University of BRISTOL

EPSRC
Engineering and Physical Sciences Research Council

EPSRC Centre for Doctoral Training in Communications

Annual Report

2016 - 2017




Foreword

It is with great pleasure that we bring you the 2017 Annual Report from the EPSRC Centre for Doctoral Training in Communications.

Since its launch in 2011, our CDT has recruited six intakes, with a total of 65 students having completed or who are now studying in the Centre. The first cohort have graduated and most students in the second cohort have either graduated or are awaiting their vivas, all having made significant contributions in their fields of research alongside fantastic engagement with industry. Many of our students also assist with promoting engineering as a discipline to schoolchildren and the general public.

In total the Centre will recruit, train and develop the skills of over 80 future leaders in the Communications sector.

In 2016, we were delighted that Dr Chris Clifton was the guest speaker for our Annual Public Lecture where he spoke to a large and enthusiastic audience on the subject of 'The Great 5G Opportunity and the Potential Implementation Challenges'. A very successful Annual Student Research Conference was held on the following day.

We are pleased to report that the Centre was recently awarded the 'top grade' in the EPSRC mid-term review process: an excellent indicator of the outstanding work being undertaken by our postgraduates and staff. The CDT also hosted a visit by EPSRC's Council in August 2016 where they met postgraduates and learnt about our internationally-leading research.

This year we successfully established an IEEE Student Chapter which will enable us to further increase our outreach activities on Communications engineering.

Sadly, I also have to report that one of our students and past course rep, Giovanni Ciurleo, passed away. He will be missed by both staff and students. In recognition of his contribution to the student life of the CDT, the annual prize awarded for contribution to Outreach is being named after him.

We are grateful for the ongoing support from EPSRC and our industrial partners. Their engagement provides relevant and challenging 'real world' research projects and also support complementary skills training and new equipment facilities that make the research generated by our postgraduates possible.

I hope this report will give you an insight into the personalities and the activities associated with our Centre over the past year. Please enjoy reading it and do not hesitate to get in touch if you would like to discuss anything in more detail.

Professor David Bull
Director, EPSRC Centre for Doctoral Training in Communications

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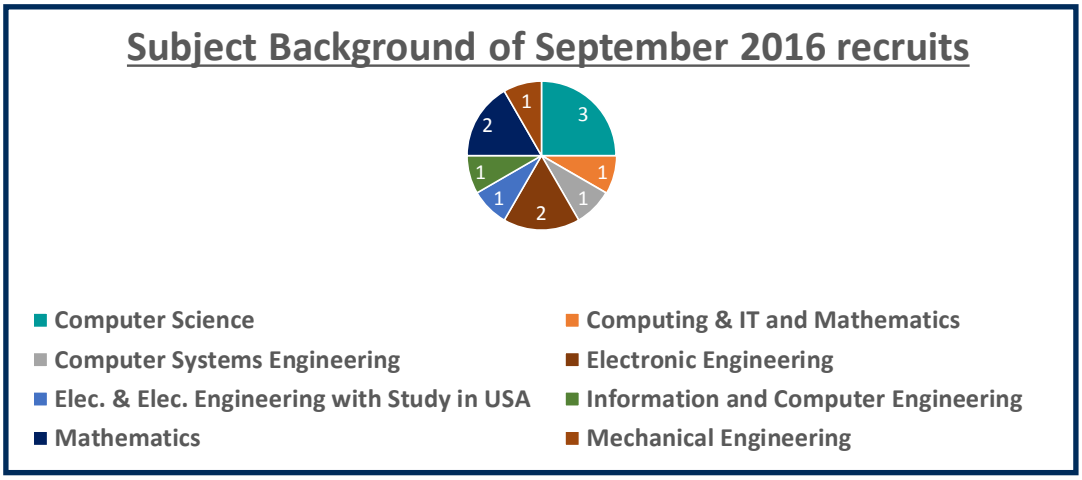
Recruitment

Twelve students joined the programme in September 2016. The academic backgrounds of the intake are shown in the chart below and reflects the Centre's policy of recruiting highly qualified enthusiastic graduates from a broad range of related disciplines.

All students are funded by the EPSRC (Engineering and Physical Sciences Research Council) with additional support from industry providing enhanced stipends.

As in previous years, the programme has proved attractive to individuals returning to education after a period working in industry who wish to improve their skills to enhance their career prospects.



Taught Phase

Students are required to successfully complete a 180 credit taught first year before progressing to their PhD research project the following October.

