MULTI-USER OFDM
'A HALF-DAY RECITAL OF THE CLASSIC AND OF THE AVANTGARDE' BY

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1. A FUTURE-PROOF MULTICARRIER STANDARD FRAMEWORK[1].

This light-hearted overview commences with a brief historical perspective on the advances in wireless multi-carrier communications, spanning from its first portrayal in the 1957 paper of Doelz, Heald and Martin to the most recent radical research ideas. It is based on an amalgam of [5]-[4]. Multi-standard operation is an important requirement for the future generations of wireless systems. This overview commences with the portrayal of a versatile broadband multicarrier scheme, which is capable of meeting the requirements of future generations of wireless systems, by supporting backwards compatibility with the existing standardised systems, while also introducing more advanced techniques facilitated by the employment of Software Defined Radios (SDR) and efficient adaptive baseband algorithms [2]-[1].

2. ADAPTIVE VERSUS SPACE-TIME CODED OFDM/MC-CDMA [3]

The presentation continues by demonstrating that Symbol-by-symbol adaptive Orthogonal Frequency Division Multiplex (OFDM) modems have the potential of counteracting the near instantaneous channel quality variations of wireless channels and hence attain an increased throughput in comparison to their fixed-mode counterparts. By contrast, various diversity techniques, such as Rake receivers and space-time coding, mitigate the channel quality variations in their effort to obtain a reduced BER. This overview investigates a combined system constituted by a constant-power adaptive modem employing space-time coded diversity techniques in the context of both OFDM and MC-CDMA. The combined system can be configured to produce a constant uncoded BER and exhibits virtually error free performance, when a turbo convolutional code is concatenated with a space-time block code. It was found that the advantage of the adaptive modem erodes, as the overall diversity-order increases [3].

3. PIC-ASSISTED CHANNEL ESTIMATION FOR SDMA-AIDED MULTIUSER OFDM [3]

OFDM systems employing multiple transmit antennas have recently drawn wide interest in the context of both space-time coded- and multi-user space-division multiple access (SDMA) arrangements. A prerequisite for using coherent detection at the receiver is the availability of reliable channel transfer factor estimates. Robust parallel interference cancellation (PIC) assisted decision-directed channel estimation (DDCE) has been shown in the literature to be also applicable to scenarios, where the number of users is in excess of the number of OFDM subcarriers - normalized to the number of Channel Impulse Response (CIR) related taps to be estimated - which imposed a limitation in the context of least-squares assisted DDCE techniques invoked in conjunction with multiple transmit antennas. In this paper we will demonstrate that the Recursive Least-Squares (RLS) algorithm is applicable to optimizing the predictors' coefficients on a CIR-related tap-by-tap basis. Compared to 'robust', non-adaptive approaches the proposed solution has the advantage of a potentially lower estimation MSE and a higher resilience to erroneous subcarrier symbol decisions [3]

4. MULTIUSER DETECTION FOR MC-CDMA [1]

In this part of the presentation a Genetic Algorithm (GA) assisted Multiuser Detector (MUD) designed for MC-CDMA is investigated in the context of frequency selective Rayleigh fading channels. The achievable BER performance of the GA assisted MUD as well as its near-far resistance are investigated for a range of parameter values. It is shown that the proposed GA assisted MUD is capable of significantly reducing the complexity in comparison to that of Verdu's optimum MUD. For example, when supporting $K = 20$ users, the number of likelihood function evaluations is reduced by a factor of 1300 [1]

5. REDUCED-COMPLEXITY MAXIMUM-LIKELIHOOD COMPLEX SPHERE DECODING FOR SDMA/SDM-AIDED RANK-DEFICIENT MULTI-USER OFDM [4]

A novel Space Division Multiplexing (SDM) detection method is considered, which constitutes a list-based search method and may be regarded as an advanced extension of the Sphere Decoder (SD). Our method may be employed in the so-called over-loaded scenario, where the number of transmit antenna elements exceeds that of the receive antenna elements. Furthermore, it is suitable for high-throughput, non-constant modulus modulation schemes, such as 16 and 64-QAM. We inroduce a series of optimization rules which facilitate a substantial reduction in computational complexity. More specifically, we demonstrate that the method proposed, which we refer to as the Soft-output OPtimized

HIErarchy (SOPHIE)-aided SDM detector exhibits the near-optimum performance of Log-MAP SDM detector in all considered scenarios. The associated computational complexity, which we control using two complexity-control parameters, is substantially lower than that imposed by all previously proposed methods.

