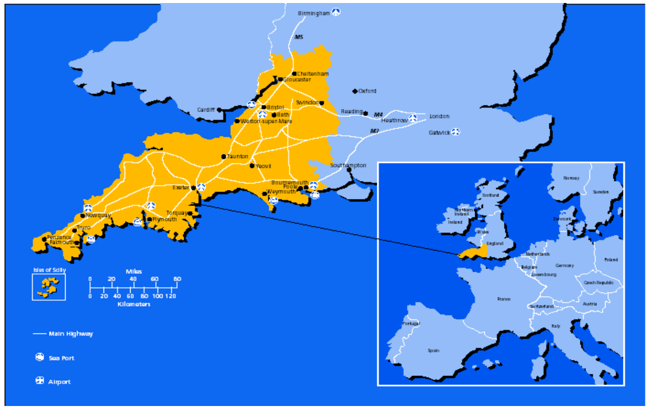
Selected Areas of Wireless Communications Research at the University of Bristol

Professor Joe McGeehan CBE FREng

The South West of England & the University of Bristol



- Home to 5 Million people, with 380,615 in the City of Bristol
- 150km from London (2hrs from Heathrow)

- University founded in 1833
- Engineering from 1878
- 5000 staff (inc.1500 academics)
- 11000 students (+ postgraduates)
- Annual income in excess of £320 million
- International reputation in teaching & research
- Most Distinguished Alumni: Prof Paul Dirac – Nobel Laureate (Electrical & Electronic Eng)

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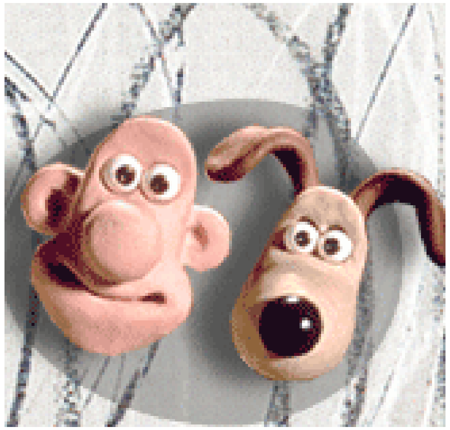
Bristol – Science City



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Department of Electrical & Electronic Engineering: Selected Awards for Research

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Bristol – Technology Clusters

Aerospace and Defence

Telecoms

Micro Electronics

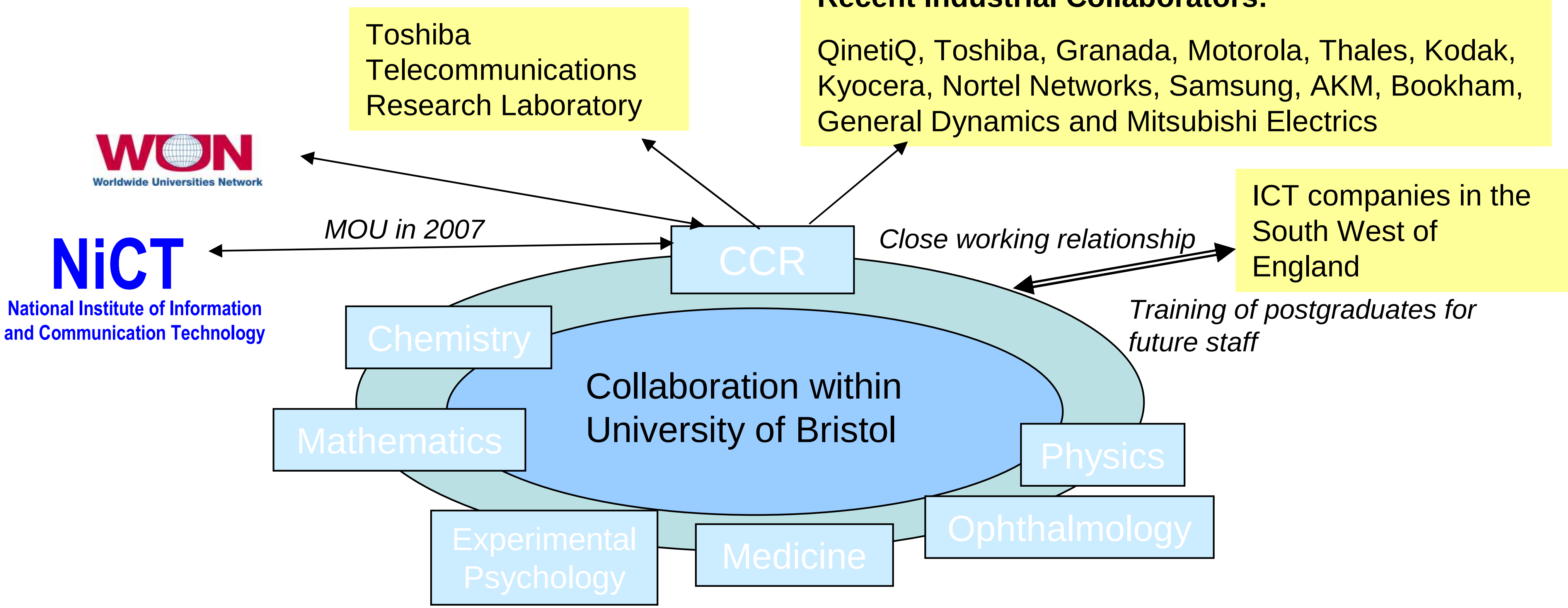
Creative Media

Centre for Communications Research (CCR)