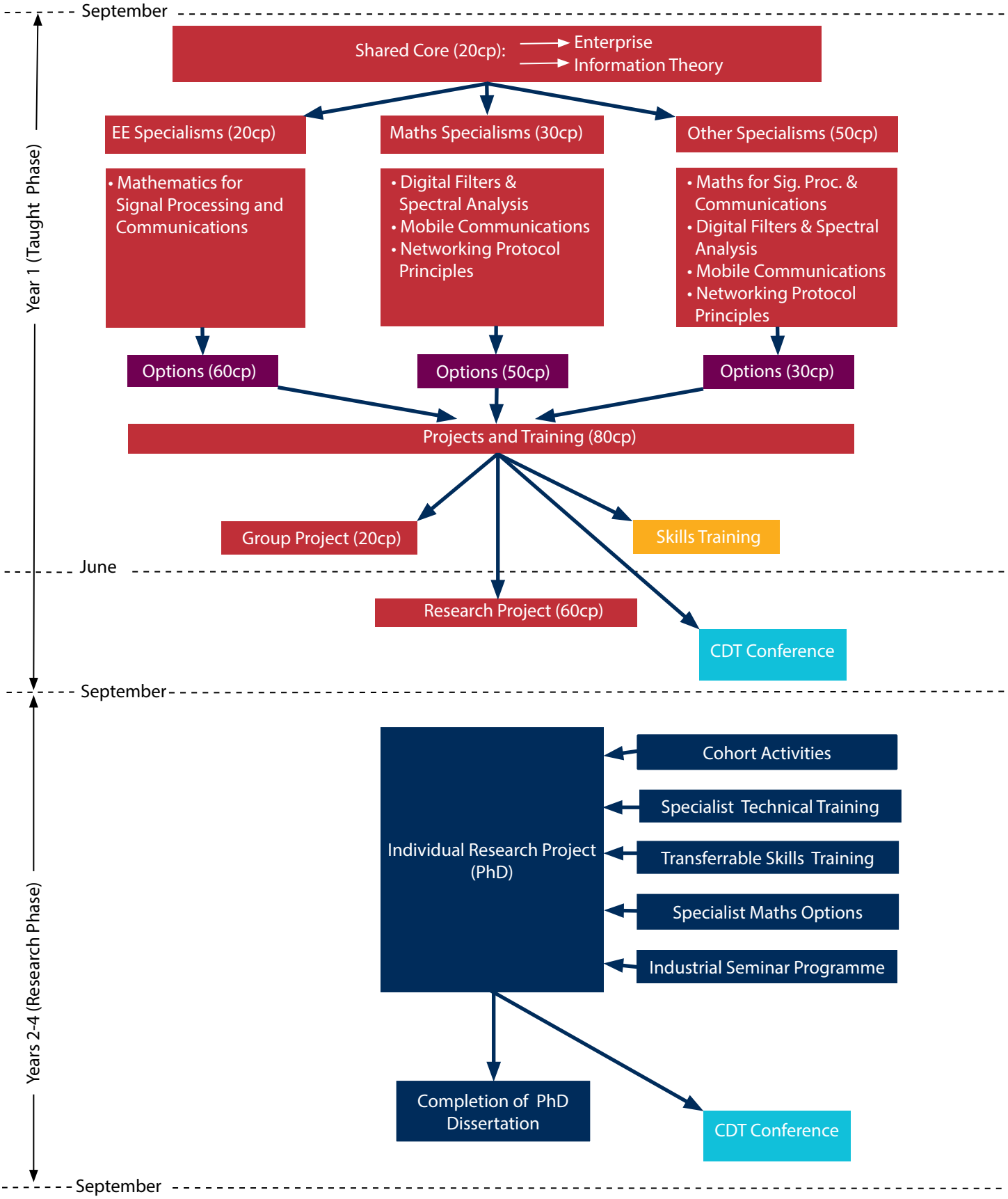
The year 1 programme consists of mandatory units, an extensive choice of optional units, group and individual research projects, and enterprise/innovation skills training.

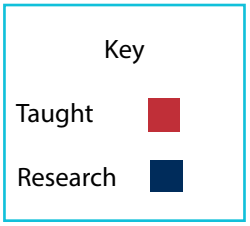
In the 2016-17 academic year, a new programme structure was introduced to provide greater flexibility for students joining from varying academic backgrounds. Those with a first degree in mathematics were not required to take the mandatory mathematics unit and instead took additional units in electronics-related topics. Students not from a mathematics background took the new mandatory unit 'Mathematics for Communications and Signal Processing', specifically designed for the programme and delivered by academics from both Electrical & Electronic Engineering and the School of Mathematics.

Our bespoke enterprise training included contributions from experts in management and innovation working in the Communications industry, and led by the University's Entrepreneur in Residence. Students, working in small teams, were assessed by the submission of a business plan and presentation.


2016 Recruits

Programme Specification 2016-2017



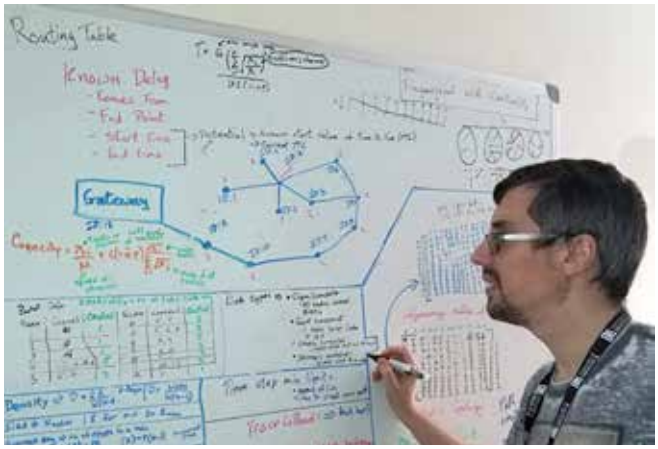


Skills Training

Throughout the year postgraduates have been involved in a variety of general transferable, and bespoke technical training opportunities. Transferable skills have included 'Presenting your research', 'Research literacy', 'Managing your PhD' and 'Ethics in ICT'.

Technical training included a group of our postgraduates joining delegates from UK and overseas academic

institutions and industry at the CommNet Winter School 2016 held at BT Adastral Park. Our students also attended the 5G workshop held at the University of Surrey. Such events enabled our postgraduates to learn from experts and to share experiences with students from other organisations. Students have also spent time with their sponsoring companies/collaborating universities. Examples are described in the case studies on pages 8 & 9.



In memory of Giovanni Ciurleo

Students have established a bi-weekly journal group where the latest technical papers on our key research themes are discussed.

They have also presented at research group seminars and also taken the opportunity to learn about the work of our visiting speakers through our regular industrial seminar programme.

