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Silke Feldmann, Markus Radimirsch, *University of Hannover, Germany*

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Arnab Das, Farooq Khan, Ashwin Sampath, Hsuan-Jung Su, *Bell Labs, Lucent Technologies, USA*

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Arnab Das, Farooq Khan, Ashwin Sampath, Hsuan-Jung Su, *Bell Labs, Lucent Technologies, USA*

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Mohamed Jaward, Visakan Kadirkamanathan, *University of Sheffield, UK*

P15 - MMSE Receiver for High Speed Multicode Data Transmission 1232
Rafal Krenz, *Poznan University of Technology, Poland*

P16 - Capacity Analysis of SIR-Based Power Controlled CDMA Systems Under Multipath Fading 1237
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P18 - Bluetooth Implementation in the WING-IP Simulator 1247
Gerben Kuijpers, *Aalborg University, Denmark*; Sonia Gameiro, Nuno Sousa, *IST - Technical University of Lisbon, Portugal*; Martijn Kuipers, Ramjee Prasad, *Aalborg University, Denmark*

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Alberto Escudero-Pascual, Gerald Maguire Jr., *Royal Institute of Tecnhnology, Sweden*

P20 - Securing Personal Area Networks 1257
Theodoulos Garefalakis, Christopher Mitchell, *University of London, UK*

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Christos Xenakis, Lazaros Merakos, *University of Athens, Greece*

P22 - Improving an Inverted Trapezoidal Antenna for Mobile Communications 1266
Pekka Eskelinen, Teemu Tarvainen, *Helsinki University of Technology, Finland*

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Chair: Fuchun Zheng, *Victoria University of Technology, Australia*

16:10 Adaptive Multiuser Detection for Frequency Selective Channel Using IMM 1275
Mohamed Jaward, Visakan Kadirkamanathan, *University of Sheffield, UK*

16:30 Frequency-Domain Approach to DS-CDMA Multiuser Detection Over Frequency-Selective Slowly Fading Channels 1280
Cha'o-Ming Chang, Kwang-Cheng Chen, *National Taiwan University, Taiwan*

16:50 BEM-Based Multiuser Detection for Synchronous DS -CDMA on Frequency Flat Fading Channels 1285
Antonio Gallo, Eugenio Chiavaccini, Giorgio Vitetta, *University of Modena, Italy*

17:10 Adaptive Multiuser Receivers for DS -CDMA Using Minimum BER Gradient-Newton Algorithms 1290
Rodrigo Lamare, Raimundo Sampaio-Neto, *CETUC/PUC-RIO, Brazil*

17:30 An Approximate Minimum BER Approach to Multiuser Detection Using Recurrent Neural Networks 1295
Rodrigo Lamare, Raimundo Sampaio-Neto, *CETUC/PUC-RIO, Brazil*

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Chair: Krzysztof Wesolowski, *Poznan University of Technology, Poland*

16:10 Multicarrier Spread Space-Spectrum Multiple Access for the MIMO Forward Link Transmission 1300
Benjamin Ng, Elvino Sousa, *University of Toronto, Canada*

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16:30 Analysis of the Influence of Walsh-Hadamard Code Allocation Strategies on the Performance of Multi-Carrier CDMA Systems in the Presence of HPA Non-Linearities **1305**
Nishita Hathi, *University College London, UK*; Miguel Rodrigues, Izzat Darwazeh, *University College London, London*; J. O'Reilly, *University College London, UK*

16:50 Reception of OFDM Signals with an Array Antenna in a SFN Environment **1310**
Yuichi Kanbe, Makoto Itami, Kohji Itoh, *Tokyo University of Science, Japan*; Hamid Aghvami, *King's College London, UK*

17:10 Detrimental Effects of Filtering in an OFDM System Using Pilot Based Channel Estimation **1316**
Sumei Sun, *Centre for Wireless Communications, Singapore*; Boroujeny Farhang, *University of Utah, USA*; Chin Ho, *Institute for Communications Research, Singapore*

17:30 Frame Timing Detection by an MMSE Adaptive Array for Multipath OFDM Signals **1321**
Song Shi, Hao Yuan, Takeo Ohseki, Tatsuaki Hamai, *KDDI Research R&D Development Laboratories, Inc., Japan*

SESSION TPO2.3: MIMO Systems IV
Chair: Kwang B. Lee, *Seoul National University, South Korea*

16:10 Theoretical and Experimental Analysis of the Channel Capacity Enhancement Based on MIMO Techniques in Subway Tunnels **1326**
Martine Lienard, Pierre Degauque, Daniel Degardin, Jacques Baudet, *University of Lille, France*

16:30 Iterative Equalization/Decoding of LDPC Code Transmitted Over MIMO Fading ISI Channels **1330**
Heung Lee, *University of Pittsburgh, USA*; Vivek Gulati, *Texas A&M, USA*

16:50 Analysis of MIMO Capacity Gains for Indoor Propagation Channels with LOS Component **1337**
Andreas Hutter, Fanny Platbrood, Jaouhar Ayadi, *CSEM, Switzerland*

17:10 A Decoder for Low-Complexity Equalization of Coded Frequency Selective MIMO Channels **1342**
Noura Sellami, *France Telecom, France*; Inbar Fijalkow, *ETIS/ENSEA, France*

17:30 Measured Capacity Gain Using Waterfilling in Frequency Selective MIMO Channels **1347**
Peter Almers, Fredrik Tufvesson, Ove Edfors, Andreas Molisch, *University of Lund, Sweden*

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Anne-Florence Canton, *Institut National des Télécommunications, France*; Samir Tohmé, *École Nationale Supérieure des Télécommunications, France*; Djamal Zeghlache, Tijani Chahed, *Institut National des Télécommunications, France*

16:30 Performance Analysis of Diversity Transmission Modes in UTRA FDD Under Time-Varying Multipath Channels **1357**
María Canales, Antonio Valdovinos, José Ramón Gállego, Fernando Gutierrez, *University of Zaragoza, Spain*

16:50 WCDMA Multi-Cell Link-Level Performance **1362**
Ralf Weber, Matthias Schulist, Hans Schotten, *Ericsson Research, Germany*

17:10 Macrodiversity Performance in the Uplink of WCDMA with Radio Over Fibre Access Network **1367**
Nazem Khashjori, Hamed Al-Raweshidy, *UKC, UK*; A. Bajwa, *Camber Systemics Limited, UK*

17:30 Performance Validation of Wideband CDMA User Equipment (UE) Modem **1372**
KyungHi Chang, Young-Hoon Kim, ChangWahn Yu, DaeHo Kim, Kyung-Yeol Sohn, Choong-Il Yeh, YoungSeog Song, HyeongSook Park, *ETRI, Korea*

SESSION TPO2.5: Satellite Networks
Chair: Tadashi Fujino, Tokyo *University of Electro-Communications, Japan*

16:10 W-CDMA Random Access Channel Transmission Enhancement for Satellite-UMTS **1377**
Victor Kueh, Andrea Capellacci, *Centre for Communication Systems Research, UK*; Rahim Tafazolli, *University of Surrey, UK*; Barry Evans, *Centre for Communication Systems Research, UK*

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16:30 Traffic Class Dependent Routing i n Packet-Switched Non-Geostationary ISLNetworks 1382
Ales Svigelj, Mihael Mohorcic, Gorazd Kandus, *Institut Jozef Stefan, Slovenia*

16:50 Service Multiplexing and Resource Allocation in S-CDMA LEO Systems 1387
Abbas Ibrahim, Samir Tohmé, *École Nationale Supérieure des Télécommunications, France*

17:10 Burst Targeted Demand Assignment Multiple Access (BTDAMA) for On-Off Type Data Traffic Via Satellite 1392
Paul Mitchell, Tim Tozer, David Grace, *University of York, UK*

