The Communication Group for the Physical layer

Guido Montorsi

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Summary

- People
- Third party contracts activities
- Basic research activities and European projects

People

- The group consisted of the following permanent staff
  - Sergio Benedetto (Full professor)
  - Guido Montorsi (Associate professor)
- and the following non permanent staff
  - Post Doc
    - Alberto Perotti
    - Alberto Tarable
    - Daniele Capirone
    - Farbod Kayhan
  - PhD
    - Christian Camarda

People

- Recently (last year) the following people left the group
  - Alberto Perotti (now CSP)
  - Daniele Capirone (now Skylogic)
  - Sergio Benedetto (now ANVUR)
  - Alberto Tarable (now CNR)
- As a result, the official group is now formed by
  - Guido Montorsi
  - Farbod Kayhan
  - Christian Camarda
- although collaborations with the other components are still on going and very active in some cases

Expertise

- Design of advanced algorithms for the physical layer of communication systems, both in the transmitter and receiver sections
  - Turbo codes and iterative decoders
  - Adaptive coding and modulation
  - Equalization and turbo-equalization
  - Synchronization and turbo synchronization
  - Pre-distortion and pre-equalization techniques
- Computation of performance limits of realistic communication channels

THIRD PARTY CONTRACTS

Ongoing third party contracts

- Ericsson Marconi (ex Marconi, Vimodrone):
  - High capacity radio links for the backhaul of the wireless system
- Alenia Spazio:
  - HDRL: Advanced Techniques for High Data Rate Links for Earth Exploration Satellites
- ESA Estec
  - EDMT: Enhanced Digital Modem Techniques Development and Validation
- Sitael
  - Receiver low-power analogue decoder

Ericsson

- High capacity radio links for the backhaul of the wireless system
- Collaboration started in 2008
- 2008-2010: Design of a high speed adaptive coding an modulation system with its versatile decoder, with spectral efficiencies from 0.6 to 9 bps/Hz
  - A chip has been currently finalized which will be used in the Ericsson product of the next generation
- 2011: Design of advanced phase synchronization algorithm
  - Especially for high spectral efficiencies the performance limits of a communication system turn out to be bounded not by thermal noise but rather from the non ideal RF frond end components like the oscillators and A/D converters, yielding phase noise and timing jitter effects
  - The use of advanced synchronization techniques (turbo-synchronization) is then mandatory to achieve competitive performance for high spectral efficiencies

Ericsson

- High capacity radio links for the backhaul of the wireless system
  - 2011-2012: Line of Sight MIMO and Dual-Polarized system
    - In the effort to increase the spectral efficiency of system, next generation products will use dual-polarized antennas and Line-of-Sight MIMO, with a potential increase of a factor of 4 of the spectral efficiency.
    - The techniques pose some additional challenges at the receiver and at the transmitter
      - Differential phase noise problems
      - Differential timing errors
      - Cross-interference mitigation techniques
    - Advanced synchronization and equalization algorithm for the MIMO channel are studied to achieve the potential gain in practice
  - 2011: Continuous Phase Modulation (CPM)
    - CPM, although not competitive with linear modulations in terms of achievable performance over the AWGN, is still used in some systems because of its robustness to non-linearities of the radio.
    - Advanced CPM coding and modulation techniques are studied to improve the performance of these systems without having to redesign the radio segment (RF).

Thales Alenia

- **Near Earth observation**
- 2008: With Alenia (now Thales/Alenia), under an ESA contract, we designed and implemented the MHOMS system, an SCCC Adaptive Coding and Modulation (ACM) system for the satellite applications achieving performance close to the theoretical limits for spectral efficiencies from 0.5 to 5.4 bps/Hz and throughput op to 1Gbps
- 2010-2011: **HDRL.** We have studied, designed and optimized a low orbit satellite communication system to deliver earth exploration data to the ground exploiting the potential of ACM
- The system has the following characteristics
  - Dual polarized antenna
    - Statistical characterization of channel transfer matrix (XPD) as a function of the atmospheric condition
  - Non linearities in the on board amplifier
  - Variable channel conditions with a deterministic and a random component due to the orbit geometry and atmospheric conditions
  - Absence or limited feed-back from ground determine the type of approach
    - Constant Coded Modulation (CCM). No feed-back. A single ACM mode is used for the total duration of the satellite passage
    - Variable Coding and Modulation (VCM). No feed-back. ACM modes based on geometry and average (seasonal) statistics on atmospheric conditions
    - Adaptive Coding and modulation (ACM). Limited feedback. The ACM mode is chosen according to the channel status (instantaneous SNR)

Thales Alenia

- Near Earth observation
- Activities within the contract
  - Computation of the theoretical limits of maximum achievable throughput for CCM, VCM and ACM.
  - Optimization of the set of required ACM modes to achieve the optimal total throughput per pass and optimal switching time of modes
  - Design of advanced MIMO equalization techniques to deal with cross-polar interference
  - Design of static and dynamic predistortion techniques to deal with non linearities

