University of BRISTOL

EPSRC
Engineering and Physical Sciences Research Council

Centre for Doctoral Training in Communications

Annual Report 2011 - 2012

Foreword

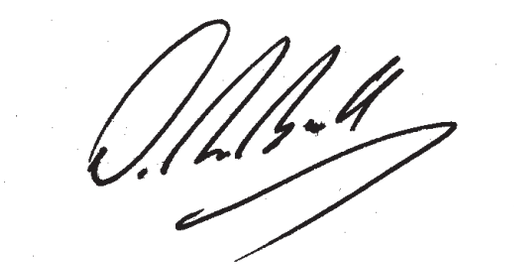
It is with great pleasure that I introduce the first Annual Report of the Centre from Doctoral Training in Communications.

The Centre was formally launched in March 2011, following a competition by the UK Engineering Physical Sciences Research Council (EPSRC) to identify the best location to host the only UK CDT in this field. EPSRC has invested £2.2M in this £10M Centre at the University of Bristol.

The CDT has the support of some 25 major UK companies and trade organisations, and will help to build UK capability in this key area by addressing the skills shortage in the sector. It focuses on Future Communications: People, Power and Performance; while communications technology is the enabler, the Centre recognises that it is people who are the creators, consumers and beneficiaries in terms of its broader applications.

The University of Bristol, through its Centre for Communications Research (CCR), has been a world leader in this field for over 25 years. The Centre for Doctoral Training combines the strengths of the CCR with Bristol's world-leading mathematics capability and its strengths in interactivity.

I hope this report will give you an insight into the people and the activities associated with the Centres first year of operation. It has been an exciting time and also a learning experience producing a strong platform to build on for future years.



Professor David Bull
Director, CDT in Communications

Contents

Introduction

"The Centre is producing a new type of PhD graduate: one who is intellectually leading, creative, mathematically rigorous and who understands the commercial implications of their work; people who are the future technical and business leaders in the sector."

- Joe McGeehan CBE FREng, Chairman

The Engineering and Physical Sciences Research Council (EPSRC) have introduced a new structure for postgraduate PhD training. The conventional 3-year PhD programme is now being complemented by an integrated 4-year programme delivered through Centres for Doctoral Training (CDTs). Bristol is host to the only UK CDT in Communications.

The Centre has completed its first full year of operation, with the original cohort of 10 now having commenced their research phase.

The second cohort are now in the second term of their taught year, and considering which research directions they wish to follow for their projects.