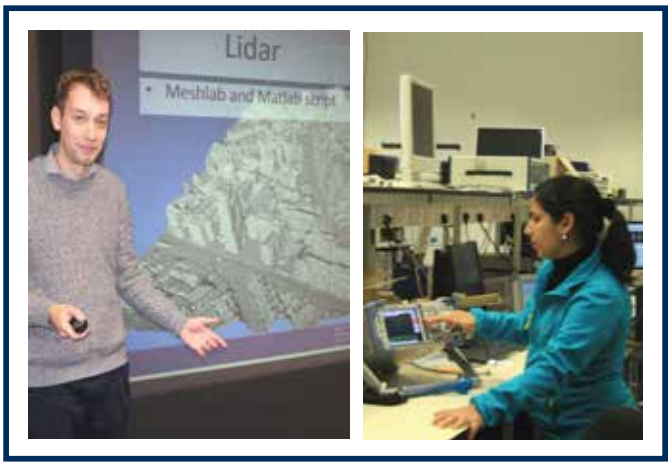
Many of our students have gained valuable teaching and communication skills by working as Lab Demonstrators/ Teaching Assistants on undergraduate courses.

Research

Paul Harris was a finalist for the IET (Institution of Engineering and Technology) 2016 Innovation Awards in recognition of his world record achievement in 5G wireless spectrum efficiency using Massive MIMO.

James Birchall, Paolo Enrico de Falco and Laurence Smith won the HEPA design competition at the International Microwave Symposium 2016, and published the research in the IEEE Microwave Magazine, December 2016.

Our postgraduates have attended and presented at many leading national and international conferences/workshops



including Globecom, ICC, VTC, COST. Jenny Chakvarty presented her research at the London Mathematical Society Women in Mathematics day, and at the European School of Information Theory held in Madrid.

A series of videos providing demonstrations of our world-leading research have been produced and are available on our YouTube channel to engage the imagination of the public, industry and academia.

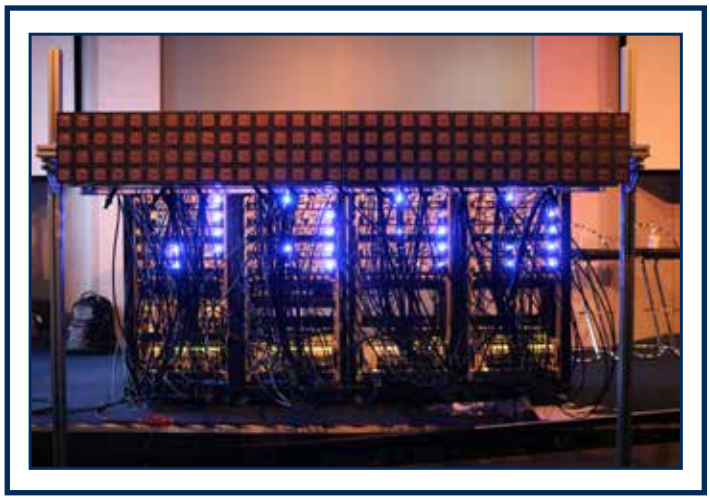
In-depth reports on the research activities of postgraduates are presented on pages 7, 8 & 9.

Working with BT

The quest for highly efficient 5G wireless connectivity has been given a boost thanks to a collaboration between a team of 5G engineers from Bristol and Lund Universities, National Instruments, and one of the world's leading providers of communications services, BT.

The research team of five PhD students from the CDT, a researcher from Lund University and Professor Mark Beach, assessed the performance of a 128 element Massive MIMO system operating at 3.5 GHz at BT's Adastral Park facility.

Using this test-bed, which supports 12 spatial streams in a 20MHz channel, they demonstrated the real-time transmission and simultaneous reception of 10 unique video streams, plus two other spatial channels in the same radio channel. This wireless communication exploited the full richness of Spatial Multiplexing in a physical system deployment within BT's large exhibition hall at Adastral Park.



A customised reconfiguring of the system also facilitated the simultaneous transmission of 24 user streams on the same radio channel and the ability to observe the digital constellation diagrams for 64QAM on all uplink bearers. The team were able to infer from these results a spectrum efficiency of just less than 100bit/s/Hz and a sum rate capacity of circa 2 Gbits/s in this single 20MHz wide channel, with all modems synchronising over-the-air.

In addition to the indoor trials, a series of outdoor experiments were conducted with the array deployed on the third floor balcony of the Orion Building at Adastral Park. Far field array characterisation, multi-element handset performance as well as experiments to improve the understanding of the Massive MIMO radio channel under mobile conditions were also carried out.

The experimental system uses COTS equipment from National Instruments (NI). The real-time FPGA behaviour and system software is written in LabVIEW, NI's graphical programming language, and was based on the recently announced NI MIMO Application Framework.

The state-of-the-art platform was made possible thanks to hardware provided by Bristol Is Open, a joint venture between the University and Bristol City Council that aims to make Bristol the first open programmable city in the world.

"We are delighted to be collaborating with BT. Massive MIMO is a key technology for 5G and the research team's achievements last year with massive MIMO arrays, demonstrates that this technology could deliver ultra-fast data rates to high densities of smartphones and tablets."

Professor Mark Beach,
Centre Manager

Keysight Secondment & Collaboration

David Reyes, a CDT postgraduate student in his first year of research, joined the annual 'S800' in-house training event with Keysight Technologies at their headquarters in Santa Rosa, California (USA); aligning with the start of the research phase of his 4-year integrated PhD programme. The focus of David's PhD is to develop a new test methodology to rapidly assess the radiated performance (Over the Air) of 5G wireless devices at millimetre wave; making this secondment very benefical to his research.

David joined Keysight applications engineers from all over the world and participated in the training which encompassed technology updates and new measurement releases as well as attending lectures and hands-on labs in 5G, Massive MIMO, millimetre waves, Internet of Things, and over-the-air measurements.