ESA Estec

- TOPCOM++
  - Starting from 2005 we developed under several consecutive contracts with ESA a C++ telecommunication library, named TOPCOM++, which is the natural evolution of the old TOPSIM.
  - Right now it includes all basic and advanced blocks for the simulation of the physical layer of a (satellite) communication systems
    - Codecs, Modems, Channel models, basic DSPs modules, Equalizers, Synchronizers…
  - The library is now recommended in many new contracts proposed by ESA

ESA Estec

- EDMT: Enhanced Digital Modem Techniques
- The main objective of this activity is to select and validate new digital transmitting and receiving techniques to enhance the spectral efficiency of data transmission for broadcast and broadband applications.
- A collaboration with the University of Parma (Giulio Colavolpe)
- Topics:
  - Faster than Nyquist (FtN) signalling.
    - a technique increasing the spectral efficiency of the system by transmitting at a symbol rate greater than that imposed by the Nyquist criterion
  - Optimal and suboptimal detectors for FTN signalling
  - Capacity evaluation of FTN in the presence of non linearities with and without memory
  - Design of optimal constellations sets and labeling for the non-linear channel
    - Optimization of pragmatic and symmetric capacity under peak power constraints

ESA Estec

- EDMT: Enhanced Digital Modem Techniques
  - LDPC code designs matched to FtN signalling
  - Investigation of precoding techniques for Faster-than-Nyquist
  - Coding for Adaptive Coding and Modulation Indicator
    - In broadband (internet service) scenarios the satellite serves a set of users with very different SNRs conditions (from -15 to 15 dB). Each user must recognize from the header (ACMI) the packets that “may” be intended to him. This setting poses a very peculiar channel coding problem that requires an ad-hoc solution
    - An original variable length code construction has been proposed and will be patented

Sitael

- Analog iterative decoders
- The use of analog circuits to implement iterative decoders has been an active field of research in the past and has the potential of reducing the power consumption of iterative decoders
- The group was active on this topic some years ago (2 PRIN with the University di Padova and 1 proof-of-concept chip implemented)
- ESA recently gave a contract to Sitael to implement a low power decoder with analog technology for satellite application
- We are supporting them in the choice of the coding scheme and in the design of a suitable architecture for the decoder

BASIC RESEARCH AND EUROPEAN PROJECTS

Basic research activities

- The research activity performed during contracts in some cases yields some relevant and original contributions worth to be published or patented, within the constraint imposed by the contract
  - Advanced efficient algorithms for equalizations in Los MIMO channels and dual-pol channels
  - Turbo phase synchronization techniques for the LoS MIMO
  - Coding with very large unequal error protection (ACMI indicator)
  - Optimization of constellations for non linear channels

Basic research activities

- Capacity computation for MIMO systems affected by realistic phase noise
- Non binary technology
- Analog Digital Belief Propagation
  - We have invented and patented a very promising techniques allowing to perform iterative decoding of non-binary codes with complexity independent from the cardinality of the code alphabet
  - The technique allows to realize communication system achieving reliable communications with finite complexity and unbounded spectral efficiency
- Several topics are now under investigation
  - Design of good codes for ADBP
  - Generalization of ADBP
  - Density evolution and other design techniques for non binary codes
  - Design of non binary codes and decoders for the MIMO channels
  - Use of non binary codes in multipoint communication system

European project: Past

- NEWCOM++
- WiMagic (ended April 2010): Worldwide Interoperability Microwave Broadband Access System for Next Generation Wireless Communications
  - A consortium for the development of IP for WiMAX and LTE standards
  - Components:
    - SEQUANS , RINICOM, BRITISH TELECOM, TURKCELL, ALCATEL, SUPELEC, UNIVERSITY CATHOLIC LEUVAIN, KADIR HAS UNIVERSITY, BILKENT UNIVERSITY
    - Sequans, Alcatel Lucent, Turkcell,

European project: Future

- NEWCOM#: you all know…
- ANTHE: Advanced Non-Binary Technology for High-Throughput Communications in Packet-Oriented Networks
  - A consortium with the purpose of studying advanced non-binary technology
  - Partners:
    1. (Coordinator)Centre Tecnològic de Telecomunicacions de Catalunya (Stephan Pfletschinger)
    2. Ecole Nationale Supérieure de l'Electronique et de ses Applications (David Declercq)
    3. Alcatel-Lucent Deutschland AG (Stephan Ten Brink)
    4. WISER srl (Marco Luise)
    5. ST-Microelectronics (Stefano Valle)
    6. Technische Universität München (Gerhard Kramer)
    7. University of Nis – Faculty of Electronic Engineering
    8. Politecnico di Torino (Guido Montorsi)
    9. TurboConcept (David Gnaedig)