17:30 Dynamic Location Management in LEO Networks 1397
Wang Liang, Zhang Nai-tong, *Harbin Institute of Technology, China*

SESSION TPO2.6: Power Control II
Chair: Jens Zander, *Royal Institute of Technology, Sweden*

16:10 Downlink Power Control of Dedicated Channels in UTRA TDD 1402
Janne Kurjenniemi, *University of Jyvaskyla, Finland*; Otto Lehtinen, *Nokia, Finland*; Tapani Ristaniemi, *University of Jyvaskyla, Finland*

16:30 Adaptive Power Increase Estimation in WCDMA 1407
Ari Hämäläinen, Kimmo Valkealahti, *Nokia, Finland*

16:50 WCDMA Common Pilot Power Control for Load and Coverage Balancing 1412
Kimmo Valkealahti, Albert Höglund, Jyrki Parkkinen, Ari Hämäläinen, *Nokia, Finland*

17:10 Evolutionary Computation and Power Control for Radio Resource Management in CDMA Cellular Radio Networks 1417
Won Song, Byung Ahn, *Kwangju Institute of Science and Technology, Korea*; Won Kim, Bo Kim, *Chungnam National University, Korea*; Sun Kim, Munkee Choi, *Information and Communications University, Korea*

17:30 A Q-Learning-Based Multi-Rate Transmission Control Scheme for RRC in WCDMA Systems 1422
Fang-Ching Ren, *Industrial Technology Research Institute, Taiwan*; Chung-Ju Chang, Yih-Shen Chen, *National Chiao Tung University, Taiwan*

SESSION TPO2.7: Equalization II
Chair: Shuzo Kato, *Omni Wireless, USA*

16:10 The Influence of the Channel Estimation Error on the Closed Loop Transmit Diversity Algorithms Performance 1427
Dejan Novakovic, Markku Juntti, *University of Oulu, Finland*; Miroslav Dukic, *Faculty of Electrical Eng., Yugoslavia*

16:30 Adaptive Channel Estimation in DS-CDMA Downlink Systems 1432
Ji-Woong Choi, Yong-Hwan Lee, *Seoul National University, South Korea*

16:50 Adaptive Channel Equalization in WCDMA Downlink i n Soft Handover 1437
Kari Hooli, Markku Juntti, *Universi ty of Oulu, Finland*

17:10 Adaptive Channel Equalization in WCDMA Downlink with Turbo Coding 1442
Kari Hooli, Dejan Drajic, Djordje Tujkovic, *University of Oulu, Finland*

17:30 DSP and ASIC Implementation of a Channel Filter for a 3G UTRA-TDD System 1447
Ronny Veljanovski, Jugdutt Singh, Michael Faulkner, *Victoria University, Australia*

SESSION TPO2.8: Wireless IP / ATM
Chair: Kaveh Pahlavan, *Worcester Polytechnic Institute, USA*

16:10 MAC Layer Retransmissions in 1XTREME 1452
Mainak Chatterjee, *University of Texas at Arlington, USA*; Giridhar Mandyam, *Nokia, USA*; Sajal Das, *University of Texas at Arlington, USA*

16:30 A RLC/MAC Protocol Architecture for a Wireless IP Network 1457
Jamil Khan, *University of Newcastle, Australia*

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16:50 Comparison of Packet Scheduling Algorithms Focusing on User Throughput in High Speed Downlink Packet Access 1462
Yoshiaki Ofuji, Sadayuki Abeta, Akihito Morimoto, Mamoru Sawahashi, *NTT DoCoMo, Japan*

17:10 Improving User-Perceived QoS in Mobile and Wireless IP Networks Using Real-Time Adaptive Multimedia Applications 1467
Pedro Ruiz, Emilio Garcia, *Agora Systems S.A., Spain*

17:30 Multi-Service Rerouting Algorithm in Wireless ATM 1472
Abdelhak Gueroui, *Université de Versailles, France*; Dominique Gaiti, *LM2S/UTT, France*

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Chair: Elvino Sousa, *University of Toronto, Canada*

08:30 Multicarrier DS-CDMA Performance with Different Assignment Strategies of Quasi-Orthogonal Codes 1477
Umberto Manzoli, Maria Luisa Merani, *University of Modena and Reggio Emilia, Italy*

08:50 Intercarrier and Intersymbol Interference Analysis of OFDM Systems on Time-Invariant Channels 1482
Van Duc Nguyen, Hans-Peter Kuchenbecker, *Institut fuer Allgemeine Nachrichtentechnik, Germany*

09:10 SINR-Based Channel Pre-Equalization for Uplink Multi-Carrier CDMA Systems 1488
David Mottier, Damien Castelain, *Mitsubishi Electric ITE, France*

09:30 Efficient Pre-Coding Schemes for FMT Broadband Wireless Systems 1493
Nevio Benvenuto, Stefano Tomasin, *University of Padova, Italy*

09:50 OFDM and DS-CDMA Approaches, Analysis of Performances on Fading Multipath Channels 1498
Nizar Hicheri, Michel Terré, Bernard Fino, *CNAM, France*

SESSION WAO1.2: Smart Antennas I
Chair: Makoto Miyake, *Mitsubishi Electric, Japan*

08:30 Analog Smart Antennas: An Overview (Invited) 1502
Takashi Ohira, *ATR, Japan*

08:50 A New Adaptive Beamforming Using Pilot and Traffic Channel 1507
Sang-Hoon Lim, Jeonghwa Lee, *Hyundai Syscomm Inc., Korea*

09:10 The Essential Degrees of Freedom in Space-Time Fading Channels 1512
Akbar Sayeed, *University of Wisconsin - Madison, USA*; Venu Veeravalli, *University of Illinois - Urbana, USA*

09:30 Joint Estimation of Direction of Arrival and Angular Spread Using the Knowledge of the Power Angle Density 1517
Hatem Boujemaa, *SUPCOM, Tunisia*; Sylvie Marcos, *LSS-SUPELEC, France*

09:50 Closed-Form Solution for Positioning Based on Angle of Arrival Measurements 1522
Alba Pagès-Zamora, Josep Vidal, *UPC, Spain*; Dana H. Brooks, *Northeastern University, USA*

SESSION WAO1.3: Spread Spectrum Receivers I
Chair: Noriyoshi Kuroyanagi, *Tokyo University of Technology, Japan*

08:30 Iterative Blind Demodulation of Synchronous CDMA 1527
Ejaz Khan, Dirk Slock, *Eurecom Institute, France*

08:50 Iterative Receiver for Synchronous CDMA Using Hidden Markov Model 1531
Ejaz Khan, Dirk Slock, *Eurecom Institute, France*

09:10 A Multi-Pass Strategy for Channel Estimation and Data Detection in Long-Code Uplink CDMA Systems 1535
Stefano Buzzi, *University of Cassino, Italy*; H. Poor, *Princeton University, USA*

09:30 First Arrival Detection for Positioning in Mobile Channels 1540
Rene Jativa, Josep Vidal, *UPC, Spain*

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09:50 Blind Channel Estimation in Multi-Rate Multicarrier DS-CDMA Systems 1545
Lei Huang, Fuchun Zheng, *Victoria University of Technology, Australia*

SESSION WAO1.4: UMTS
Chair: Jann Erik Dietert, *Vodafone D2, Germany*

08:30 Required Guard Bands for Co-Operation of DVB-T and UMTS 1550
Christian Hamacher, *RWTH Aachen University, Germany*

08:50 An Efficient Monitoring Strategy for Intersystem Handover from TD-SCDMA to GSM Networks 1555
Gianluca Durastante, *Siemens, Italy*; Alberto Zanella, *University of Bologna, Italy*