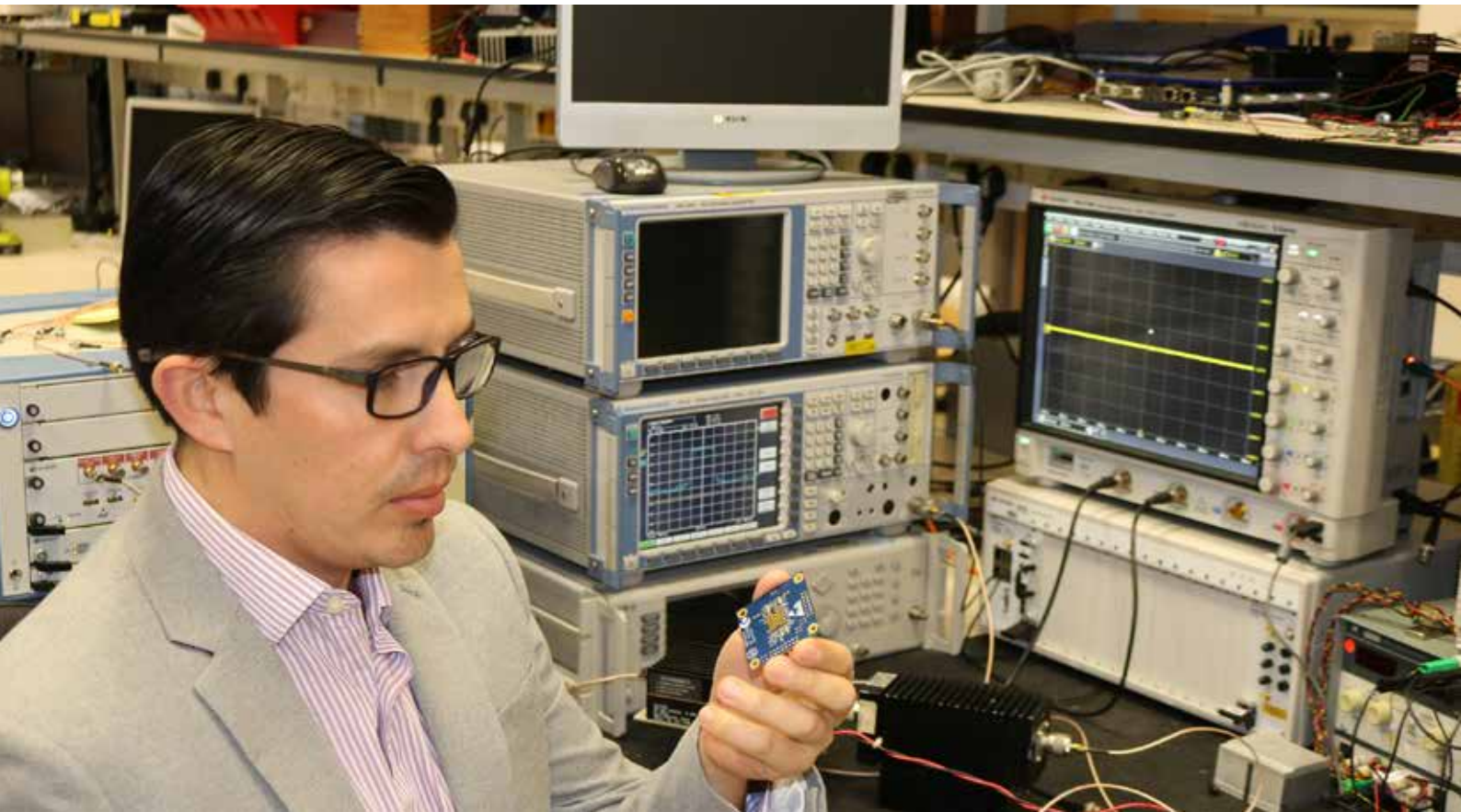
Future 5G devices that will work on frequencies above 30 GHz require high gain antenna arrays in order to compensate the higher losses whilst the electromagnetic waves propagate from the transmitter to the receiver through the air. Such arrays will be very compact and directly integrated to the devices without connectors in between, therefore new techniques for evaluate their performance in a cost effective manner are required to be developed which requires extensive research.

In addition to the training sessions, David was invited to present on his experience designing and implementing the LTE network for the National Telecommunications Corporation CNT EP in Ecuador. The presentation generated substantial interest and provided valuable insight as to how the equipment developed by Keysight can be strategically positioned in markets planning network deployments.

In September 2015, Keysight made a substantive donation of equipment, software, dedicated technical support and inward secondment of Keysight staff which has facilitated in-depth training and advancement of 5G metrology for both CDT and regular PhD students as well as post-doctoral researchers. This strategic investment complemented the EPSRC funded equipment made available at Bristol in the field of Communications through the CDT Equipment and Experimental Equipment Awards in July 2014 and January 2015 respectively. Bristol is one of Keysight's strategic locations for academic engagement.

Postgraduate students Tom Barratt and Alberto Loaiza Freire conducted millimetre wave channel measurements with high temporal and spatial resolution hitherto not possible using Keysight technology. Further hardware and software customisation by Tom has produced a series of millimetre wave channel measurements yielding a much greater insight to the complex interactions within the propagation environment at these frequencies. Collaboration with EU universities and global industry (Ericsson, Huawei, Nokia and Samsung) through the H2020 project mmMAGIC has been facilitated through this measurement facility, greatly enriching the PhD training experience for those at Bristol.

Strategic 'user' collaboration with Keysight has included both inward and outward secondments. Many wireless researchers at Bristol have benefitted from Moray Rumney's on-going Visiting Industrialist appointment with the University. Regular visits, seminars and discussions at the 'lab-bench', have resulted in several joint publications as well as contributions (Technical Recommendations) to the evolving 3GPPP standards for 5G.