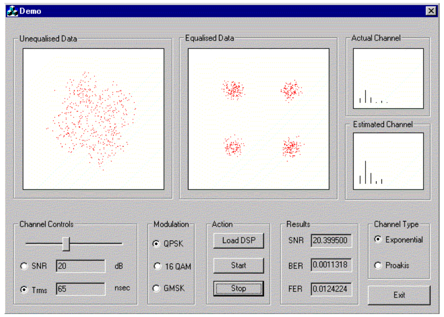
- Interdisciplinary University Research Centre within Department of Electrical and Electronic Engineering
- Established in 1987
- Successful model repeated around the world
- Currently home to over 140 researchers involved in areas including:
  - Wireless Communications
  - Electromagnetics
  - Signal processing
  - Networks and Protocols
  - Photonics including Quantum Information & Nanotechnology
- Founding Member of Mobile VCE (with Universities of Bradford and Surrey)
- Member of Worldwide University Network and Wireless Communications Exemplar Lead

Areas of Expertise include:

- Communications systems
- RF Engineering
- Photonics/nanotechnology
- Bio-engineering
- Digital signal processing
- Electromagnetics
- Networks & protocols

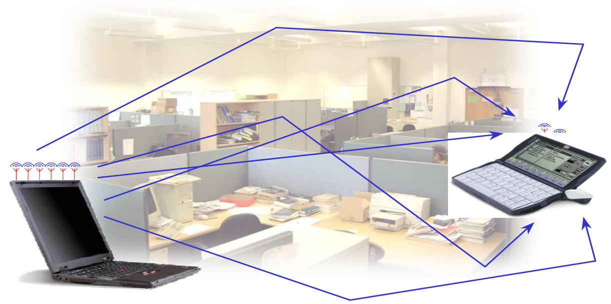


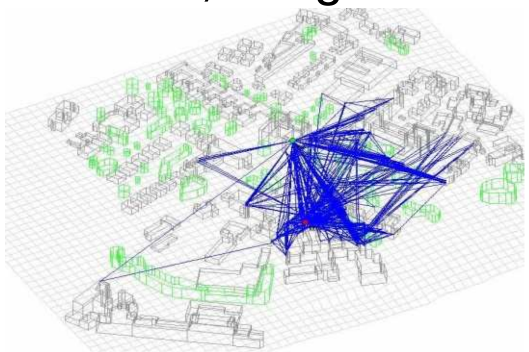
CSN Research Group (17 Academics)



Fundamental analysis & novel transceiver architectures for Spectrum and Power Efficient advanced wireless access (OFDM, WCDMA, UWB, Chaotic Waveform Design,…) including Software Defined Radio and Cognitive Radio

Smart Antenna techniques for Capacity Enhancement (SDMA, Diversity, MIMO, low complexity decoding algorithms, etc), Test-bed design, performance evaluation, integrated and optimisation of MAC & RRM.





Wideband multi-sensor spatial temporal propagation. Full 3D ray tracer (Infoterra database & Antenna patterns), Medav RUSK MIMO sounder & Elektrobit C8 channel emulator).

Power Efficient Linear RF Technologies (Basestation & Handset). Enabling techniques for Cognitive Radio (MEMS, Metametials…)

Key achievements

- Ray-tracing & Spatial temporal propagation
  - Outdoor, indoor, hotspot…
- State of art Linear RF amplifiers
  - Highly linear and power efficient
  - Narrowband and Broadband Amplifiers
- Linearised mixers & linear modulation
- Smart antenna arrays*
  - Diversity, SIMO, MIMO, testbeds, Reduced Lattice Decoder
- Wideband CDMA (pre 3G)
- Wireless LAN technologies
  - EU Project LAURA ⇨ HIPERLAN 1 Standard
- Physical layer/MAC layer interactions
  - Novel protocols and radio resource management
- Analogue Signal Processing – MIMO detection
- IEEE Trans VTC: Best Paper Award on Antennas and Propagation