09:10 A Low Complexity Algorithm for Frame Synchronization in TDD-LCR System 1561
Alessandro Ventura, *Siemens, Italy*; Thomas Hindelang, *Siemens AG, Germany*

09:30 A Non-Linear Frequency Synchronization Algorithm for TDD-LCR System 1566
Caterina Cangemi, Alessandro Ventura, *Siemens Mobile Communications S.p.A., Italy*

09:50 Soft Orthogonal Phase Shift Keying (SOPK) Modulation with OVSF-MAC for UMTS 1572
João Pereira, *Polytechnic Institute of Leiria, Portugal*; Henrique Silva, *University of Coimbra, Portugal*

SESSION WAO1.5: High Altitude Platforms
Chair: David Grace, *University of York, UK*

08:30 Technology Development for Wireless Communications System Using Stratospheric Platform in Korea (Invited) 1577
Jong-Min Park, Bon-Jun Ku, Yang-Su Kim, Do-Seob Ahn, *ETRI, Republic of Korea*

08:50 Design of Linear Array Antenna System for HAPS in S Band 1582
Bon-Jun Ku, Jong-Min Park, Yang-Su Kim, Do-Seob Ahn, *ETRI, Korea*

09:10 Channel Assignment Strategies for a High Altitude Platform Spot-Beam Architecture 1586
David Grace, Candida Spillard, John Thornton, Tim Tozer, *University of York, UK*

09:30 Delivering IP with QoS/CoS Over HeliNet 1591
Janez Bostic, Uros Drcic, Mihael Mohorcic, Gorazd Kandus, *Institut Jozef Stefan, Slovenia*

09:50 Centralized Total Received Power Based Call Admission Control for High Altitude Platform Station UMTS 1596
Yu Foo, Woo Lim, Rahim Tafazolli, *University of Surrey, UK*

SESSION WAO1.6: Power Control III
Chair: Silvia Ruiz, *Polytechnical University of Catalonia, Spain*

08:30 Power and Rate Assignment Policies for Best-Effort Services in WCDMA 1601
Muhammad Kazmi, Niclas Wiberg, Per Magnusson, *Ericsson Radio Systems AB, Sweden*

08:50 Dynamic Step-Size Power Control in UMTS 1606
Siamäk Naghian, *Nokia, Finland*; Matti Rintamäki, *Helsinki University of Technology, Finland*; Ramin Baghaie, *Nokia, Finland*

09:10 Influence of the Common-Channel Power on the System Capacity of UMTS FDD Systems that Use Beam Switching 1611
Thomas Baumgartner, Ernst Bonek, *Institut für Nachrichtentechnik und Hochfrequenztechnik der TU-Wien, Austria*

09:30 Analysis of Closed Loop Power Control Modes in UTRA-FDD Under Time Varying Multipath Channels 1616
José Ramón Gállego, Antonio Valdovinos, María Canales, Jesús Mingo, *University of Zaragoza, Spain*

09:50 Prediction of the Received Power for the UMTS Closed Loop Power Control 1621
Hatem Boujemaa, Mohamed Siala, *SUPCOM, Tunisia*

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SESSION WAO1.7: MIMO Channels I
Chair: Andreas Hutter, *CSEM, Switzerland*

08:30 A Wave-Based Wideband MIMO Channel Modeling Technique 1626
Hao Xu, Dmitry Chizhik, Howard Huang, Reinaldo Valenzuela, *Lucent Technologies, USA*

08:50 MIMO Channel Measurement in Manhattan 1631
Jonathan Ling, Dmitry Chizhik, Peter Wolniansky, Reinaldo Valenzuela, *Lucent Technologies, USA*; Nelson Costa, Kris Huber, *McMaster University, Canada*

09:10 A First Order Markov Chain Based Model for Flat Fading Channel 1636
Saadani Ahmed, Patrick Tortelier, *France Telecom, France*

09:30 A 2-D Fading Forecast of Time-Variant Channels Based on Parametric Modeling Techniques 1640
Sven Semmelrodt, Ralf Kattenbach, *University of Kassel, Germany*

09:50 Adjacent Channel Interference Cancellation for MSK-Type Signals Using Antenna Diversity 1645
David Gidony, Irving Kalet, *Israel Institute of Technology, Israel*

SESSION WAO1.8: Novel Networks
Chair: Susumu Yoshida, *Kyoto University, Japan*

08:30 Synchronization in Ad Hoc Networks Based on UTRA TDD 1650
Andre Ebner, Hermann Rohling, *TUHH, Germany*; Ruediger Halfmann, Matthias Lott, *Siemens AG, Germany*

08:50 The Effect of Discrete Power Levels on Energy-Efficient Wireless Broadcast in Ad Hoc Networks 1655
Jeffrey Wieselthier, Gam Nguyen, *Naval Research Lab, USA*; Anthony Ephremides, *University of Maryland, USA*

09:10 An Architecture for Providing Range Extension by Deploying Mobile Gateways in Ad Hoc Networks 1660
Mohiuddin Ahmed, Son Dao, *HRL Laboratories, USA*; Srikanth Krishnamurthy, *University of California - Riverside, USA*; Randy Katz, *University of California - Berkeley, USA*

09:30 The Italian TERRA Project. An Innovative Telecommunication Network Solution Preserving the Environment 1665
Massimo Celidonio, Dario Zenobio, *Fondazione Ugo Bordoni, Italy*

09:50 MuPAC: Multi-Power Architecture for Cellular Networks 1670
Jayanth Kumar, B. Manoj, C. Murthy, *Indian Institute of Technology, India*

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P1 - Performance of TCH Codes in a Land Mobile Satellite Channel 1675
Pedro Sebastião, Francisco Cercas, Adolfo Cartaxo, *IST - Technical University of Lisbon, Portugal*

P2 - MPEG-4 Video Transmission in the 5 GHz Band Through an Adaptive OFDM Wireless Scheme 1680
Davide Dardari, Maria Martini, Marco Milantoni, Marco Chiani, *University of Bologna, Italy*

P3 - Improving the Robustness of MPEG-4 Video Communications Over Wireless/3G Mobile Networks 1685
Francisco Delicado, Antonio Garrido, Pedro Cuenca, *University of Castilla la Mancha, Spain*; Luis Orozco-Barbosa, *University of Ottawa, Canada*; Francisco Quiles, *University of Castilla la Mancha, Spain*

P4 - Automorphisms of F. K. Schmidt Codes and a New Method to Derive Cyclic Sub-Codes from Algebraic Geometric Codes 1690
Leocarlos Lima, , *ENST, France and State University of Paraiba, Brazil*; Francisco Assis, *State University of Paraiba, Brazil*

P5 - Performance Analysis of Time-Hopping Ultra-Wideband Systems in Multipath Fading Channels (Uncoded and Coded Schemes) 1694
Hamid Ahmadi, Masoumeh Nasiri-Kenari, *Sharif University of Technology, Iran*

P6 - Soft Detection of USF for EGPRS Modems 1699
Evgeny Yakhnich, *Comsys Ltd., Israel*

P7 - Performance of Multi-Split Decision Feedback Equalizer 1703
Walid Saif, Azzedine Zerguine, Asrar Sheikh, *KFUPM, Saudi Arabia*; Maurice Bellanger, *CNAM-FR, France*

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P8 - Adaptive Rate Communication System Based on New DECT Standard 1708
Tomaz Javornik, Gorazd Kandus, *Institut Jozef Stefan, Slovenia*

P9 - Spectral Efficiency of OCDMA/OCDMA with Asymmetric Power Assignment 1713
Frederik Vanhaverbeke, Marc Moeneclaey, *University of Ghent, Belgium*