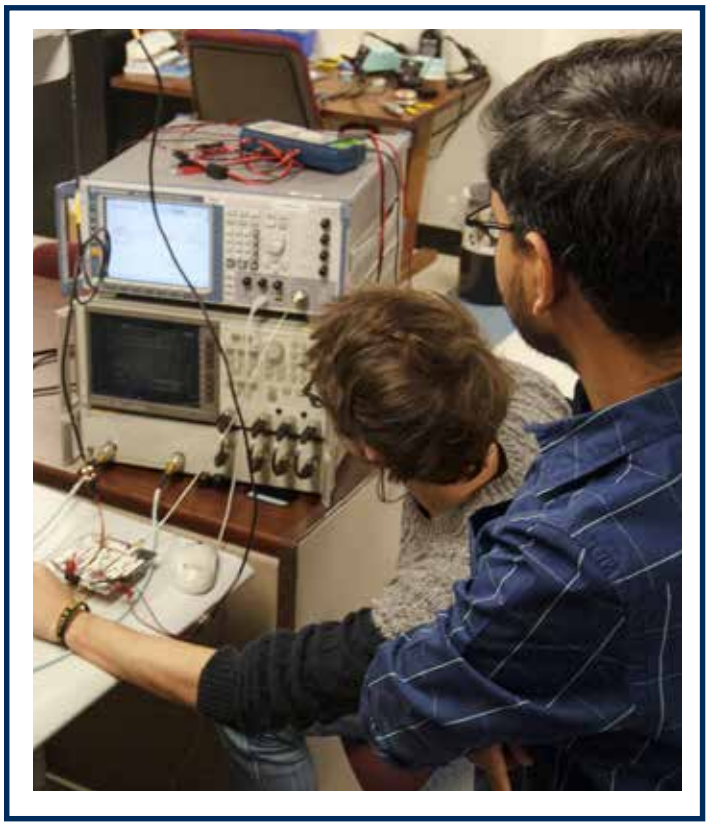
University of Boulder Secondment

Between January and June 2017 one of our postgraduate students, Paolo Enrico de Falco, spent time on an extended research visit to the University of Colorado-Boulder, USA. His visit was hosted by Professor Barton (RF Power Laboratory), and IEEE Fellow & Distinguished Lecturer Professor Zoya Popovich (Microwave & RF Research Group) in the Department of Electrical, Computer, and Energy Engineering.

The visit was as a result of a successful application for funding to attend the 2015 International Microwave Symposium (Phoenix, USA) at which he met Professor Barton, one of the world-leading researchers investigating outphasing amplification systems; the focus of his PhD.

Outphasing systems are a candidate architecture for future amplifiers in wireless transceivers, which could allow the transmission of high Peak to Average Power Ratio signals yielding better energy efficiency. The collaboration successfully developed the concepts and implemented some of the ideas generated throughout Paolo's PhD project.

During the visit Paolo worked with Prathamesh Pednekar, a postgraduate student at the University of Colorado-Boulder, in the development of the first outphasing system implemented with Class J amplifiers. The experimental results proved the soundness of the concept with the system achieving high efficiencies over a large dynamic range. The next phase will be to improve the bandwidth of the technique collaborating with Sushia Rahimizadeh, a postgraduate in Professor Popovich's group.



As part of the research visit Paolo also led a group of 12 postgraduate students from Boulder and Chalmers universities, to form 3 teams who participated in the 2017 IMS High Efficiency Power Amplifier Design Competition, which took place in Hawaii during July.

"The opportunity to work at the University of Boulder has been extremely valuable; enabling me to experience a different research environment as well as having the chance to visit new places."

Paolo Enrico de Falco, PhD student

2016 Annual Student Research Conference

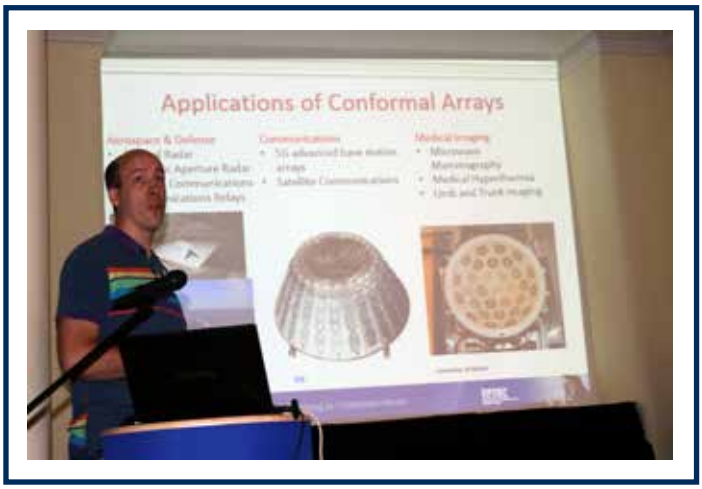
On the 23rd September 2016, the Annual Student Research Conference was held at Armada House in Bristol. This year's presenters presented to an audience of 120 industrialists, academics and postgraduates who heard about the latest research being undertaken in the Centre and provided valuable feedback.

The audience also included Year 12 students and staff from a local school, Colston's, who presented posters on their project with our postgraduate students to design, build and test antennas for a mountain rescue team scenario.

First year students presented technical posters on the projects they had undertaken over the summer months. Topics included 'Physical layer security in next generation communication technologies', 'Reducing the hardware requirements of massive MIMO' and 'Future Wi-Fi:

enhanced indoor modelling and waveform design and analysis'.

Second and fourth year CDT students presented elevator pitches, and those in the third year showcased their research via either presentations or technical posters. Latest results on a wide range of research topics including 'Conformal antenna arrays: addressing the design capability gap', 'Distributed interference management in dense unplanned wireless networks', 'Utilising artificial intelligence for heterogeneity and enhanced performance



within a SDN controlled network' and 'Detecting regions of interest over a superpixel framework' were given.

