Technical report

SPWC ESF-Exploratory Workshop On Signal Processing for Wireless Communications

19-20 May 2003
IEE, Savoy place
London

Organiser: M. Shikh-Bahaei
Committee: Jonathon Chambers, Hamid Aghvami, and Farokh Marvasti

The workshop had two main parts of; keynote speeches by the leading figures of the area, and panel session discussions by the keynote speakers.

A main subject of the talks and discussions during the speeches and panel sessions was the role of multi-input-multi-output (MIMO) antennas, space-time coding, and beamforming in today and future of wireless communication systems.

On MIMO systems in wireless communications, the following conclusions were made;

In MIMO/MISO system channel knowledge at Tx channel state information (CSI-Tx) can be used for
– Improving Capacity / Rate
– Reducing BER / Enhancing Diversity
– SNR
In MISO and MIMO wireless any CSI-Tx can improve performance.
• Practical systems usually have some CSI-Tx.
• This is an important research area for emerging wireless systems with many open questions.

Actual applications of MIMO will occur in multiuser environments, and assess performance in the presence of MAI.

On beamforming, a new method was presented in the workshop by the inventor of space-time coding method (prf. Tarokh) that has a remarkable effect in combating the hidden beam problem, and will enhance the capacity of the wireless systems.

Another subject of the talks was broadband technology, and in particular, the ultra-wideband technology for wireless communications.

On Broadband technology in wireless communication the speakers believed that;
An important issue is how to offer both cellular and nomadic users broadband multimedia services everywhere. A global wireless system was suggested to offer broadband wireless services to cellular and nomadic users.

Many dedicated wireless systems are efficiently interconnected, including 2~4G cellular systems, wireless LANs, broadcasting systems, etc., each optimized to the other communications environments.

Common wireless technology of 100M~1Gbps capability in 4G, cellular of ~100Mbps and hot spot wireless access of ~1Gbps, Software defined radio, and MIMO systems Giga-wireless technology are challenging research issues for the coming years.

UWB is one of the most important fields of R&D for ultimate wireless communications. Academia, Industry, and Government should cooperate to promote and accelerate R&D of UWB.

USA, Europe, Japan and the rest of a world should fairly compete in research and business in these fields.

The most important development for UWB is how to implement low-cost Chip set and SoC with low-power consumption for portable UWB systems.

Another title for discussions was wireless channel analysis methods, and a new asymptotic approach was provided in the workshop. This mathematical method is given in the workshop proceeding. One of the conclusions during the discussions of the panels and from the talks regarding these analyses was that increasing the degree of diversity would help, in terms of capacity enhancement, only to some extent. That is, when the diversity degree by, say, increasing the number of antennas at the transmitter or the receiver, exceeds some threshold, we will not gain any more capacity.

Another subject of the talks was; Multifold turbo coding;
Multifold coding is a technique that can potentially improve the bit and frame error performance of any given turbo code.
Multifold coding brings the codeword weight distribution closer to binomial distribution, which contributes to the improved error performance. It involves;
• Segmentation of an information block
• Grouping of information segments
• Turbo encoding of the grouped segments

During panel sessions, also was discussed about the future of MIMO systems for cellular and WLAN systems, Joint optimization of cellular and Wireless LAN networks, Cross-layer issues in enhancement of capacity/performance of wireless

networks, interference cancellation issue in UWB systems, migration toward 4G and the need to support heterogeneous wireless systems, and finally about future of wireless optical networks.

As about MIMO systems, the conclusion was that the next generation of wireless communications will be more extensively involved with the applications of MIMO mechanisms, but the number of Antennas at the input and output are to be limited by about 8 antennas practically, as there is no remarkable gain in exceeding that level. They also will be applied in WLAN systems to enhance the capacity and the performance of the systems.

Joint optimization of wireless LAN and cellular systems is a very involving task, but the applications are limited. However, cross-layer optimization of the networks is a vital issue for achieving the channel capacity. In particular, the MAC and network layers should be taken into account along with the physical layer in the design of the networks to achieve higher levels of performance.

UWB still has a large number of unsolved issues, and particularly the interference on/from other coexisting systems can be a significant challenge for signal processing in wireless communications.

Wireless optical communication has grown, but the applications remained very limited.

The trend toward 4^{th} generation of wireless systems is more likely to be toward heterogeneous systems rather than a unified access technology.

Finally, in addition to the transmit power limits, the issue of power dissipation within the circuits should be taken seriously when the design of wireless networks with power limitations is concerned. This has a major effect on achieving capacity of the wireless channels.

Detail of the technical and mathematical material can be found in the workshop proceedings (in hard copy and CD format).