Early mobile developments

Image from PYE Museum Website http://www.qsl.net/gm8aob/group.htm
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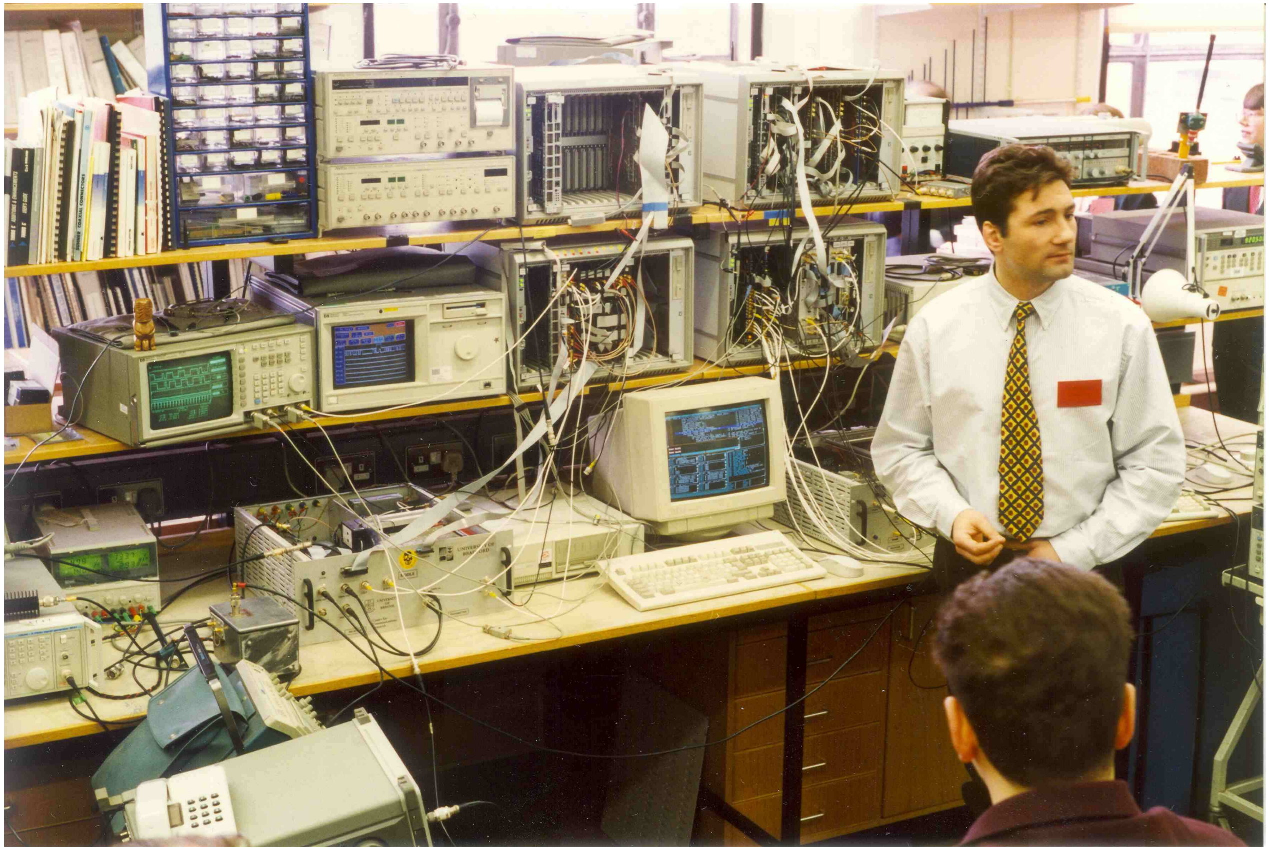
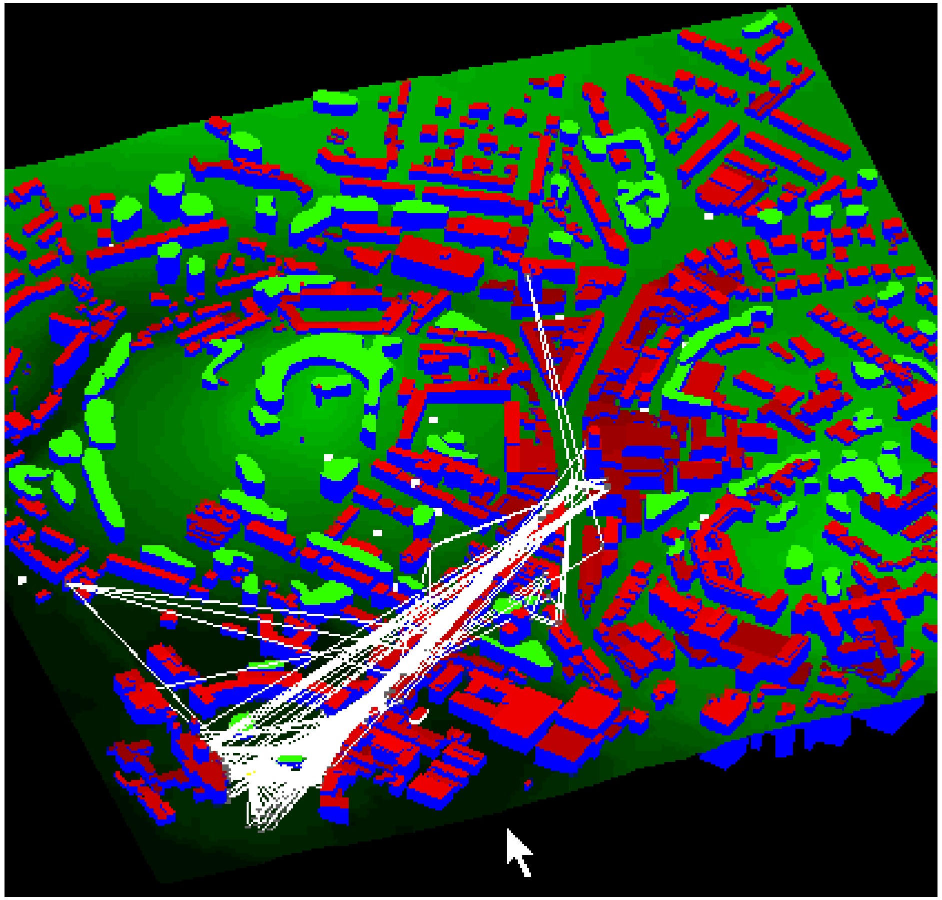
World-class Research: WCDMA & 3G