Prizes for best presentations, posters and contributions to outreach activities were presented to postgraduate students by Mr Denis Burn, Chair of the University of Bristol's Board of Trustees.

The annual conference and public lecture provided an opportunity for staff, students and industry to network in an informal environment and to discuss issues current in the industry as well as allowing for in-depth Q&As on the research being undertaken.

2016 Annual Public Lecture

Chris Clifton, Chief Technology Officer and Divisional Director for Europe at Sony Semiconductor and Electronic Solutions (SES) was the guest speaker at the CDT Annual Public Lecture on the 22nd September 2016.

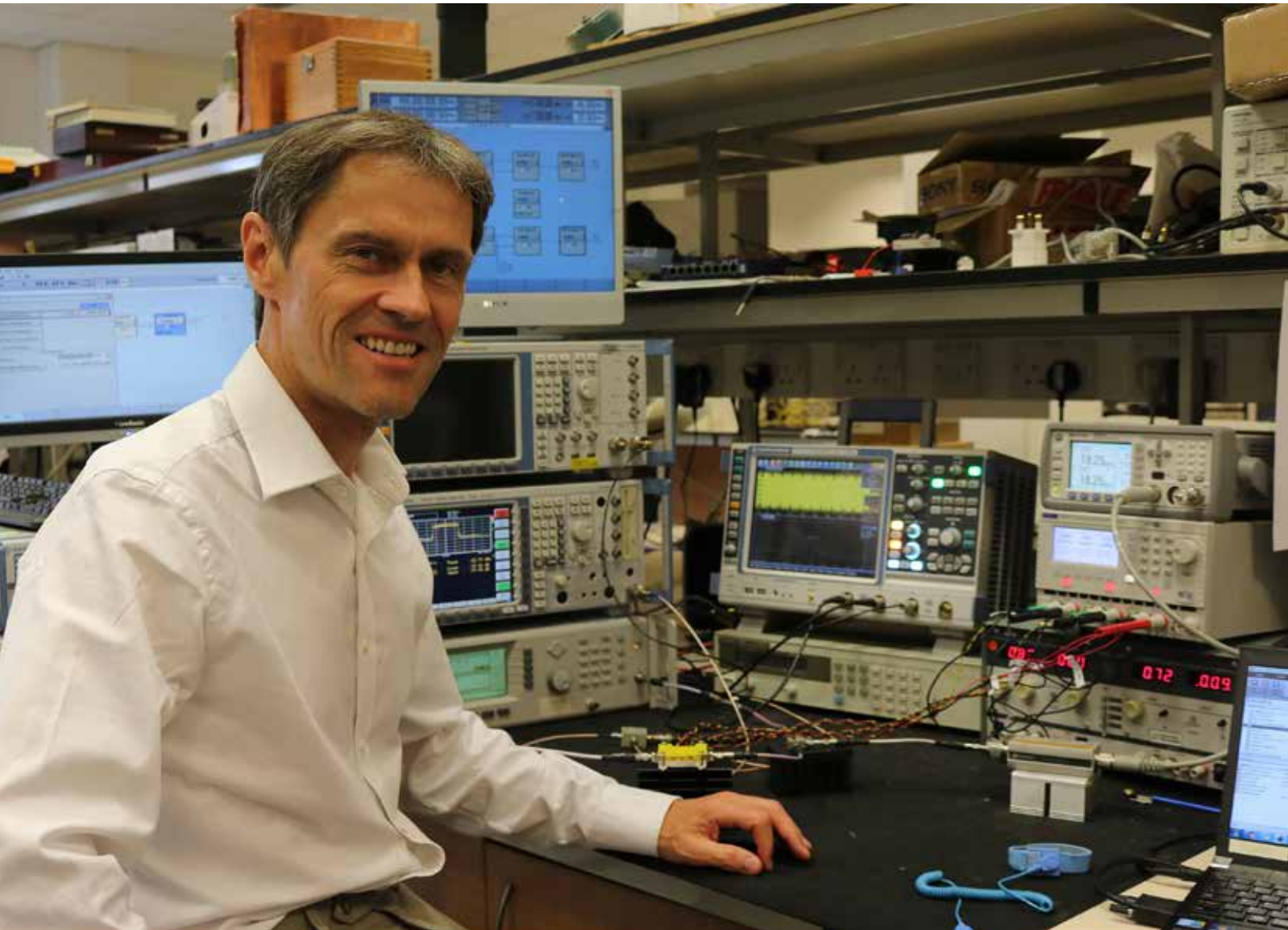
The lecture entitled 'The Great 5G opportunity and the potential implementation challenges' considered the potential disruptive applications relating to consumer electronics and industrial/automotive applications; along with the implementation challenges for device and module technology. Chris highlighted beamforming and massive MIMO as two key enabling technologies. He also emphasised that IC integration and thermal management factors are essential aspects which need to be addressed in order to achieve size and cost objectives.

The lecture reviewed some of the more promising options which are likely to be better suited to 5G product requirements.

It was argued that techniques previously used for front-end efficiency and linearity enhancement start to become less attractive over the larger modulation bandwidths under consideration.

"We were delighted that such a distinguished speaker as Chris Clifton was able to deliver this year's prestigious CDT lecture on such an important and fascinating topic."

Professor David Bull,
Director



Outreach

Outreach activities for the Centre are co-ordinated through the student-led Outreach Committee and during the year they have organised a number of events. Outreach has a vital role to play in encouraging future engineers, raising the profile of the Centre and of the discipline, as well as providing practical transferable skills training eg. presentation, communication skillls.

