



FP7-ICT Future Networks
SPECIFIC TARGETTED RESEARCH PROJECT
Project Deliverable

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Abstract: During this fifth semester, the dissemination activity has mainly consisted in the publication of articles and papers at the conferences whose scope includes the technical area of the project and the organization of special sessions in conferences. A new presentation of the website has been made available with new features. The demonstrator hardware has been presented at exhibitions during EW'2010 in April and the ICT-Mobile Summit in June.

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1 INTRODUCTION

This document describes the actions of dissemination taken by the phydyas project members during the fifth semester.

List of partners:

Beneficiary Number *	Beneficiary name	Beneficiary short name	Country
1(coordinator)	Conservatoire National des Arts et Métiers	CNAM	France
2	Technische Universität München	TUM	Germany
3	Tampere University of Technology	TUT	Finland
4	Université Catholique de Louvain	UCL	Belgium
5	SINTEF - Trondheim	SINTEF	Norway
6	Centre Tecnologic de Telecomunicacions de Catalunya	CTTC	Spain
7	Research Academic Computer Technology Institute	RA-CTI	Greece
8	University of Napoli Federico II	UNINA	Italy
9	CEA-LETI	LETI	France
10	Agilent-Belgium	AGI	Belgium
11	Alcatel-Lucent Swindon	ALUK	United Kingdom
12	Alcatel-Lucent Deutschland	ALUD	Germany
13	COMSIS	COMSIS	France

2 JOURNAL ARTICLES AND CONFERENCE PAPERS

The following articles and papers were presented or submitted during the year 2010 by the partners, in relation with their work in the project.

Journals

A. M. Kuzminskiy, Y. I. Abramovich, "Decentralized dynamic spectrum allocation based on adaptive antenna array interference mitigation diversity," *IEEE Trans. on Signal Processing*, vol. 58, no.4, pp. 2246-2260, Apr. 2010.

T. Ihalainen, A. Ikhlef, J. Louveaux and M. Renfors, "Channel Equalization for Multi-Antenna FBMC/OQAM Receivers", submitted to *IEEE Trans. Vehicular Technology*, May 2010.

T. Ihalainen, A. Viholainen, T. Hidalgo Stitz and M. Renfors, "Generation of Filter Bank-Based Multicarrier Waveform Using Partial Synthesis and Time Domain Interpolation", *IEEE Trans. Circuits and Systems I. Regular Papers*, Forthcoming, 2010, 13 pages.

T. Hidalgo Stitz, T. Ihalainen, A. Viholainen, and M. Renfors, "Pilot-Based Synchronization and Equalization in Filter Bank Multicarrier Communications", *EURASIP Journal on Advances in Signal Processing*, vol. 2010, Article ID 741429, 18 pages

D. Katselis, E. Kofidis, A. Rontogiannis, and S. Theodoridis, "Preamble-based channel estimation for CP-OFDM and OFDM/OQAM systems: A comparative study," *IEEE Trans. Signal Processing*, vol. 58, no. 5, pp. 2911-2916, May 2010.

A. Merentitis and D. Triantafyllopoulou, "Resource allocation with MAC layer node cooperation in cognitive radio networks," *International Journal of Digital Multimedia Broadcasting*, special issue on "Spectrum Sharing and Sensing for Future Broadband Networks: The Cognitive Radio Technology," vol. 2010, Article ID 458636, doi:10.1155/2010/458636.

M. Shaat, F. Bader, "Computationally Efficient Power Allocation Algorithm in Multicarrier Based Cognitive Radio Networks: OFDM and FBMC systems", *EURASIP Journal on Advanced Signal Processing (ASP)*. Volume 2010, Article ID 528378, doi:10.1155/2010/528378. March 2010.

T. Fusco, A. Petrella and M. Tanda, "Joint symbol timing and CFO estimation for OFDM/OQAM systems in multipath channels," *EURASIP Journal on Advances in Signal Processing*, Special issue on Filter Banks for Next-Generation Multicarrier Wireless Communications, Volume 2010, article ID 689824, 11 pages.

H. Zhang, D. Le Ruyet, D. Roviras, Y. Medjahdi, and H. Sun, "Spectral Efficiency Comparison of OFDM/FBMC for Uplink Cognitive Radio Networks", *EURASIP Journal on Advances in Signal Processing*, Volume 2010, Article ID 621808, 14 pages.