Advanced Wireless Access: Propagation Prediction

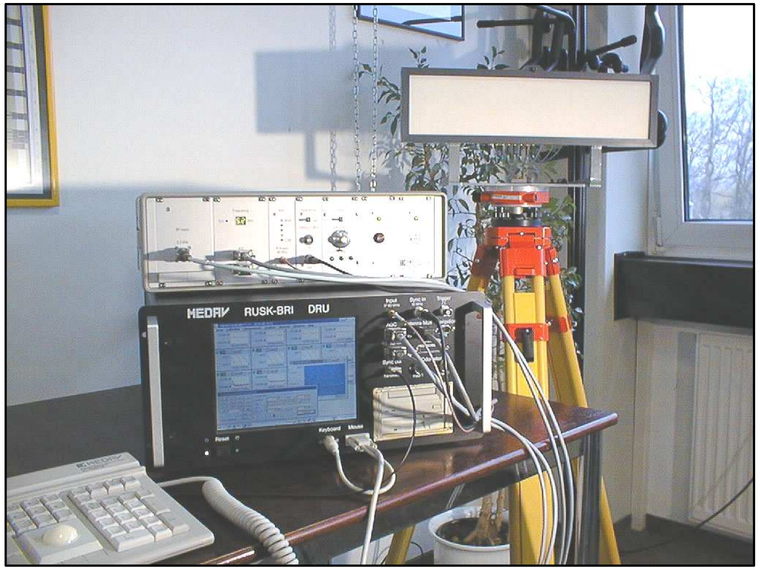


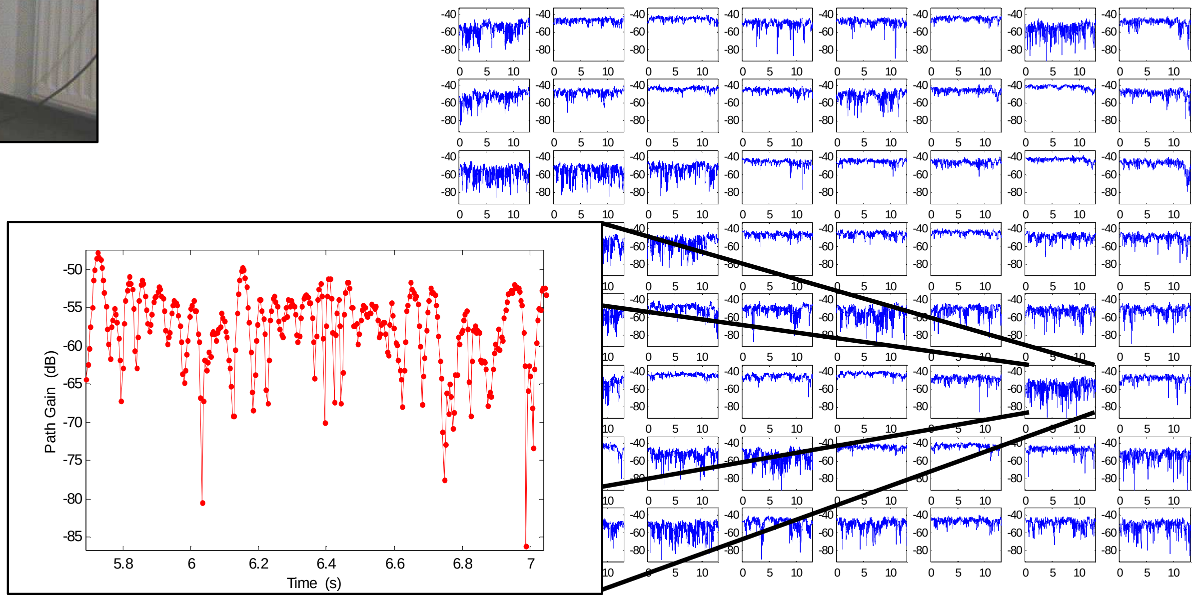
- The 3D ray model utilises urban geographic data to produce spatial/temporal channel predictions over irregular terrain. Predictions include:
    - received power;
    - K-factor;
    - time dispersion;
    - spatial dispersion (AoD/AoA).

- Ray traced CIR can be exported for use in PHY layer simulations.

MIMO: Propagation measurement & analysis

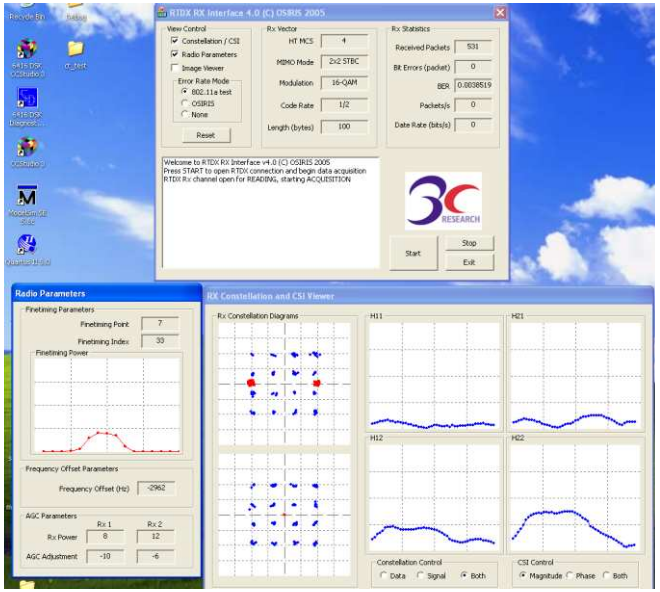
- State of the art channel sounding
- Extensive analysis & modelling
- Fundamental understanding of MIMO
- Realistic simulations