This year students in the CDT developed interactive demos for a local science festival. The demos were showcased at the Bath TAPS into Science Festival, held on the 17th March 2017 organised as part of the British Science week, and attended by 1,700 local schoolchildren. The Fair consisted of 30-40 stands run by students, science organisations and businesses. The activities were designed for Year 5 to 8 students to demonstrate that everyone can enjoy, and engage with science & engineering, technology & maths via exhibits presented in a fun, engaging and hands-on manner. The CDT also invited Year 12 students from a local school, Colston's, to co-present the demos.

The demos provided a practical insight into developing communications technology and included a morse code challenge where students had to send messages that created 'smiley' faces using a morse code machine designed by the postgraduates using shoe boxes, car horns, buzzers and wires; a demo on the development of technology in mobile phones from the 2G models of the early 1980s through to the 4/5G phones of the 2010s; a demo on the challenge of deploying base stations to maximise signal coverage at the lowest cost, and a demo explaining the concept of interference (and its causes) between antennas.

Prior to the event, the Year 12 students and the Head of Physics from Colston's attended a ½ day workshop organised by the CDT where the demos were tested and feedback given on how they could be fine-tuned. The Deputy Headmaster, Dr Paul Hill, also provided training to the postgraduate students on communicating science & engineering to schoolchildren of different age groups.

Our postgraduate students also strongly supported the outreach work of the University by assisting with school visits. For example, in November 2016, they created and delivered a very successful activity for a group of 30 students from Fairfield school as part of the programme of events organised by the Merchant Venturers School of Engineering Outreach & Student Liaison Manager.

Student Research Projects - First Year Researchers

Student: Jenny Chakravarty
Project: Physical layer security in next generation communication technologies

Consider a scenario where a transmitter wishes to send information to a legitimate receiver, but an eavesdropper attempts to overhear the message. Tried and tested cryptographic security schemes such as secret key methods may be too computationally intensive for some Internet of Things (IoT) devices which require low complexity, cost and power consumption. One solution is offered by physical layer security, which makes no assumptions on the computational power of the eavesdropper but instead exploits the inherent randomness of a channel, as described in the seminal paper by Shannon (1948) and the work of Wyner (1975).

However, while these papers can give information-theoretic secrecy guarantees for single-antenna systems, the problem remains open for modern multiple antenna (MIMO) systems, and future 5G technologies including massive MIMO. This project offers an interdisciplinary approach. We aim to extend the secrecy bounds to the multiple antenna setting, using mathematical techniques from linear algebra, random matrix theory and free probability, to provide a rigorous solution which is achievable in practice.

Student: Nakrop Jinaporn
Project: Resource allocation in heterogeneous networks

Due to ever increasing traffic demands, heterogeneous networks (HetNets) have been proposed and adopted for 4G Long-Term Evolution (LTE)-Advanced and are also anticipated for 5G. By using a mix of high power nodes (HPNs) and low power nodes (LPNs), HetNets are anticipated to improve upon the spectral efficiency (SE) and energy efficiency (EE) of traditional cellular networks. However, there are still considerable questions as to why a HetNet is required and how it can be best configured to serve heterogeneous user and traffic characteristics.

This research project aims to examine how resource allocation can be enhanced for HetNets. Firstly, two-tier LTE-A cellular networks including macro and femtocell base stations are investigated by means of Monte Carlo simulations. The system performance of various frequency re-use and scheduling techniques have been evaluated in terms of SE, throughput and fairness. Secondly, consideration has been given to how suitably designed resource allocation could facilitate coexistence between LTE-A and other technologies such as WiFi in unlicensed spectrum. Carrier Aggregation (CA) and Licensed-Assisted Access (LAA) appear to enable such systems to cooperate and mitigate the effects of interference. To verify this, the joint resource allocation has been formulated and system-level simulations of coexisting networks have been performed. Further enhancement of resource allocation in HetNets are also to be considered, covering factors such as alternative network topologies, interference control and spectrum assignment in both licensed and unlicensed bands.

Student: Pawel Kowalski
Project: Multi-source large-scale heterogeneous information fusion

Today's decision makers and analysts are faced with an overwhelming amount of information, arriving in a variety of formats from multiple sources. These sources may provide the data using various representation formats, with varying uncertainty levels and with a degree of ambiguity and inconsistency. The three main problem areas addressed by this research project are uncertainty alignment, semantic alignment and provenance.

Multiple sources may provide information under varying uncertainty representation paradigms. One potential tool for uncertainty alignment is random sets theory. Unfortunately its common implementations scale very poorly, as the memory consumption and computation time increase exponentially with the number of hypotheses to be tested or targets to be tracked. As such fusion algorithms which would make it possible to reduce the number of focal sets need to be investigated.

Ontology based approaches have been previously proposed as means of handling semantic alignment, however currently there exists no ontology handling random set uncertainty representation.

Given that the fusion result can have a significant impact on decision making, it is important to be able to trace the origin of the information and the impact of uncertainty. Besides existing provenance tracking methods, initial results suggest that it may be possible and useful to develop a metric which would show the extent to which the various sources of evidence have contributed to both the final fusion outcome as well as to the belief in the individual hypotheses.

Student: David Reyes
Project: Over-the-air validation of millimeter wave active antenna performance

In order to address the ever-increasing demands for wireless connectivity, with forecasts predicting 26.1 Exabytes/month for consumer based mobile traffic by 2020, 5G New Radio (NR) technology will employ access technologies offering higher spectrum efficiencies as well as make use of millimetre wave spectrum.

To combat additional path-loss at millimetre wave, increased antenna gain through beamforming is necessary. Given the reduced feature size of the antenna components at such frequencies, compact integration of the antenna array, beamformer and RF transceiver is viable and highly desirable for consumer products such as 5G Smart phones. However, performance testing and optimisation of such an implementation is now a considerable research challenge for the RF test and measurement community.