Chrislin Lélé and Didier Le Ruyet, "Decoding Schemes for FBMC with Single-Delay STTC", EURASIP Journal on Advances in Signal Processing, vol.2010, Article ID 689824, 11 pages.

Conference papers

M. Lagunas, A. I. Perez-Neira, M. Rojas, "Spectrum Sensing for Cognitive Radio in Filter-Bank Multi-Carrier Communications Systems: The Candidate Estimate", WSEAS 2010 Circuit, Systems Signals CSS2010, September 8-12. 2010, Malta.

E. Kofidis and A. Rontogiannis, "Adaptive BLAST decision-feedback equalizer for MIMO-FBMC/OQAM systems," Proc.of IEEE Personal, Indoor and Mobile Radio Communications Symposium (PIMRC), Istanbul, Turkey, 26-29 Sept. 2010.

M. Shaat, F. Bader, "Fair and Efficient Resource Allocation Algorithm for Uplink Multicarrier Based Cognitive Networks", Proc. of IEEE Personal, Indoor and Mobile Radio Communications Symposium (PIMRC), Istanbul, Turkey, 26-29 Sept. 2010.

F. Bader, "Pilot Pattern Adaptation and Channel Estimation in MIMO WIMAX-Like FBMC System", in Proc. of Sixth International Conference on Wireless and Mobile Communications (ICWMC'2010). September 20-25, 2010 - Valencia, Spain.

M. Shaat, "Efficient Uplink Subcarrier and Power Allocation Algorithm in Cognitive Radio Networks", accepted in IEEE Seventh International Symposium on Wireless Communication Systems (ISWCS'2010). York, United Kingdom, 19th-22nd September, 2010

L. Izzo, D. Mattera and M. Tanda, "Multipath-aware joint symbol timing and CFO estimation in multiuser OFDM/OQAM systems" Proc.of EUSIPCO 2010, Aalborg, Denmark, August 23-27, 2010.

Vidar Ringset, Helge Rustad, Frank Schaich, Jurgen Vandermot, Montse Najar," Performance of a FilterBank MultiCarrier (FBMC) Physical Layer in the WiMAX Context", Proc. Future Network & Mobile Summit (FNMS'2010), 16-18 June 2010, Florence, Italy.

T. Ihalainen, A. Viholainen, T. Hidalgo Stitz and M. Renfors, "Spectrum Monitoring Scheme for Filter Bank Based Cognitive Radios", in Proc. Future Networks and Mobile Summit (FNMS 2010), Florence, Italy, 16-18 June 2010.

I. Estella, M. Payaró, A. Pascual-Iserte, "OFDM and FBMC performance comparison for multistream MIMO systems," in Proc. Future Network and MobileSummit (FNMS 2010), 16-18 June 2010, Florence (Italy).

H.Zhang, D.LeRuyet, D.Roviras and H.Sun, "Capacity analysis of OFDM/FBMC based cognitive radio", CROWNCOM conference, Cannes, 9-11 June 2010.

T.Ihalainen, A.Viholainen, T.H.Stitz and M.Renfors, "Reappearing primary user detection in FBMC/OQAM cognitive radios", CROWNCOM conference, Cannes, 9-11 June 2010.

M. Shaat, F. Bader, "An Uplink Resource Allocation Algorithm for OFDM and FBMC Based Cognitive Radio Systems", CROWNCOM conference, Cannes, France. 9-11 June 2010.

A. Merentitis and D. Triantafyllopoulou, "Transmission power regulation in cooperative cognitive radio systems under uncertainties," Proc. International Symposium on Wireless Pervasive Computing (ISWPC), 5-7 May 2010, Modena, Italy.

M. Shaat and F. Bader, "A Two-Step Resource Allocation Algorithm in Multicarrier Based Cognitive Radio Systems", IEEE Wireless Communications and Networking Conference (WCNC'2010). Sydney, Australia. April 2010.

R.Zakaria, D.LeRuyet and M.Bellanger, "Maximum Likelihood decoding in MIMO-FBMC", proc. of European Wireless conference (EW 2010), Lucca, Italy, 12-15 April 2010.

Q. Bai, N. Passas, and J. Nossek, "Scheduling and resource allocation on OFDM and FBMC systems: an interactive approach and performance comparison," European Wireless 2010, Lucca, Italy, April 2010.