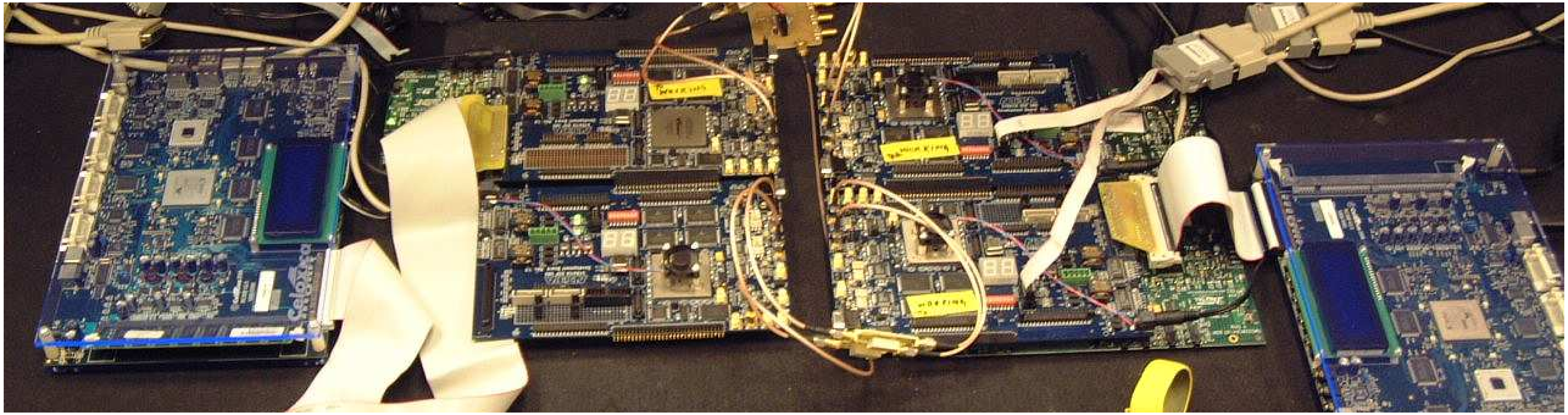




MIMO: Real-time MIMO hardware test-bed

- DTI funded project
- Transfer of knowledge, skills and expertise from theory to simulation, through to implementation



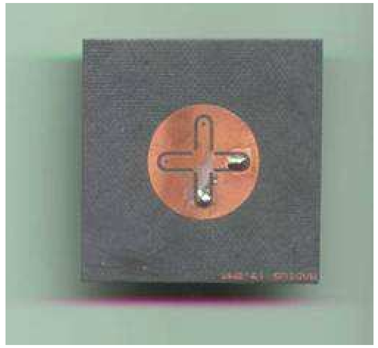


Antenna Element and Array Design

- Passive antenna design
- Arrays for Handset/ PDA/ laptop applications
- Pattern Analysis (Beamforming and MIMO applications)
- Electrically-small antennas
- Active (self-tuning) printed antennas
- Integrated antenna-RF transceiver elements

Conformal vehicle-mounted antenna under testing

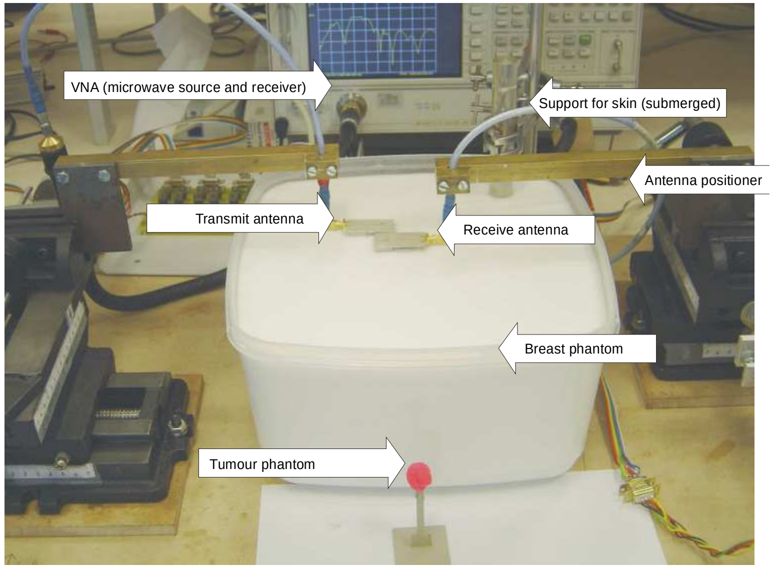
Handset antenna design for 4th Generation Mobile phones