P10 - A High Data Rate MDPSK Receiver Architecture for Indoor Wireless Application 1718
Poh Boon-Kiat, Phang Piao-Chun, *Oki Techno Centre, Singapore*

P11 - MMSE Decision Feedback Equalizer from Channel Estimate 1722
Arnaldo Spalvieri, Maurizio Magarini, *Politecnico di Milano, Italy*

P12 - Error Control Mechanisms Over Correlated Fading Channels 1727
Carl Wijting, Eva Braia, *Aalborg University, Denmark*; Ernestina Cianca, *University of Rome, Italy*; Ramjee Prasad, *Aalborg University, Denmark*

P13 - Performance of Binary Nonsymmetric and Binary Erasure Memoryless Channels with Viterbi Decoding Using Importance Sampling 1732
Bruno Albert, Francisco Assis, *State University of Paraiba, Brazil*

P14 - Diversity Analysis for QAM in Nakagami Fading Channels 1737
Dongweon Yoon, *Daejeon University, Korea*; Younghwan Lee, Changho Bae, *ETRI, Korea*; Kyongkuk Cho, *LG Electronics, Korea*; Pyeongdong Cho, *ETRI, Korea*

P15 - Performance of a Bluetooth Piconet in the Presence of IEEE 802.11 WLANs 1742
Wang Feng, Nallanathan Arumugam, Garg Krishna, *National University of Singapore, Singapore*

P16 - IEEE 802.11 Optimal Performaces: RTS/CTS Mechanism Vs. Basic Access 1747
Raffaele Bruno, Marco Conti, Enrico Gregori, *IIT Institute - CNR, Italy*

P17 - Bluetooth and IEEE802.11 Coexistence: Analytical Performance Evaluation in Fading Channel 1752
Oreste Andrisano, Andrea Conti, Davide Dardari, Gianni Pasolini, Barbara Masini, *University of Bologna, Italy*

P18 - Dynamic Intelligent Hub Station for Wireless 1394 1757
Hisanori Tanada, *Keio University, Japan*; Tomoyuki Udagawa, Takemi Arita, *Telecommunications Advancement Organization of Japan, Japan*; Masao Nakagawa, *Keio University, Japan*; Honggang Zhang, *Telecommunications Advancement Organization of Japan, Japan*

P19 - Integrated System of White Led Visible-Light Communication and Power-Line Communication 1762
Toshihiko Komine, Masao Nakagawa, *Keio University, Japan*

P20 - An All-Digital Feed-Forward CFO Cancellation Scheme for HIPERLAN/2 in Multipath Environment 1767
Andreas Miaoudakis, Apostolos Koukourgianis, Grigorios Kalivas, *University of Patras, Greece*

P21 - Adaptive Subspace Modulation in Spatially Correlated MIMO Systems 1772
Gerhard Gritsch, Hans Weinrichter, *Vienna University of Technology, Austria*

P22 - MIMO Capacities for Different Antenna Arrangements Based on Double Directional Wide-Band Channel Measurements 1777
Thomas Fügen, *University of Karlsruhe, Germany*; Gerd Sommerkorn, *Technical University of Ilmenau, Germany*; Jürgen Maurer, *University of Karlsruhe, Germany*; Dirk Hampicke, *Technical University of Ilmenau, Germany*; Werner Wiesbeck, *University of Karlsruhe, Germany*; Reiner Thomä, *Technical University of Ilmenau, Germany*

P23 - Topology Optimization of a CDMA-Based Network of Hyperbolic Remote-Positioning Cells 1782
Damià Vidal, Bartomeu Serra, *University of the Balearic Islands, Spain*

SESSION WAO2.1: Smart Antennas II
Chair: Tricia Willink, *Communications Research Centre, Canada*

10:40 Initial Weight Computation Method with Rapid Convergence for Adaptive Antennas 1788
Yoshitaka Hara, *Mitsubishi Electric Corporation, Japan*; Chihiro Fujita, Yukiyoshi Kamio, *YRP Mobile Telecommunications Key Technology Research Labs, Japan*

11:00 Dependence of Adaptive Beamforming Performance on Directional Channel Modelled Micro-Cell Scenarios 1794
João Gil, *IST, Polytechnic Institute of Leiria, Portugal*; Luís Correia, *IST - Technical University of Lisbon, Portugal*

11:20 A Feedback-Type Adaptive Array Antenna for Two-Frequency Duplex Communications 1799
Takayuki Funama, Makoto Taromaru, Yoshihiko Akaiwa, *University of Kyushu, Japan*

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11:40 An Adaptive Wide-Band Array Using a Single Real Multiplier for Each Antenna Element 1805
Mohammad Ghavami, *King's College London, UK*

12:00 Advanced Detection Scheme for Multicode CDMA Systems with V-BLAST Architecture 1810
Gang Wu, *Southeast University, China*; Haifeng Wang, *Nokia, Finland*; Ming Chen, Shixin Cheng, *National Mobile Communications Research Laboratory, China*; Jorma Lilleberg, *Nokia, Finland*

SESSION WAO2.2: Spread Spectrum Receivers II
Chair: Yong-Hwan Lee, *Seoul National Univ., South Korea*

10:40 Performance Degradation Due to Code Tracking Errors on a Rake Spread-Spectrum Receiver in the Presence of Unresolvable Multipath 1815
Ivo Maljevic, Elvino Sousa, *University of Toronto, Canada*

11:00 Advanced Differentially Non-Coherent Code Acquisition in Jamming and Data Modulation 1820
Pasi Pirhonen, Tapani Ristaniemi, *University of Jyvaskyla, Finland*

11:20 Multiple-Shift Acquisition Algorithm i n Ultra-Wide Bandwidth Frame Time-Hopping Wireless CDMA Systems 1824
Hossein Bahramgiri, Jawad Salehi, *Sharif University of Technology, Iran*

11:40 Multi-Coded VSG CDMA Personal Communications System for High-Rate Applications 1829
Cheol-Hee Park, *Korea Electronics Technology Institute, South Korea*; Young-Hwan You, *Sejong University, South Korea*; Dae-Ki Hong, Min-Chul Ju, Kyu-Jung Yun, Jin-Woong Cho, *Korea Electronics Technology Institute, South Korea*

12:00 A Multipath Resistant PN Code Tracking Algorithm 1834
Mohamed El-Tarhuni, Ali Ghrayeb, *American University of Sharjah, United Arab Emirates*

SESSION WAO2.3: CDMA 2000
Chair: Sandip Sarkar, *Qualcomm, USA*

10:40 Forward Link Coding and Modulation for CDMA2000 1xEV-DO (IS-856) 1839
Nagabhushana Sindhushayana, Peter Black, *Qualcomm. Inc., USA*

11:00 Link Budget of CDMA2000 1xEV-DO Wireless Internet Access System 1847
Peter Black, Qiang Wu, *Qualcomm Inc., USA*

11:20 System Design and Performance of CDMA2000-1x Transceiver 1853
Kapseok Chang, Youngnam Han, *Information and Communications University, Korea*

11:40 Resource Reuse for 3G WOS 1858
David Lee, Michel Basmaji, *Cisco Systems, USA*

12:00 New Channels for Efficient Data Services in CDMA2000 1863
Sarkar Sandip, Yongbin Wei, David Puig, *Qualcomm Inc., USA*

SESSION WAO2.4: Antennas and RF Sub-Systems
Chair: Takashi Ohira, *ATR, Japan*

10:40 New Processes for Highly Integrated Planar Microwave Circuits - Applications to Active Filters for Telecommunication Systems 1868
Hassan Bazzi, Frédéric Biron, Stéphane Bosse, Luc Delage, Bruno Barelaud, Laurent Billonnet, Bernard Jarry, *IRCOM, France*