6. GENETIC ALGORITHM ASSISTED JOINT CHANNEL ESTIMATION AND COMPLEX SPHERE DECODING FOR SDMA-AIDED RANK-DEFICIENT MULTI-USER OFDM [4]

Multiple-Input-Multiple-Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) systems have recently attracted substantial research interest. However, compared to Single-Input-Single-Output (SISO) systems, channel estimation in the MIMO scenario becomes more challenging, owing to the increased number of independent transmitter-receiver links to be estimated. In the context of the Bell LAyered Space-Time architecture (BLAST) or Space Division Multiple Access (SDMA) multi-user MIMO OFDM systems, none of the known channel estimation techniques allows the number of users to be higher than the number of receiver antennas, which is often referred to as an "overloaded" scenario, owing to the constraint imposed by the rank of the MIMO channel matrix. Against this background, in this paper we propose a new Genetic Algorithm (GA) assisted iterative Joint Channel Estimation and Multi-User Detection (GA-JCEMUD) approach for multi-user MIMO SDMA-OFDM systems, which provides an effective solution to the multi-user MIMO channel estimation problem in the above-mentioned overloaded scenario. Furthermore, the GAs invoked in the data detection literature can only provide a hard-decision output for the Forward Error Correction (FEC) or channel decoder, which inevitably limits the system's achievable performance. By contrast, our proposed GA is capable of providing "soft" outputs and hence it becomes capable of achieving an improved performance with the aid of FEC decoders. A range of simulation results are provided to demonstrate the superiority of the proposed scheme.

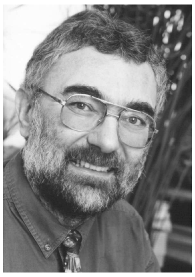
7. MINIMUM BER MULTIUSER DETECTION FOR MIMO-OFDM [4]

The family of minimum bit error rate (MBER) multiuser detectors (MUD) is capable of outperforming the classic minimum mean-squared-error (MMSE) MUD in term of the achievable bit-error rate (BER) owing to directly minimising the BER cost function. In this paper, we will invoke genetic algorithms (GA) for finding the optimum weight vectors of the MBER MUD in the context of multiple-antenna aided multi-user OFDM. We will also show that the MBER MUD is capable of supporting significantly more users in so-called rank-deficient scenarios than the number of receiver antennas available, while outperforming the MMSE MUD.

This overview of next-generation wireless enabling techniques will be concluded with a future-proof new design paradigm, highlighting a range of open problems for the radical researcher.

Primary and Secondary Audience

Whilst this overview is ambitious in terms of providing an advanced research-oriented outlook, potential attendees require only a modest background in mathematics, signal processing and wireless communications. The mathematical contents are kept to a minimum and a conceptual approach if adopted. Postgraduate students, researchers and signal processing practitioners as well as managers looking for crossfertilisation of their experince with other topics may find the coverage of the presentation beneficial. The participants will receive the set of slides as supporting material and they may find the detailed mathematical analysis in the above-mentioned books.



During his 30-year carreer **Lajos Hanzo**, FRAEng, DSc, FIEEE, FIEE has held various academic and research positions in Hungary, Germany and the UK. Since 1986 he has been with the University of Southampton, where he holds the Chair of Telecommunications. Over the years he has co-authored 15 books on mobile radio communications, published in excess of 700 research papers. Lajos has also been awarded a number of distinctions and he is an IEEE Distinguished Lecturer of both the Communications and the Vehicular Technology Society. For further information on research in progress and **for associated papers and book chapters please refer to http://www-mobile.ecs.soton.ac.uk**

Lajos presented short courses for example at the following IEEE conferences:
ICCS'94 in Singapore; ICUPC'95 in Tokyo; ICASSP '96 in Atlanta, USA; PIMRC'96 in Taipei, Taiwan; ICASSP'96 in Atlanta; ICCS'96 in Singapore; VTC'97 in Phoenix, USA; PIMRC'97 Helsinki, Finland; VTC'98, Ottawa, Canada; Globecom'98 Melbourne, Australia; VTC'99 Spring Houston, USA; EURASIP Conference'99, June, 1999, Krakow, Poland; VTC'99 Fall Amsterdam, The Netherlands; VTC'2000 Spring Tokyo, Japan; VTC'2001 Spring Rhodes, Greece; Globecom'2000 San Francisco, USA; Globecom'2001 San Antonio, USA; ATAMS'2001 Krakow, Poland; Eurocon'2001, Bratislava, Slovakia; VTC'2002 Spring Birmingham Alabama, USA; VTC'2002 Fall Vancouver, Canada; ICC'2002, New York, USA; Wireless'02, Calgary, Canada; WPMC'02 Honolulu, Hawaii; ATAMS '2002, Krakow, Poland; WCNC'03 New Orleans, USA; VTC'2003 Spring, Jeju Island, Korea; PIMRC'2003, Beijing, China; VTC'03 Fall Orlando, USA; VTC'04 Spring, Milan, Italy; European Wireless Conference'04, Barcelona, Spain; ICC'04, Paris, France; EUSIPCO'04, Vienna, Austria; European Wireless Conference'2005, Nicosia, Cyprus; VTC'05 Spring Stockholm, Sweden; VTC'05 Fall, Dallas, USA; WPMC'05 Aalborg, Denmark; VTC'06 Spring Melbourne, Australia; ICC'06 Istanbul, Turkey; VTC'06 Fall, Montreal, Canada; VTC'07 Spring, Dublin, Ireland; ICC'07, Glasgow, Scotland; IST'07, Budapest, Hungary; ColCom'07, Bogota, Colombia; VTC'07 Fall, Baltimore, USA; ICSPC'07, Dubai;

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