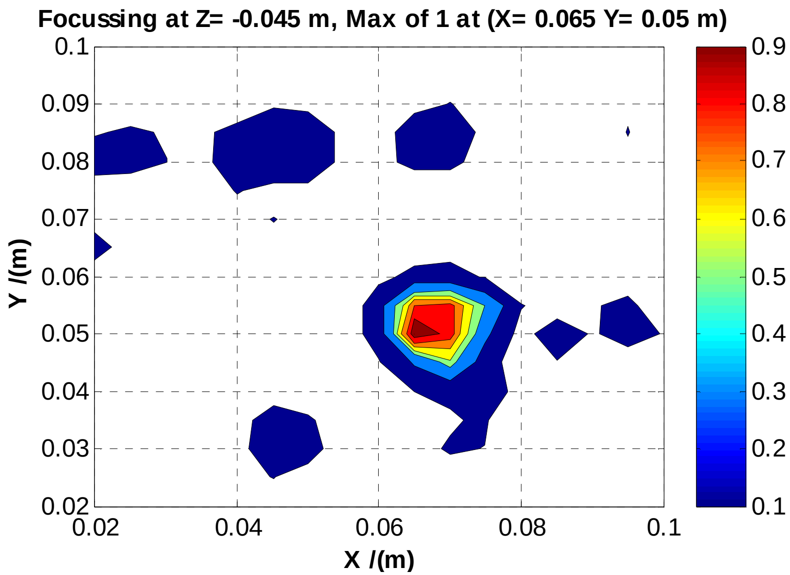


Dual polarised antenna for 5.2GHz MIMO applications

Electromagnetics: Breast Cancer Detection using Microwaves

- A market in Europe, US and Japan of £150m per annum.
- A non-invasive, non-ionising detection technique (traditional X-rays *cause* cancer if repeated).
- Being tested in lab conditions. Patient trials expected in late 2005.





Left: lab set-up (breast phantom and antennas), Right: experimental results (6mm tumour)

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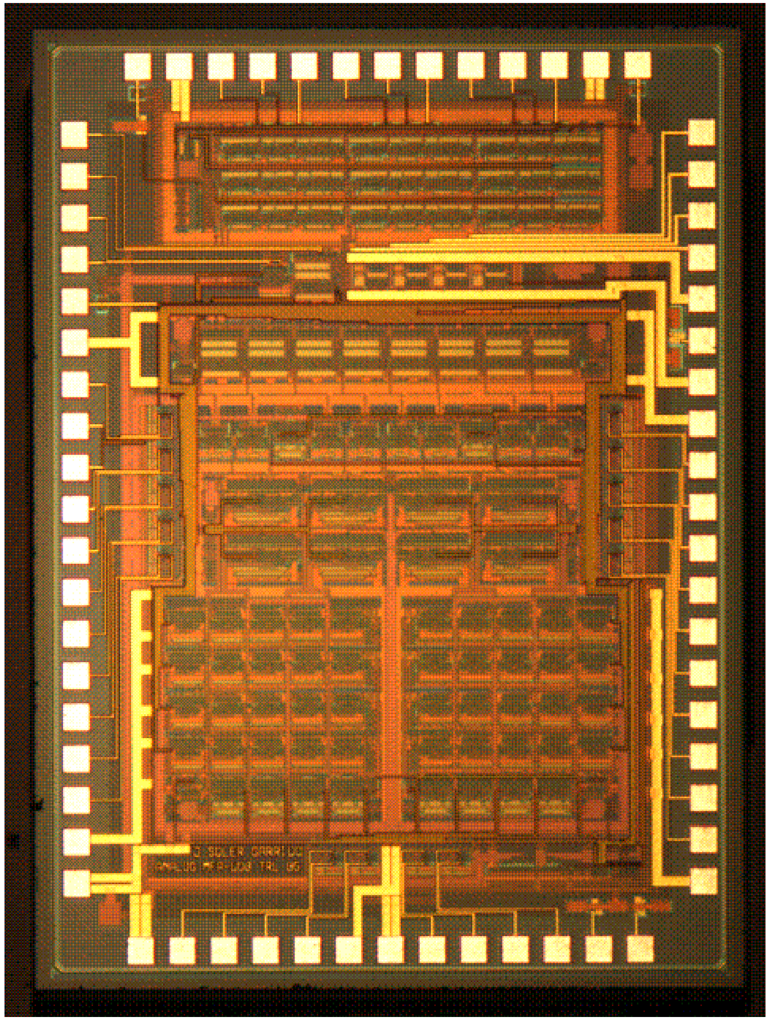
Analogue signal processing