For 2G cellular devices conducted signals bypassing the device's antenna were used. More recently for 3G and 4G devices radiated measurements within a control environment, known as Over-the-Air-Testing or OTA, can be employed. However, OTA does not scale to millimetre wave based devices and with a fully integrated antenna array, beamformer and RF transceiver, antenna connectors are no longer accessible.

The aim of this project is to devise a testing methodology for 5G millimetre wave handset technology capable of fully assessing the performance of the intelligent antenna facet.

Student: Lawrence Sayer

Project: Future Wi-Fi: enhanced indoor modelling and waveform design and analysis

Wi-Fi networks are a ubiquitous technology for connecting wirelessly to the Internet. From an Information Assurance (IA) point of view there is a need to model, with high fidelity, the propagation of Wi-Fi signals in order to understand how far these might leak outside their desired domain. With this objective, methods of indoor propagation modelling are critically analysed. Ray-tracing is identified as a tractable and high fidelity method that is suitable for IA applications. A ray engine is under development with promising early results. It is shown that ray engines can be combined with third party software, which enables rapid generation of building models, which addresses a limitation of previous indoor ray tracers. Electromagnetic models are of critical importance, and popular models are assessed in light of the high fidelity requirements of the proposed application. In order to future proof the analysis tool against new technological developments, such as those proposed for 5G, modelling of propagation at millimetre wavelengths is investigated.

The aim of the project is to contribute to security policy in various settings. Whilst initial work will be heavily focused on the design and validation of the analysis tool, proposals are made concerning how results could be used in network and device design to achieve the objectives of IA.

Student: Stavros Typos

Project: Ray-tracing propagation modelling for next generation wireless communication systems

With the growing demand for wireless communication systems, wireless concepts for data exchange in time variant networks become increasingly interesting. In order to describe and assess the mobile radio channels in such networks, detailed models and simulations are required. Ray-tracing based radio wave propagation prediction models are currently one of the most deployed methods of channel modelling due to their intrinsic ability of balancing between accuracy and computational load. The University of Bristol's ProPhecy ray tracer has distinguished itself in this specific field for its accuracy in modelling 4G systems along with its scalability. However, there is a vital need for a further upgrade to cope with the propagation and more importantly application challenges of 5G and beyond technologies. During this research, the current ProPhecy ray-tracing capabilities and modelling limitations will be explored. Physical radiowave propagation models for mmWave and massive MIMO will be discussed along with suggestions for geographical environment considerations for such technologies. The effects of propagation models on 5G applications such as high mobility scenarios, IoT sensoring systems, body-centric communications are also considered. Finally, the integration infrastructure of a universal indoor and outdoor ray-tracing model will be addressed.

Student: Fred Wiffen
Project: Reducing the hardware requirements of massive MIMO

Effective exploitation of the spatial domain will play a vital role in enabling future wireless communication systems to meet ever-increasing traffic and service requirements. 'Massive' MIMO, in which single antenna terminals are simultaneously served on the same frequency resource by a basestation with an excess of antennas, is now widely seen as the key technology for achieving large scale spatial multiplexing, and therefore unlocking unprecedented increases in wireless capacity. Whilst the propagation environment created by the excess of antennas produces a number of mathematical results with favourable implications for computational complexity and power consumption, a significant challenge remains in finding a cost effective implementation of the technology, due to the large number of RF chains required to drive the basestation antenna array.

This project focuses on relaxing the hardware requirements of massive MIMO systems, by investigating beamforming techniques that reduce the number of RF chains required to drive the antenna array. This will be achieved by first identifying and evaluating the performance and requirements of current state-of-the-art decoding and precoding methods, before novel algorithms and architectures are investigated and developed, with the aim of finding an appropriate balance between system performance and cost. This will initially involve a combination of theoretical analysis and simulation, before the performance of candidate solutions is verified and assessed using the University of Bristol's massive MIMO testbed.

Student: Sam Young
Project: Decentralised algorithms for swarming networks

This PhD project aims to develop decentralised algorithms for co-ordination and data fusion among large networks of robots. The robots themselves are likely to be small and cheap, with limited computational and communication resources. Anticipated applications include creating ad hoc aerial networks for communication in disaster and conflict zones. For example, we may aim to distribute a network of balloons or fixed wing UAVs in order to optimise coverage to the ground stations.

To engineer the desired behaviours, a mathematical framework is required that makes it possible to predict the collective dynamics of the swarm, based on the rules for each robot and the surrounding environment. Due to the limitations of each individual robot, a large amount of measurement noise is introduced locally. This can be modelled at the swarm level using techniques such as Stochastic differential equations and nonlinear control theory. By applying this framework to known control schemes such as electrostatic repulsion and diffusion, we hope to find the best performing individual control rules for achieving the desired collective behaviour.

Recent Graduates

Michael Collett

working as a Patent Examiner at the Intellectual Property Office

Brett Hosking

working as a Researcher at the UK National Oceanography Centre

Alexander Kartun-Giles

working as a Postdoctoral Research Fellow at Hanyang University, Seoul, South Korea

Paul Worgan

working as a Research Associate at MIT, USA

Our Supporters & Collaborators

How to Get Involved

Industry

Proposals for research project topics that can be sponsored - through fully funded studentships, Case conversion and iCASE awards from industry (exisiting and new collaborators) are welcome.

We are also keen to further develop the specialist training available to our students and ensure the provision of state-of-the-art test & measurement equipment. If you wish to become a partner in the Centre please contact Professor Mark Beach, Centre Manager (M.A.Beach@bristol.ac.uk).

Prospective Students

Applications from potential students are accepted from October each year for entry in the following September.

Please contact the Admissions Tutor, Dr Simon Armour, (Simon.Armour@bristol.ac.uk) if you would like to discuss opportunities for study.

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