11:00 Input Impedance Antenna Automatic Matching System 1872
Jesús Mingo, Alfredo Crespo, Antonio Valdovinos, *University of Zaragoza, Spain*

11:20 Evaluating Exposure to Radio-Frequency Emissions from Base Station Antennas 1877
Andrzej Karwowski, *Silesian University of Technology, Poland*

11:40 Low-Loss Tuning Circuits for Frequency-Tunable Small Resonant Antennas 1882
Jani Ollikainen, Outi Kivekas, Pertti Vainikainen, *Helsinki University of Technology, Finland*

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Gert Pedersen, Jesper Nielsen, *Aalborg University, Denmark*

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10:40 UMTS Medium Access Control Quality of Service Scheduling 1893
Silke Heier, Matthias Malkowski, Christian Ellerbrock, *RWTH Aachen University, Germany*

11:00 DiffServ Based QoS Architecture to Support Streaming Applications in 3G Networks 1898
Sanjeev Verma, Roberto Barnes, *Nokia, USA*

11:20 An End-to-End QoS Framework for Multimedia Services in 3G Networks 1904
Hector Montes, Gerardo Gomez, Daniel Fernandez, *Nokia, Spain*

11:40 Support of IP QoS Over UMTS Networks 1909
Manuel Ricardo, *FEUP, Portugal*; Jaime Dias, *Instituto Superior de Engenharia do Porto, Portugal*; Gustavo Carneiro, *INESC Porto, Portugal*; José Ruela, *FEUP, Portugal*

12:00 QoS-Based Adaptive Scheduling for a Mixed Service in HDR System 1914
Kapseok Chang, Youngnam Han, *Information and Communications University, Korea*

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10:40 Superresolution Algorithms for Detecting Overlapped Paths in DS-CDMA Systems with Long Codes 1919
Elena-Simona Lohan, Ridha Hamila, Markku Renfors, *Tampere University of Technology, Finland*

11:00 A Study of Stochastic and Deterministic Procedures for the Design of Simulation Models for Spatial Channels 1924
Matthias Pätzold, Qi Yao, *Agder University College, Norway*

11:20 Results from MIMO Channel Measurements 1932
Steven Howard, Hakan Inanoglu, Mark Wallace, Rod Walton, John Ketchum, *Qualcomm Inc., USA*

11:40 Capacity of the Mobile MIMO Channel for a Small Wireless Handset and User Influence 1937
Wim Kotterman, Gert Pedersen, Kim Olesen, *Aalborg University, Denmark*

12:00 Spatial Domain Modeling of Microcellular Systems Operating in Multipath Nakagami Channels 1942
Asrar Sheikh, Saad Al-Ahmadi, *KFUPM, Saudi Arabia*

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10:40 System Configuration for Private Mobile Network Using Slotted-ALOHA Based Autonomous Packet Routing 1947
Fumihide Kojima, Hiroshi Harada, Masayuki Fujise, *Communications Research Laboratory, Japan*

11:00 A Simple and Effective Cross Layer Networking System for Mobile Ad Hoc Networks 1952
Wing Yuen, *Rutgers University, USA*; Heung Lee, *Univeristy of Pittsburgh, USA*; Timothy Andersen, *University of Texas, USA*

11:20 Integrating Short-Range Wireless Networks: An Energy Efficient Proposal 1957
Juan-Carlos Cano, Pietro Manzoni, *Polytechnic University of Valencia, Spain*

11:40 EasiShop: Context Sensitive Shopping for the Mobile User Through Mobile Agent Technology 1962
Stephen Keegan, Gregory O' Hare, *University College Dublin, Ireland*

12:00 WhereMoPS: An Indoor Geolocation System 1967
Michael Wallbaum, *RWTH Aachen University, Germany*

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14:00 Semi-Blind Beamspace-Time Interference Cancellation Using Subspace Channel Identification for DS-WCDMA Systems 1972
Ivan Casella, Paul Jeszensky, *University of São Paulo, Brazil*; Elvino Sousa, *University of Toronto, Canada*

14:20 Field Test Results of Space-Time Equalizers and Delayed Diversity Transmission in Central Tokyo Area 1977
Takeshi Toda, *Fujtsu Laboratories Ltd., Japan*; Yuukich Aihara, *Matsushita Commun. Industrial Co., Ltd., Japan*; Jun-ichi Takada, *Tokyo Institute of Technology, Japan*

14:40 On the Effective Spatio-Temporal Rank of Wireless Communication Channels 1982
Frank Dietrich, Wolfgang Utschick, *Munich University of Technology, Germany*

15:00 Channel Time Variation Effects on Transmit Beamforming in the TDD Mode of UMTS 1987
Guillaume Andrieux, Jean-François Diouris, Yide Wang, *University of Nantes, France*

15:20 On the Impact of Estimation Errors on Subspace-Based Array Processor Performance 1992
Tricia Willink, *Communications Research Centre, Canada*

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Chair: Atílio Gameiro, *University of Aveiro, Portugal*

14:00 Novel Serial Group Interference Canceller Scheme for Asynchronous Multirate DS-CDMA Systems 1997
Paul Jeszensky, *University of São Paulo, Brazil*; Taufik Abrão, *University of Londrina, Brazil*

14:20 Successive Parallel Interference Canceller for Asynchronous Multirate DS-CDMA Systems 2003
Taufik Abrão, *University of Londrina, Brazil*; Paul Jeszensky, *University of São Paulo, Brazil*

14:40 Interference Cancellation in Multi-Cell CDMA Systems 2009
Chun Lu, *ITRI, Taiwan*

15:00 Multi-Rate Multi-Tone-CDMA with Multiuser Detection for Wireless Multimedia Communications 2014
Po-Wei Fu, Kwang-Cheng Chen, *National Taiwan University, Taiwan*

15:20 Performance Analysis of Balanced QPSK DS-CDMA Using Hilbert Transformed PN Code 2019
Myoung Lim, *Chonbuk national university, South Korea*

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Chair: Lazaros Merakos, *University of Athens, Greece*

14:00 Improving Packet Delivery in GPRS/UMTS Networks 2024
Shiao-Li Tsao, *Industrial Technology Research Institute, Taiwan*

14:20 Steady State Analysis of Mobile Station State Transitions for General Packet Radio Service 2029
Yun Chung, *King's College London, UK*; Dan Sung, *KAIST, Korea*; Hamid Aghvami, *King's College London, UK*

14:40 Steady State Analysis of User Equipment State Transitions for Universal Mobile Telecommunication System 2034
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June Moon, Yong-Hwan Lee, *Seoul National University, South Korea*

15:20 The Random Early Detection Concept Applied to the W-CDMA UMTS Medium Access Control 2044
Erickson Trejo-Reyes, Tim O'Farrell, Des McLernon, *The University of Leeds, UK*

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Chair: Gorazd Kanduz, *Institut Jozef Stefan, Slovenia*

14:00 Transmit Power Allocation for BER Performance Improvement in Multicarrier Systems 2049
Chang Park, Kwang Lee, *Seoul National University, South Korea*

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Yi Ma, Yi Huang, Waleed Al-Nuaimy, Yiyuan Xiong, *University of Liverpool, UK*

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Matteo Albanese, Ivan Rinaldi, Arnaldo Spalvieri, *Politecnico di Milano, Italy*

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Kenneth Shum, *The Chinese University of Hong Kong, Hong Kong*

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Fernando Nunes, José Leitão, *Institute for Telecommunications, Portugal*

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Stefano Tomasin, Alexei Gorokhov, Haibing Yang, Jean-Paul Linnartz, *Philips Research, Netherlands*

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Saloua Ammari, *Bouygues Telecom R&D, France*; Armelle Wautier, *SUPELEC, France*; Ahmed Braik, Laroussi Gattoufi, *Bouygues Telecom R&D, France*

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DESIGN CONSIDERATIONS AND INITIAL PHYSICAL LAYER PERFORMANCE RESULTS FOR A SPACE TIME CODED OFDM 4G CELLULAR NETWORK

Angela Doufexi, Simon Armour, Andrew Nix and Mark Beach

Centre for Communications Research, University of Bristol,
Merchant Venturers Bldg. Woodland Road, BS8 1UB, U.K.
E-mail: A.Doufexi@bristol.ac.uk

Abstract - The exponential growth of cellular radio, WLANs and the Internet sets the context for a discussion on the role and objectives of 4G. In this paper OFDM is proposed as a leading candidate for a 4G cellular communications standard. The key design considerations and link parameters for a 4G OFDM system are identified and initial physical layer performance results are presented for a number of transmission modes and channel scenarios. Additionally, space-time techniques are considered as a means of enhancing the performance of the coded OFDM system.