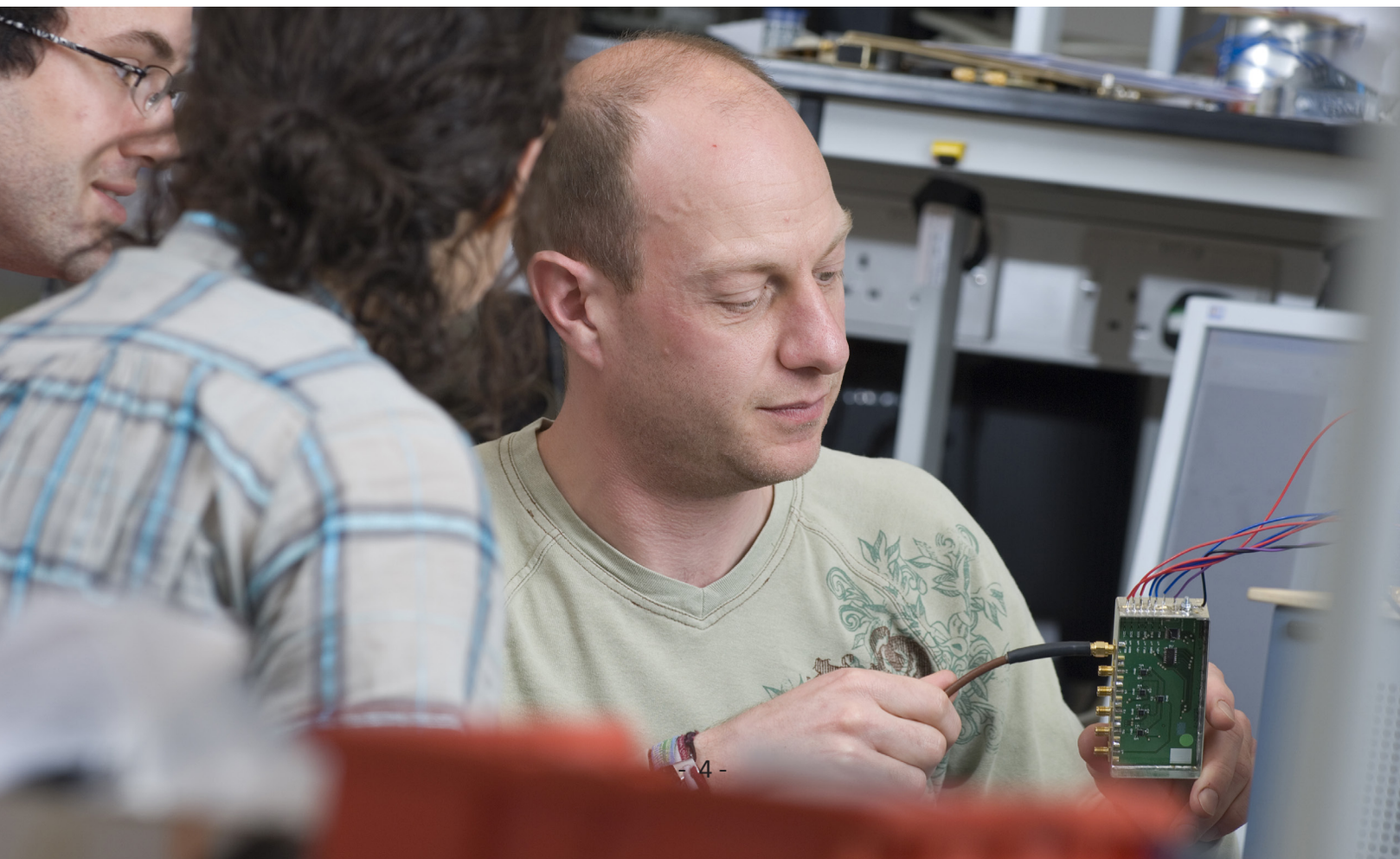
Recruitment

Our PhD students are recruited from a wide variety of disciplines and we encourage applicants with backgrounds across Engineering and Science. So far we have attracted students from Computer Science, Electrical & Electronic Engineering, Computer Systems Engineering, Mathematics and Physics. The taught first year is designed to ensure students attain a high level of knowledge in core topics associated with Communications before they commence their research projects.

Training & Transferable Skills

Students undertake a 4-year enhanced PhD with a taught programme in year 1 followed by a 3 year specialised research project.

Successful research partnerships across the world have shown that mathematicians can make significant contributions to characterising the performance of real-life communication networks. In Bristol, long-established links between the School of Mathematics and the Department of Electrical & Electronic Engineering have



led to a number of jointly supervised PhDs, generating patents and papers. This relationship has developed further through the joint supervision of students and shared curriculum of the Communications CDT.

The University of Bristol has been very successful in attracting a large number of EPSRC funded Centres for Doctoral Training across Engineering and Science. These collaborate closely to develop and provide transferable skills training, for example in Innovation and Enterprise. Best practice in administration and management is also shared across all Centres.

Industrial Support

Strong links with industry and sector organisations are fundamental to the success of the Centre, and are highly valued by all involved. The format of the interaction with stakeholders is diverse - funding and industrial mentoring of students, participation in management meetings, specialist training, transferrable skills, and seminars. The input of stakeholders is essential to the continuing evolution of the Centre and is a core feature of its ethos.

Engagement with a Wider Audience

Staff and students are involved in promoting the work of the Centre and its associated disciplines to the general public, industry and public bodies.

Five of our students have already undergone training to qualify as STEM (Science, Technology, Engineering and Mathematics) Amabassadors.

Staff

Staff involved with the Centre are from both the Engineering and Science Faculties at Bristol, and from a wide variety of disciplines. They are experts in their research fields with many years of experience of working with industry and developing innovative and world-leading ideas. They are also skilled, enthusiastic and dedicated teachers.

"Graduates from this unique Centre will be highly employable in both industry and academia."

- David Bull FIEEE, Director

Official Launch

The official launch of the Centre took place in Bristol on the 30th March 2011. Vice-Chancellor Professor Eric Thomas formally opened the event.

Industrial partners and stakeholders joined the academic community to celebrate the launch and to discuss the exciting opportunities available for collaborative research and training.

The CDT Chairman, Professor Joe McGeehan commented that *"Our partnership with industry has been critical in shaping and winning this Centre and will continue to be so in its delivery phase.*

As well as producing innovative solutions to key emerging research challenges, the Centre will provide an advanced training network for the communications community nationally, and develop the skilled and entrepreneurial engineers needed to underpin the future of the industry."

Recruitment

"The CDT is a great way of doing a PhD, if like me, you are unsure as to what you wanted to do your research project on. Having the first year taught means you can find your feet and work out what you want to spend the following 3 years doing research on. It's also a good way of getting the basics in a lot of areas. The number of opportunities for engaging with the industrial partners associated with the Centre will be a real benefit to my future career."

- Peter Bagot, CSE graduate (2011 entry student)

The Bristol Centre for Doctoral Training recruits graduates who are enthusiastic, highly motivated and with at least an upper second class degree in Engineering, Mathematics, Physics or a related discipline.

Core funding is provided by EPSRC and complemented by industrial support with scholarships available for UK and some EU students. We aim to develop graduates who will be highly employable both in industry and academia, with a strong mathematical understanding of Communications. We are dedicated to attracting more female students on to our programme as well as returners to education after a period in industry.

