez Serrano David. US Patent 9281847 B2. Granted.

4. **Sistema de comunicaciones entre una interfaz radio NFC y un segundo dispositivo y procedimiento para la puesta en práctica del mismo**. Monserrat del Río Jose Francisco; Cardona Marcet Narcis. Spanish Patent Office ES 2 403 337. Under exploitation by SistelNetworks S.L.

5. **Procedimiento y sistema de monitorización, gestión y control de redes inalámbricas multi-tecnología**. Spanish Patent Office ES 2 395 638. Under exploitation by Sistelbanda S.A.

6. **Method, device, Computer program and Computer program product for broadcasting a road hazard warning**, European Patent Office EP13179511.4-1858. Granted.

7. **Method for Non-Coherent Multi-User MIMO Data Communication and System for Performing Such Method**, European Patent Office, application PCT/EP2014/072518. Granted.

8. **Methods, telematics server and base station for supporting vehicular communications in a cellular network**, European Patent Office, application PCT/EP2014/0842. Granted.

9. **Method and device for service following between digital audio broadcasting (DAB) services and enhanced multimedia broadcast/multicast services (eMBMS)**, European Patent Office, application PCT/EP2014/0840. Granted.

2.2.- Awards.

1. Merit Decoration Award as best young researcher, Royal Academy of Science, Spain. (José F. Monserrat del Río, David Gómez Barquero, Daniel Calabuig Soler, Sandra Roger Varea y David Martín-Sacristán Gandía).

2. Best Conference Paper award at the International Broadcasting Convention (IBC 2016) (Jordi Joan Gimenez Gandía).

3. Best Student Paper Award at the 2017 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB) (José Luis Cárcel Cervera).