Expected outcomes

SPWC ESF exploratory workshop

Contributions to the field:

A number of contributions to the field of signal processing in wireless communications were made by the leading figures of the realm during the SPWC workshop. In the following is given outcome of some of these contributions;

A new processing method for increasing capacity/coverage of the wireless systems: For the first time, the complementary beamforming (CBF) technique was revealed by Prof. Tarokh (the inventor of Space-Time codes for wireless systems). This technique was invented by himself and his associates at Vivato research and development, WA, and can be used in wireless communication systems to increase the range/capacity.

This method potentially avoids unnecessary transmissions, subsequent back-offs, increased network latency and interference, and in summary, the Hidden Beam Problem. Furthermore, employing the CBF technique can conserve the battery life of the remote devices.

New method for wireless channel analysis; Analysis of the wireless channels is of great significance, for the capacity of such channels can only be predicted by means of such analytical information of the channel. Prof. Verdu, who has conducted many original analyses of the multi-user detection methods for wireless communication applications, discussed about his new asymptotic methods for performing wireless channel analysis.

Signal processing aspects of energy-constrained wireless networks; This highly important issue in signal processing for wireless communications was discussed within the workshop by Dr. Bahai. According to discussions about this issue, in an energy-constrained wireless network where all the nodes operate on batteries, the individual energy consumption should be minimized while satisfying certain throughput requirement in order to maximize the battery life. It was discussed that in short-range applications the circuit energy consumption overhead is comparable to the transmission energy, so a significant outcome of the discussions was that **traditional techniques must be modified to minimize the total energy consumption.**

Some of the conclusions was that TDMA and FDMA are the same as far as the transmission energy concerned. However, TDMA does have an advantage of saving circuit energy consumption when the transmitter works on a multi-mode basis.

Further Collaborations:

-It was decided that our group (CDSPR at King's College) will collaborate with Lancaster university (through Prof. Honary, one of the keynote speakers and panellists during the workshop) to expand on some of the signal processing aspects of wireless communications which was discussed in the workshop. Specifically, we will work on system capacity enhancement methods using signal processing with energy-constraints.

-It was decided that we (CDSPR at King's College) will closely work, and collaborate with Nokia (the company who participated and had a keynote speaker in the workshop), on the signal processing issues of wireless communications.

-There will be also collaborations between our centre/college with the Harvard university, through prof. Tarokh, and with Prof Kohno (Yokohama university, Japan, on UWB technology), in the future.

Final Programme

Monday 19 May

08:30	Registration
09:00	Workshop Inauguration by: the Workshop Organiser, the Director of CDSPR at King's, and the ESF representative
09:30	Prof Paulraj, Stanford University, on 'Recent Advances in Channel Pre-Coding for MIMO Wireless'
10:30	Break
11:00	Prof Tarokh, Harvard University, on 'Complimentary Beam-forming', and Prof Adachi, Tohoko University, on 'Broadband wireless technology'
12:40	Lunch
13:30	Prof Kohno, Yokohama National University, on 'Soft-Spectrum Adaptation for Ultra Wideband (UWB) Wireless', and Prof Hanzo, Southampton University, on 'Adaptive modulation, channel coding and diversity techniques for next-generation wireless systems'
15:00	Break
15:30	Panel Session
17:00	End of Monday sessions

Tuesday 20th May

09:00	Prof Biglieri, Politecnico di Torino, on 'Coding for multiple antennas with linear and nonlinear suboptimum interfaces' and Dr Bahai, National Semiconductor (Wireless CTO) and Stanford University, on 'Analog/Digital Signal Processing- Joint Optimization under Energy Constraints'
11:00	Break
11:30	Prof Verdu, Princeton University, on 'New Asymptotic Methods for the Analysis of Wireless Channels'
12:30	Lunch
13:30	Prof Honary, Lancaster University, on 'Multi-fold turbo codes for image transmission' and Prof Al-Akaidi, De Montfort University, on 'M-QAM Modulation and Diversity Effects on Wireless Communication'
14:30	Dr Charbit, Nokia Networks, on GERAN Algorithm and system research - Physical Layer
15:00	Panel Session
16:30	Refreshment and End of the Workshop

List of Participants:

Prof Biglieri, Politecnico di Torino
Prof Paulraj, Stanford University
Prof Tarokh, Harvard University
Prof Adachi, Tohoko University
Prof Kohno, Yokohama National University
Prof Hanzo, Southampton University
Prof Verdu, Princeton University
Dr Bahai, National Semiconductor
Prof Chambers, King's College London
Prof Aghvami, King's College London
Prof Honary, Lancaster University
Dr Charbit, Nokia Networks

There were also a number of participants from the academia and industry within Europe who attended the sessions and questioned the expert speakers during the speeches and panel sessions.

Here are some of them;

Dr. Adedi, Fujitsu Laboratories Europe Ltd.
Dr. Karimi, Lucent technologies UK
Sun Yong, Toshiba Research Europe Limited
Prof Koivunen, Helsinki University of Technology
Dr Desmond McLernon, Leeds University
Jordy Potman, University of Twente, Netherlands
Dr Malcolm Macleod, QinetiQ, UK