M. Renfors, T. Ihalainen, T. Hidalgo Stitz, "A Block-Alamouti Scheme for Filter Bank Based Multicarrier Transmission", in Proc.of European Wireless 2010, Lucca, Italy, 12-15 April 2010.

M. Payaró, A. Pascual-Iserte, M. Nájjar, "Performance Comparison between FBMC and OFDM in MIMO Systems under Channel Uncertainty", European Wireless conf.(EW2010), Lucca, Italy, 12-15 April 2010.

D. Xenakis, D. Tsolkas, N. Passas, and L. Merakos, "Dynamic resource allocation in adaptive multiuser multicarrier systems," European Wireless conf.(EW2010), Lucca, Italy, 12-15 April 2010.

F.Schaich, "FBMC in the WiMAX context", proc. of European Wireless conference (EW 2010), Lucca, Italy, 12-15 April 2010.

A. M. Kuzminskiy, Y. I. Abramovich, "Rule-breaks effect on decentralized rule-regulated "good neighbor" DSA based on adaptive antenna array interference mitigation diversity," in Proc. DySpan, Singapore, April 2010.

M.Bellanger, M.Renfors, T.Ihalainen and C.A.da Rocha, "OFDM and FBMC transmission techniques: a compatible high performance proposal for broadband power line communications", Proc. of IEEE-ISPLC conference, Rio, Brazil, 29-31 March 2010

A. M. Kuzminskiy, Y. I. Abramovich, "Randomized decentralized "good neighbor" DSA based on adaptive antenna array interference mitigation diversity," in Proc. ICASSP, Dallas, March 2010.

M.Bellanger, "Physical layer for future broadband radio systems", Proc. of IEEE Radio and Wireless Symposium (RWS'2010), New Orleans, 10-14 January 2010.

3 SPECIAL SESSIONS AT CONFERENCES

Special sessions have been organized at the 2010 conferences European Wireless and Crowncom (Cognitive radio oriented wireless networks and communications).

EW2010- European Wireless - 12/15 April 2010 - Lucca (www.ew2010.org)

Session title: Advances in multicarrier technologies: the Phydyas FP7 project
After a brief introduction entitled “Multicarrier physical layer for cognitive radio” given by M.Bellanger, the following talks were presented

- F.Schaich, “FBMC in the WiMAX context”
- M.Najar, ” MIMO Schemes for filter bank multicarrier systems”
- M.Renfors, “ FBMC and the Alamouti scheme”
- R.Zakaria, D.Le Ruyet and M.Bellanger “ML decoding in MIMO-FBMC”
- Q.Bai, N.Passas and J.Nossek, “Scheduling and resource allocation on OFDM and FBMC systems: an interactive approach and performance comparison”.

Due to last minute problems encountered by the author, the last paper scheduled in the session

- D. Xenakis, D. Tsolkas, N. Passas, and L. Merakos, “Dynamic resource allocation in adaptive multiuser multicarrier systems”

could not be presented.

A demonstration prepared by partners AGI, SINTEF and CTTC consisted of

- a poster describing the complete system, with transmitter, channel emulator and receiver,
- a slide show for simulation results,
- a hardware setup comprizing OFDM and FBMC transmitters, a channel emulator and a spectrum analyzer. The visitors could see the difference in emitted spectrum between OFDM and FBMC, in the WiMax context.

Hand-outs were distributed to the interested visitors, as well as the FBMC primer.

Crowncom - 9/11 June – Cannes (www.crowncom2010.org)

A special session entitled “ Filter Bank Multi Carrier PHY versus OFDM for Unsynchronized Cognitive Radio Networks” has been organized and chaired by Faouzi Bader (CTTC) and Alexandr Kuzminskiy (ALUK). Four out of the five papers in the session were authored by Phydyas partners and the list is as follows

- M.Shaat and F.Bader, ”An Uplink Resource Allocation Algorithm for OFDM and FBMC Based Cognitive Radio Systems”
- C. H. Yuen, P. Amini and B. Farhang-Boroujeny, “Single Carrier Frequency Division Multiple Access (SC-FDMA) for Filter Bank Multicarrier Communication Systems”, (University of Utah, USA)
- T. Ihalainen, A. Viholainen, T. H. Stitz, M.Renfors, “ Reappearing Primary User Detection in FBMC/OQAM Cognitive Radios”
- A. Kuzminskiy and Y. Abramovich, “ Decentralized "good neighbor" DSA based on adaptive antenna array interference mitigation diversity: Finite amount of data effects”
- H. Zhang, D. LeRuyet, D. Roviras, and H. Sun, “Capacity Analysis of OFDM / FBMC based Cognitive Radio Networks with Estimated CSI”

4 FUTURE NETWORK AND MOBILE SUMMIT, June 16-18, 2010

The project presented 3 papers at the conference, by partners SINTEF-AGI-ALUD-CTTC, TUT and CTTC, respectively.