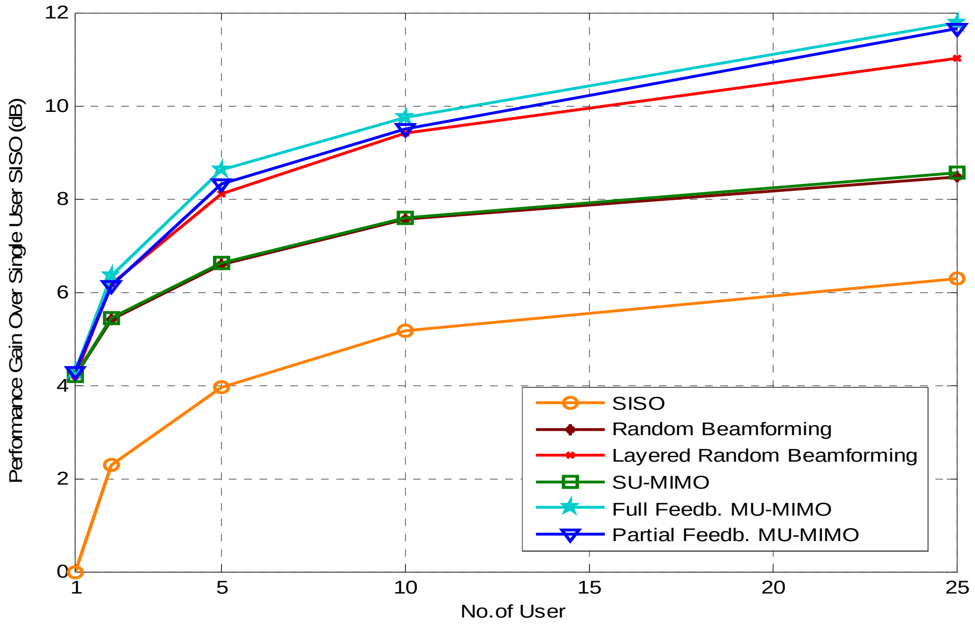
- Receiver signal processing using analogue modules.
  - High speed – Low precision
  - Towards ADC-less receiver
  - E.g. analogue MIMO detector: [UoB, TRL, *ihp* (Germany)]
- Shift in processing from baseband to RF frequency?



Current and Future Research: Areas of Collaboration

- Cognitive radio and Environment
- Advanced Wireless Access
- Information theory and coding for multi-terminal wireless networks
- Home Information Systems & Smart Grid
- Very High Throughput Systems (>1TBps)
- Analogue Signal Processing
- Multimedia Signal Processing
- RF & Microwave Engineering
- Computational Electromagnetics including FDTD and Hybrid Techniques
- Wearable Electronics and Flexible Antennas
- Medical Devices and Systems

Research topics to collaborate (1)
Power Efficient MIMO Techniques for 3GPP LTE and Beyond



Theoretical Results of Performance Gain in dB of Multiuser SISO and other MIMO Precoding Schemes over Single User SISO Scenario as a function of the number of users at a fixed spectral efficiency of 3bps/Hz

Research topics to collaborate (2)
Car-2-Car Communications

- The upcoming new amendment 802.11p (WAVE) to the IEEE 802.11 standard would address some of the concerns of inter-vehicular communication
- 802.11p defines 10MHz wide channels at 5.9 GHz for vehicular communications. It is expected that increased rms delays spread and Doppler will be observed in the time and frequency selective vehicular environments
- Physical, MAC and cross layer enhancements are required to improve performance

Research topics to collaborate (3)

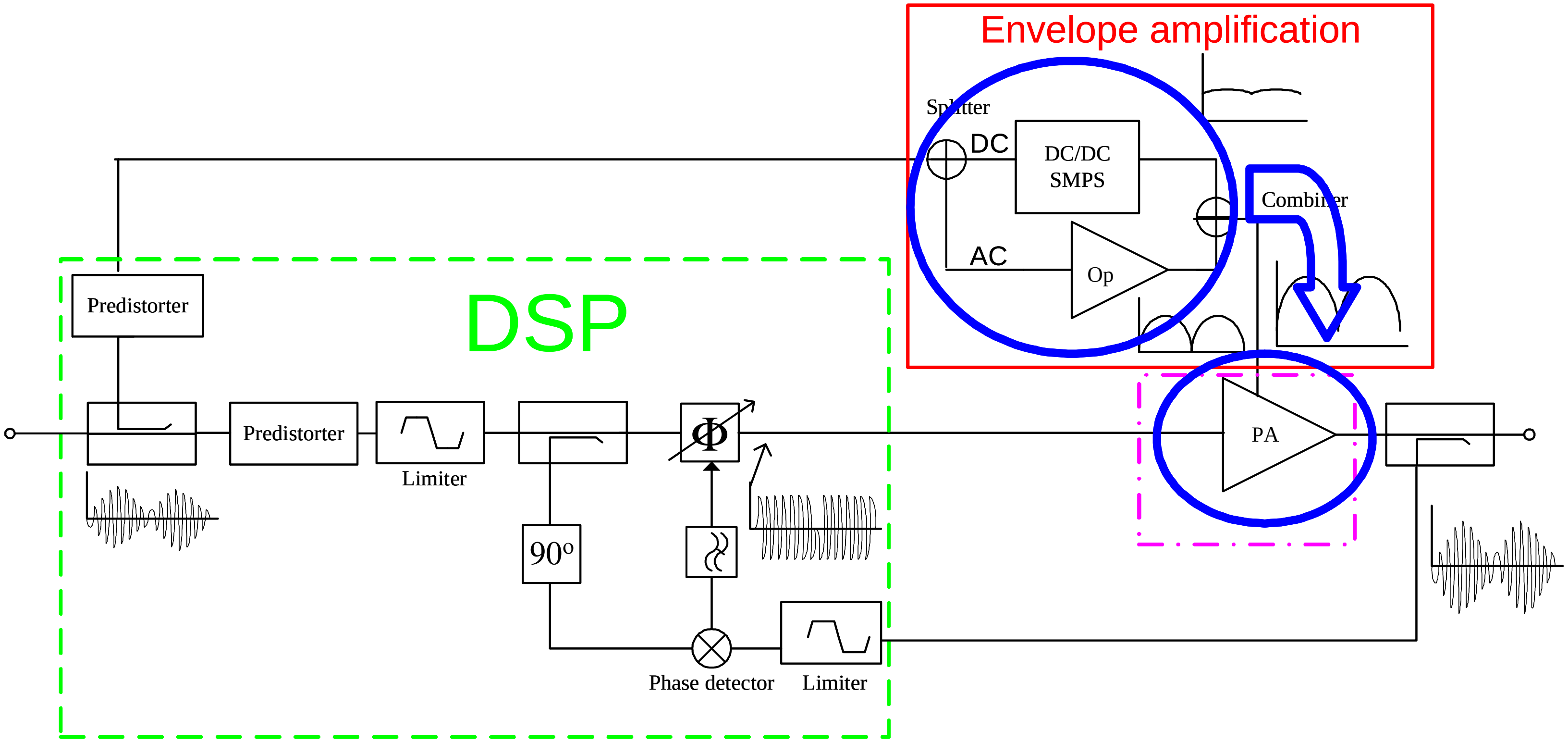
Use of location information to improve communications