Keywords - OFDM, 4G, Space-Time Coding.

I. INTRODUCTION

The rapid growth of world-wide cellular subscribers (expected to exceed one billion in 2003 and two billion in 2005 [1]) and the increasing number of Internet users suggest that higher data rates are needed, especially for multimedia traffic. Transmission rate is one of the most fundamental parameters in the radio access network. The amount of information will increase because of complex graphics and video required by anticipated future applications [2]. 4G systems are also expected to fulfil the requirements of next generation Internet, featuring QoS and Mobile IP. Furthermore, WLANs can be connected to the 4G system. "Smart" antenna technologies can be applied to 4G to further improve performance and reduce interference. In this paper, novel work performed under the framework of the IST SATURN project is presented that considers the application of wide area OFDM to 4G.

OFDM is an effective technique for mitigating the effects of delay spread in frequency selective channels. This paper identifies and describes the key link parameters of OFDM for a potential 4G cellular standard. These include the number of carriers, the subchannel spacing, the choice of modulation scheme and channel coding, and the choice of the guard interval. Since 4G systems will be deployed in a wide range of environments, a fixed set of parameters is not capable of achieving high performance in all cases. A system capable of dynamically adapting one or more of the above parameters may offer superior performance.

A simple space-time coded diversity technique for wireless communications over frequency selective fading channels is also investigated in this paper [3-5]. Performance results with and without space time coding will be presented in Sections VI and V respectively.

II. CHANNEL SCENARIOS

In order to study the performance of 4G systems it is essential that the transmission channels are satisfactorily characterized. The radio link performance in a mobile environment is primarily limited by Doppler and delay spread. In order to establish some assessment scenarios, the channels proposed in the Evaluation Report for ETSI UMTS Terrestrial Radio Access (UTRA) [6] are considered (Table 1). The channel is time varying, with Doppler rates, f_D, as high as 220 Hz for vehicular operation in the 2GHz band. For the indoor and pedestrian channels, f_D of ~5 Hz are expected.

Table 1. Rms delay spreads.

Number	Test Environment	Rms (ns)
1	Indoor A	70
2	Indoor B	125
3	Outdoor to indoor and pedestrian A	65
4	Outdoor to indoor and pedestrian B	655
5	Vehicular A	370
6	Vehicular B	4000

III. OFDM FOR 4G

From Table 1 it can be seen that the channel models considered have a wide range of possible delay spreads. Tables 2 and 3 show the values that were chosen for the proposed OFDM parameters and transmission modes respectively.

The operating frequency dictates the channel characteristics of a specific environment. For this study an operating frequency of 2 GHz and a channel bandwidth of 4096 kHz was assumed. In order to eliminate ISI for most channels, a guard time T_g =15.625μs and a useful symbol duration of T=62.5μs were chosen (T_g= $T/4$). This results in T_{symbol} = 78.125μs. However, a variable guard time can be employed in order to either improve efficiency or handle more ISI.

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Table 2. OFDM Parameters for 4G.

Parameter	Value 1	*Value 2*
Operating Frequency	2GHz	*2GHz*
Bandwidth *(B)*	4096 kHz	*4096 kHz*
Useful Symbol Duration *(T)*	62.5 μs	*125 μs*
Guard Interval Duration (T_g)	15.625 μs *(T/4)*	*31.25μs (T/4)*
Total Symbol Duration (T_{symbol})	78.125 μs (with GI =*T/4*)	*156.25 μs (with GI =T/4)*
Inner Channel Coding	Punctured 1/2 rate convolution code, Constraint length 7, $\{133, 171\}_{octal}$	*Punctured 1/2 rate convolution code, Constraint length 7, $\{133, 171\}_{octal}$*
FFT Size	256	*512*
Number of data sub-carriers (N_D)	216	*432*
Sub-carrier spacing (Δ_f)	16 kHz	*8 kHz*

Table 3. Mode dependent parameters.

Mode	Modulation	Coding Rate, R	Bit rate [Mbit/s]	Coded bits per sub-carrier
1	BPSK	1/2	1.3824	1
2	QPSK	1/2	2.7648	2
3	QPSK	3/4	4.1472	2
4	16QAM	1/2	6.2206	4
5	16QAM	3/4	8.2944	4
6	64QAM	3/4	12.4416	6

The subcarrier spacing is $\Delta_f = 1/T = 16$ kHz. The number of sub-carriers can be found by dividing the available bandwidth B_s by the subcarrier spacing:

$$N = B_s / \Delta_f = B_s * T = 256$$

The symbol duration may be increased by employing a larger FFT in the modulation process. However, this results in increased complexity of implementation and increased sensitivity to Doppler and phase noise. A FFT size of N=512 is also under consideration, since it will improve guard interval efficiency and can handle more ISI. The OFDM parameters for N=512 are shown in Table 2 (*italic*). However, in this paper performance results for the case of N=256 will be presented. The individual carriers will be modulated by either BPSK, QPSK, 16QAM, or 64QAM with coherent detection. In order to employ coherent detection, channel estimation must be performed. For the simulations in this paper, a preamble before every packet was used to estimate the channel and it was assumed that the channel does not change over the duration of the packet. (In practise this method would be suitable only for the pedestrian and indoor channels. For the vehicular channels, channel estimation techniques, such as pilot symbol assisted modulation should be employed).

Channel coding can be performed on a service type basis. The following options could be available: (a) Convolutional coding, (b) Outer Reed Solomon (RS) + Outer interleaving + Convolutional coding, (c) Turbo coding.

Additionally, Automatic Repeat Request (ARQ) schemes can be employed for packet services with no delay constraints (for example, data services). High peak rate modes (such as mode 6) that have high PERs can be used in conjunction with ARQ protocols for non delay sensitive services. Turbo codes also allow the modem to trade off improved PER at the cost of latency. Interleaving is used to ensure that the channel coding performs well in the presence of burst errors introduced by the fading channel. This paper considers the case of convolutional coding with soft decision Viterbi decoding.

The raw bit rate depends on the chosen modulation scheme. Channel coding also affects bandwidth efficiency. Different modes with different modulation and coding rates will provide a number of data rates. These modes can be selected by a link adaptation scheme. Table 3 shows the bit rate for the different transmission modes considered in this paper.