At the exhibition, the project had a stand for which a show had been prepared by the partners AGI, SINTEF, CTTC and ALUD, in connection with their paper at the conference, which was presented the second day by V.Ringset. As a complement, COMSIS had offered to display their MIMO system. The show consisted of

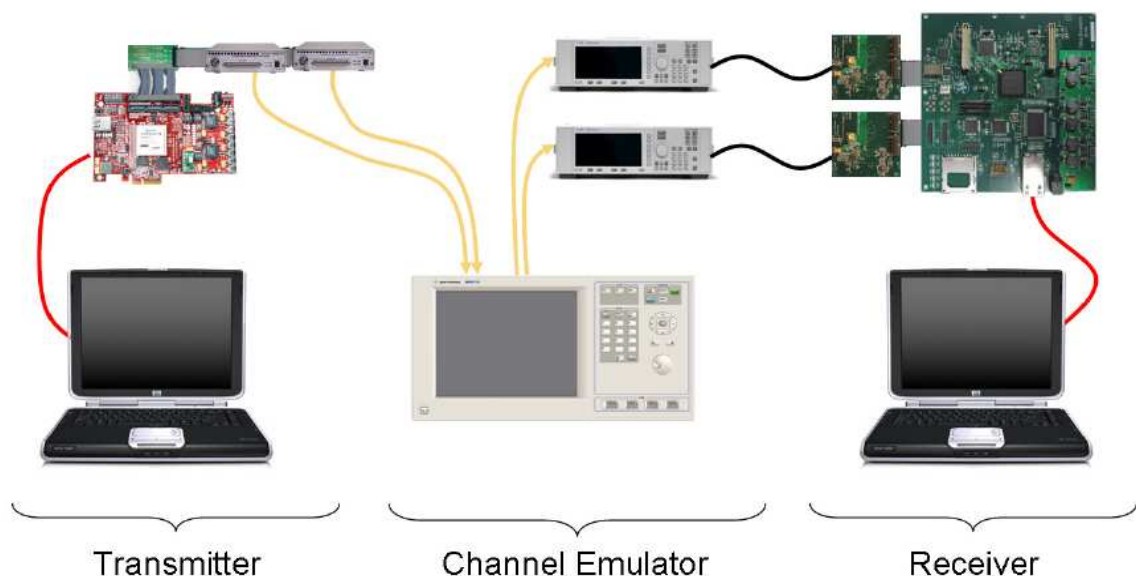
- a transmission system comprising an FBMC/OFDM transmitter, up and down conversion to RF and an FBMC receiver (SISO), with equipments to visualize some signals, particularly the transmitted spectrum and the received data. (see figure below).
- a set of slides showing diagrams and simulation results,
- A WiFi MIMO 2x2 transmitter and receiver.

The visitors could have an overview of the performance of the FBMC physical layer and see some key signals. They could appreciate the sharpness of the transmitted spectrum edges and see a QPSK constellation at the output of the receiver. Due to some remaining problems, in particular in the formatting of the signals between transmitter and receiver, intermediate storage had to be included in the transmission chain and no real time transmission could be performed.

The MIMO equipment presented by COMSIS is based on OFDM and it serves as the reference for assessing FBMC.

The interaction with the visitors was fruitful, through questions and comments. In the discussions, computational complexity was a recurrent subject.

Transmission system deployed at the exhibition



5 STANDARDIZATION

At the November 2009 meeting of ITU-R/WP5A in Geneva, a contribution entitled: “Cognitive radio systems in the land mobile service – technical characteristics and functionalities of cognitive radio systems” was presented by the project. The next step might be a contribution about opportunistic unsynchronized networks, which could be envisaged for the meeting of next November.