- Use location information to improve the performance and fairness of Random Beamfoming
- Use location information in a network MIMO system
- Relaying system by using location and environmental information
- Beamforming based on location information

Power Efficient Base station Hardware

- Current Base station Efficiency
  - Climate Control 65%
  - Power Supply 85%
  - Power Amplifier 15%
  - Overall Efficiency 4%
- Target is to increase overall efficiency to > 50%
- Main area where improvements are possible is the Power Amplifier
- Current base stations consume 135MW of power which results in over 1Million tons of CO_2 annually
- Reducing consumption by the target amounts would reduce CO_2 emissions by over 50%

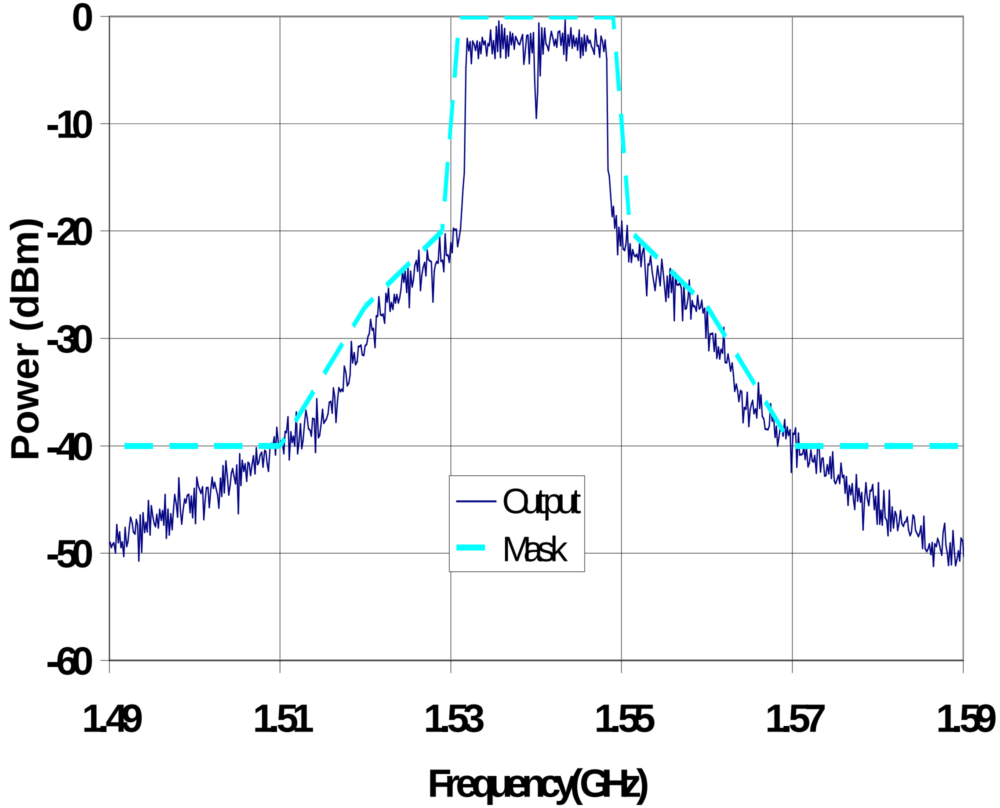
Split Frequency Envelope Elimination and Restoration Transmitter (EER)



- Signal generated from ADS, uploaded to Rhode & Schwarz SMU200A
- Envelope signal to the envelope modulator
- Phase signal to the PA, driven by the output of the envelope modulator
- Two paths synchronized

Performance of an example handset Transmitter: Envelope Tracking /EER

- Pin=15 dB for linearity
- Output power: 26.3 dBm
- ACPR
  - First ACPR 23 dB
  - Second ACPR 41 dB
- PAE
  - 80% PAE for the modulator
  - 43% PAE for the PA
  - 34% PAE for the system



Thank you for your attention