IV. MULTIPLE ACCESS

The multiple access scheme considered here is TDMA. The TDMA scheme is capable of accommodating multirate traffic, which is essential to multimedia applications. Note that in general, within a given time slot, a mobile station may use all or some of the allocated subcarriers. Hence, the transmission rate of each mobile station may dynamically vary from slot to slot. This situation is known as orthogonal frequency division multiple access (OFDMA) [7,8]. Although this technique provides the means for extended flexibility and multirate transmission, it requires precise synchronisation between the mobile stations and thus high implementation complexity. However, OFDMA provides better coverage by allocating a power level that is a function of user distance on the downstream and concentrating the available user terminal power on a few carriers in the upstream. This gain is increased with the number of subcarriers. Hence, both multiple access schemes are under consideration in the SATURN project. For this paper, the simpler OFDM/TDMA scheme will be considered, where each time slot is dedicated to a mobile terminal. However, the physical layer OFDM results are not dependent on the multiple access scheme.

If we assume a TDMA/TDD approach the base station informs the 'Mobile Terminals' (MTs) at which point in time in the MAC frame they are allowed to transmit their data. Time slots are allocated dynamically depending on the

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need for transmission resources. Multiple virtual connections with different bit rates and QoS requirements can be established. If a frame duration of 10ms is assumed then the number of OFDM symbols in a frame is N_{frame}= 128. This approach is similar to that taken in the 802.11a and HIPERLAN/2 standards [13].

For packet based services, if the parameters of Table 3 are assumed then a packet size of 162 bytes will result in an integer number of OFDM symbols for most transmission modes. Of course, if additional Reed Solomon coding is employed then the packet size will be reduced according to the number of redundant bits in the outer code. In each packet, 3 bytes can be used for error detection, using CRC (Cyclic Redundancy Check) codes.

V. PERFORMANCE RESULTS

Figures 1 and 2 present the BER and PER (Packet Error Rate) performances of the different transmission modes (specified in Table 3) versus the average SNR for channel model 4 (see Table 1). An outer RS code or an ARQ scheme (in combination with CRC codes) - depending on the QoS requirements of the application - can be employed to reduce the application error rate. These codes can reduce the residual PER to approximately 10^{-9} - 10^{-11} for PERs of 10^{-1} - 10^{-3} for a code rate in the region of 0.9.

Figure 3 shows the simulated PER performance versus SNR for mode 4 under all considered channels. It can be seen that as the delay spread increases the performance improves. This continues until the delay spread becomes so large that ISI and ICI become limiting factors (channel 6). It is important to point out that the symbol duration, T=78.125μs, is much smaller than the channel coherence time, even in the case of fast variation (vehicular model), where the coherence time is approximately Tc≈3ms. Therefore, channel time variations can be neglected within each OFDM symbol. Thus, a time invariant impulse response can be associated with each transmitted OFDM symbol, which may change between OFDM symbols [12].

Channels 1 and 3 have similar performances due to their similar values of rms delay spread (see Table 1). Channels 2, 5 and 4 have increasingly better performances relative to channels 1 and 3 due to the increased frequency diversity of the channels. In channel 6 the excess delay (~20 μs) of the channel is larger than the guard interval (~16 μs) so ISI cannot be completely eliminated. Thus, performance starts to deteriorate for excess delays more than ~16 μs. Employing an FFT size of 512 instead of 256 with T_g=31.25μs (see Table 2) can solve this but at the expense of increased implementation complexity and sensitivity to Doppler and phase noise.

It can be observed from Figures 1 and 2 that modes 3 and 4 have similar performances for the case of channel 4. Hence, approximately the same degradation in performance results from increasing the code rate or changing the modulation scheme. The similar performance of QPSK ¾ rate and 16-QAM ½ rate is due to the fact that the latter is able to tolerate more erroneous subcarriers, which compensates for the smaller distance between constellation points [9].

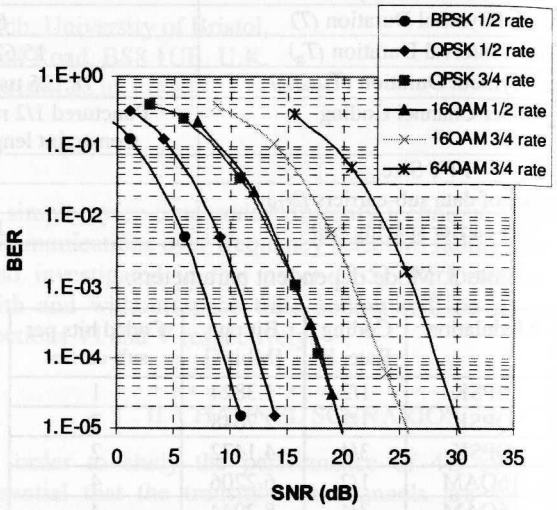


Fig. 1. BER Performance of the 4G system.

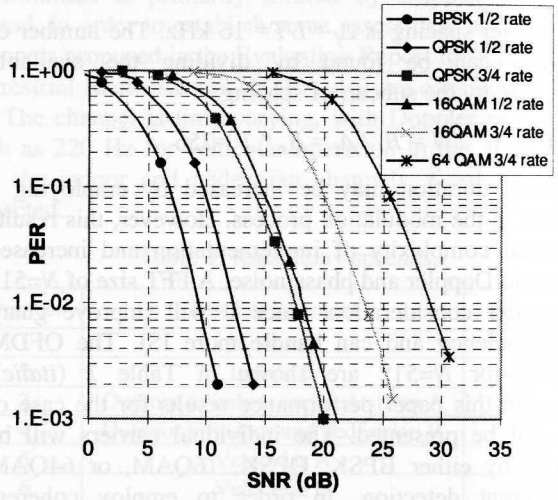


Fig. 2. PER Performance (Packet size =162 bytes).

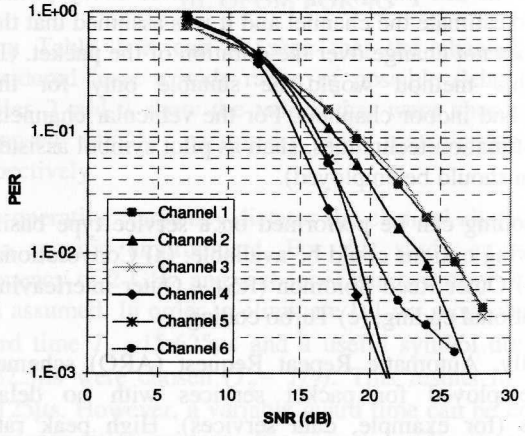


Fig. 3. PER Performance of mode 4 for all the channels.

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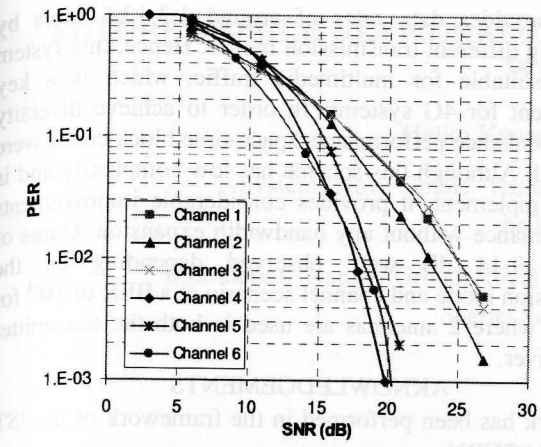


Fig. 4. PER Performance of mode 3 for all the channels.

However, it can be seen from Figures 3 and 4 that these two modes do not have the same performance for all channels. It can also be observed that the performance of mode 3 is much better than that of mode 4 in channel 6. The error floor in mode 3 appears for much lower PER values. This is due to the fact that lower order modulation schemes cope better with ISI.

VI. SPACE TIME CODING

In [3] Alamouti proposed a simple transmit diversity scheme which was generalized by Tarokh [10] to form the class of Space-Time Block Codes (STBC). These codes achieve the same diversity advantage as maximal ratio receive combining (allowing for a -3dB offset for the case of 2 Tx antennas due to power normalization) [5].