Regarding power line communications (PLC), a paper entitled “OFDM and FBMC transmission techniques: a compatible high performance proposal for broadband power line communications” has been presented at the conference ISPLC2010 in March 2010. In the paper, it was shown that applying the Phydias technique to the band 2-28 MHz led to a maximum bit rate of 228 Mbit/s, while OFDM is limited to 197 Mbit/s. In addition, several advantages of the FBMC approach were pointed out, as well as the level of compatibility. Now, it is expected that the paper will impact the discussions going on in the standardization groups, at IEEE and ITU.

An indirect contribution has been made to the standardization activity in broadcasting, DVB-NGH. The MIMO block Alamouti technique developed by TUT has been presented by France-Telecom at the May meeting of the DVB-NGH standardization group.

6 PATENTS

A patent has been filed on 11 December 2009 by ALUD, entitled “Efficient estimation/compensation of increased time-delays without extra pilot tones” . The application serial number is: 09 290 930.8.

7 WEBSITE (<http://www.ict-phydvas.org>)

The February deliverables have been made available in the public area of the website. The document “ FBMC physical layer: a primer” posted on the public area has been updated.

The website itself has been transferred to a plone platform and redesigned. The objective is to have an easy access and more functionalities. Moreover, the management is simplified.

8 EXPLOITATION PLAN OF INDUSTRIAL PARTNERS

CEA-LETI

In CEA-LETI, the PHYDYAS project will contribute to increase the know-how of the teams working on FBMC system design and compensation algorithms. Some specific results, such as new compensation algorithms or techniques, may be patented and afterwards published. The main objective of CEA-LETI in this project will be to make a technology transfer covered by a license, which entitles partners to draw on CEA-LETI know-how and patents. The license fees will be further used to fund new research projects. One possible alternative for results exploitation might be the creation of a spin-off company as it has been done in a recent past in other areas (more than 20 successful startups created thanks to technology transfer).

ALCATEL-LUCENT

The exploitation aspects are as follows

- Development of patentable techniques for efficient resource sharing and cognitive radio.
- From a long-term perspective, the proposed "good neighbour" rule-regulated spectrum sharing strategy aims at influencing the value chain and the business model of wireless operators.
- Analysis of mixed "good neighbour"/"selfish" networks gives qualitative support for development of incentives and regulations for rule-regulated spectrum sharing wireless networks.
- FBMC may be a possible evolution of actual and future OFDM based networks (e.g. LTE, WiMAX, power line communications, DSL, optical core, optical access). Provided that FBMC proves to guarantee performance improvement with justifiable complexity, FBMC should be pushed within future standardization bodies. On-going standardization procedures (LTE advanced, 802.16m) have advanced beyond the fundamental characteristics of the physical layer.
- Once FBMC has found its way into any standardization body covering a topic within the portfolio of Alcatel-Lucent, this technique should be implemented.

*AGILENT**COMSIS*

As an IC provider in wireless communications area, COMSIS focuses on customized Wi-Fi solution by virtue of its unique expertise in MIMO technology. In PHYDYAS project, COMSIS is charged to provide FPGA evaluation of MIMO 4x4 decoder. The following industrial objectives have been achieved:

1. FPGA implementation of Rx1.2h MIMO 2x2 decoder for high-throughput decoding with ML performance. This implementation supports the decoding of one or two spatial streams and provides a generic solution for OFDM-MIMO communication systems, for example Wi-Fi, WiMAX and LTE. This ML decoder solution will update current COMSIS IP core for both customized and standard Wi-Fi solution.
2. Based on Rx1.2h MIMO decoder, COMSIS proposes Rx1.3h MIMO 4x4 decoder as well as the hardware evaluation. This decoder supports up to 4 spatial streams and which is ready to decode very high-throughput MIMO system. At present, mainstream commercial Wi-Fi products operate with one or two spatial streams. However, multiple spatial stream solution is always expected by the market for its higher data throughput and larger communication coverage. COMSIS Rx1.3h MIMO decoder is ready to be implemented with easy interface updating, which enables us a quick answer to the market demand in the coming next years.
3. FMBC modulation technique is known as a possible evolution of the current OFDM system. By investigating the combination of FMBC technique and MIMO system, COMSIS provides an FPGA evaluation of FMBC-MIMO decoder which is based on the variant of Rx1.2h MIMO decoder. With respect to CNAM proposed MMSE-ML algorithm, COMSIS is

prepared to give the hardware implementation solution for the future FBMC-MIMO based communication systems.