In [4], Lee and Williams applied a 2Tx-1Rx antenna, transmit diversity scheme to OFDM in order to achieve diversity gain over frequency selective fading channels. In this paper, STBC will be applied to the OFDM system with convolutional coding as described in the previous sections in order to enhance system performance. Figure 5, shows a block diagram of the 2Tx, mRx (m = 1,2), proposed space-time coded OFDM system for the case m = 1. In Alamouti's encoding scheme two signals are transmitted simultaneously from the two transmit antennas. The transmission matrix, is given by [3-5,11]:

$$X=\begin{bmatrix} X_1 & -X_2^* \\ X_2 & X_1^* \end{bmatrix} \quad (1)$$

where in the case of OFDM, X_1, X_2 are two consecutive vectors (forming a pair of vectors) to be input to the IDFT after the serial to parallel conversion (S/P) of the QAM modulated data [4]. At the first antenna, X_1 is transmitted during the first symbol period followed by $-X_2^*$ in the second symbol period. At the second antenna, X_2 is transmitted during the first symbol period followed by X_1^* in the second symbol period.

At the receiver, after the DFT and the cyclic prefix removal, the received vectors are given by [4,5]:

$$\begin{aligned} Y_1 &= H_1X_1 + H_2X_2 + N_1 \\ Y_2 &= -H_1X_2^* + H_2X_1^* + N_2 \end{aligned} \quad (2)$$

where N_1, N_2 are AWGN and H_1, H_2 are diagonal matrices whose diagonal elements are the frequency responses (DFT of h_1, h_2) of the channels between Tx1 and Rx1 and between Tx2 and Rx1 respectively (see Figure 5). It is assumed that the channel responses are constant during the period of two OFDM symbols, something that is reasonable for the OFDM parameters chosen here, where T_{symbol} = 78.125μs.

After channel estimation, the channel parameters are known to the receiver, and the signals Y_1, Y_2 can be combined at the receiver according to [4,5]:

$$\begin{aligned} S_1 &= H_1^* Y_1 + H_2 Y_2^* \\ S_2 &= H_2^* Y_1 - H_1 Y_2^* \end{aligned} \quad (3)$$

Substituting for Y_1, Y_2 from (2), the combined signals can be written as [4,5]:

$$\begin{aligned} S_1 &= (|H_1|^2 + |H_2|^2)X_1 + H_1^* N_1 + H_2 N_2^* \\ S_2 &= (|H_1|^2 + |H_2|^2)X_2 + H_2^* N_1 - H_1 N_2^* \end{aligned} \quad (4)$$

In order to perform the soft decision Viterbi decoding, the Channel State Information of both channels (H_1, H_2) is passed to the decoder in order to calculate the metric. For the case of 1 Rx antenna, the above scheme is similar to that of two branch maximal ratio receive combining (MRRC). For the case of 2 Rx antennas, the signals from the two receivers are combined and the scheme performs similarly to four branch MRRC.

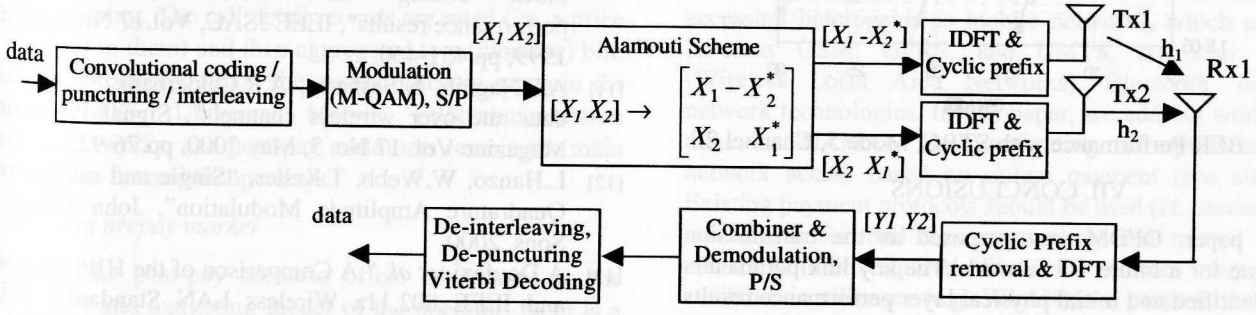


Fig. 5. Block diagram of the proposed space time coded OFDM system for the case of 2Tx, 1Rx.

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However, the Alamouti scheme has a 3 dB power loss compared to MRRC because each transmit antenna transmits only half the power so that the average received power is the same when comparing receive with transmit diversity [4,5].

Figures 6 and 7 show the BER performances of modes 1 (channel 5) and 5 (channel 2) versus the average SNR with STBC respectively. It was assumed that a perfect channel estimate was available at the receiver. It can be observed that the performance is significantly improved for both the cases of 2Tx, 1Rx and 2Tx, 2Rx antennas.

From Figure 6, it can be seen that the proposed STBC provides ~ 3.5dB gain at a BER of 10^{-4} for the case of 2Tx and 1Rx antennas and a further 5.5dB gain for the case of 2Tx and 2Rx antennas (mode 1, channel 5). For mode 5 (in channel 2), an 8dB gain for the case of 2Tx and 1Rx antennas and a further 6dB gain for the case of 2Tx and 2Rx antennas can be observed from Figure 7. Hence, the gain depends on the transmission mode and channel scenario.

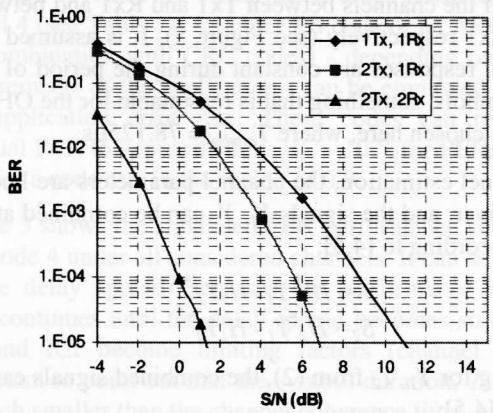


Fig. 6. BER Performance with STBC, Mode 1,Channel 5.

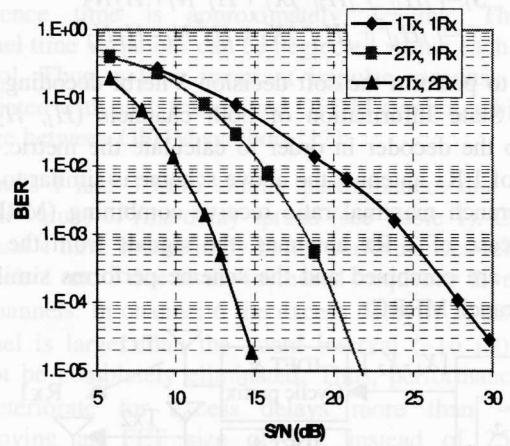


Fig. 7. BER Performance with STBC, Mode 5, Channel 2.

VII. CONCLUSIONS

In this paper, OFDM was proposed as the transmission technique for a future 4G network. The key link parameters were identified and initial physical layer performance results were presented for a number of channel models. The OFDM system provides data rates of around 1.3-12.5 Mb/s by employing different transmission modes. Hence, this system will be suitable for multimedia traffic, which is a key requirement for 4G systems. In order to achieve diversity gain and enhance performance, space-time block codes were employed. Although this scheme has low complexity and is easy to implement, it provides considerable improvements in performance without any bandwidth expansion. Gains of between 9-14 dB were observed depending on the transmission mode and channel scenario at a BER of 10^{-4} for the case where 2 antennas are used in both the transmitter and receiver.

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