First degree subject: 2011-2012 entry

Computer Science	1
Computer Science with Electronics	1
Electrical & Electronic Engineering	4
Mathematics	2
Physics	2

"I knew that after spending four years in Bristol, I had to stay. It's an amazing city, and I wanted to work or study in this great city once more."

- Peter Bagot, CSE graduate (2011 entry student)

Training

The Centre provides training for graduates in a state-of-the-art collaborative research environment and offers close interactions with Industry.

It is located in newly refurbished dedicated space with access to outstanding test and measurement research facilities in wireless communications, signal & image processing, and interactive technologies.

Our students are members of a close-knit cohort, working with a team of multidisciplinary academics from engineering, mathematics and computer science as well as with mentors and technical specialists from UK industry.

The first year of the programme comprises taught training in the broad area of Communications providing the research skills necessary to undertake cutting-edge research. Students also participate in a bespoke course on Enterprise that is given by the University's 'Entrepreneur in Residence'. In addition, students undertake a short individual project and a group project developed in conjunction with and mentored by industrialists.

Students choose their PhD projects from a wide range of proposals, most of which are collaborative with industry, and are addressing diverse challenges ranging across theoretical and applied research.

The programme also includes a number of workshops and short courses in years 2 to 4 on specialist technical subjects and business skills. Industrial partners provide access to, and training in, the latest commercial technology.

"The CDT's foundation year allows for a much smoother transition from mathematics to engineering."

- Richard Porter, Mathematics graduate (2011 entry student)

Transferable Skills

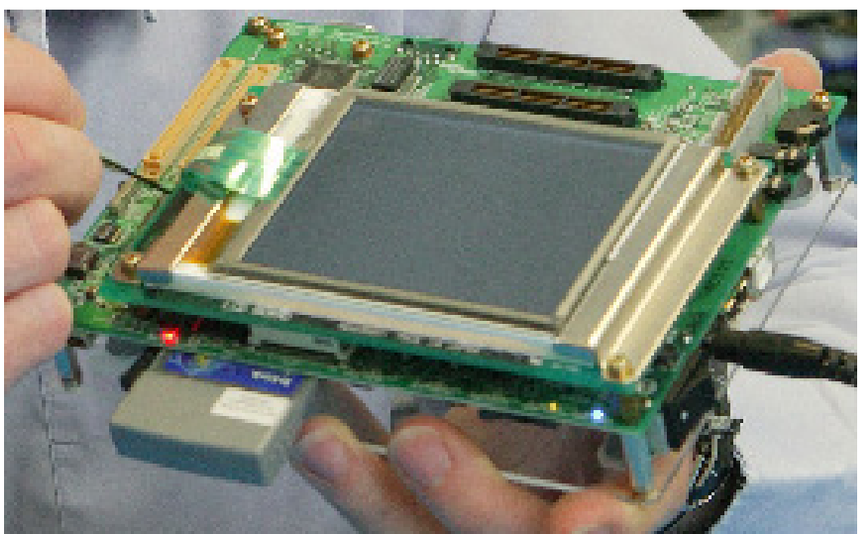
	Year 1	Year 2	Year 3	Year 4
Innovation & Enterprise	Comms Enterprise Taught Module	Comms Enterprise Workshops	Comms Enterprise Workshops	Comms Enterprise Workshops
Public Engagement	STEM Ambassador Training	STEM Ambassador Training	Engagement Activities	Engagement Activities
	Engagement Activities	Engagement Activities	Conference Attendance	Conference Attendance
		Introduction to Public Engagement		
Communication Skills	Comms Enterprise Module: Personal Commuications	BEN/iNET Events *	BEN/iNET Events *	BEN/iNET Events *
	Communication & Influence: Theories & Approaches	Managing your PhD Workshop	Comms Enterprise Workshops: Negotiation Skills; Presentations & Public Speaking	Comms Enterprise Workshops
	Non Disclosure Agreement Training	Conference Attendance	Conference Attendance	Conference Attendance
Careers	CV Preparation for Industry Engagement		CV Preparation for Employment	Interview Skills Training
		Postgraduate Teaching Assistant Duties	Postgraduate Teaching Assistant Duties	Postgraduate Teaching Assistant Duties
	Seminars/meetings with Industry	Seminars/meetings with Industry	Seminars/meetings with Industry	Seminars/meetings with Industry

**Bristol Enterprise Network*

Industry

"The number of opportunities for engaging with the industrial partners associated with the Centre will be a real benefit to my future career."

- Brett Hosking, Digital Communication Systems graduate, (2011 entry student)



Communications technology not only provides personal voice, data and multimedia services but also underpins the aerospace, medical, defence and security industries. The UK is a leader in this field with the sector contributing some £139 billion last year for an R&D spend of £4.5B. As a consequence, there is a growing demand, currently not being met, for high quality communications researchers and engineers with a need to produce the next generation of innovators who can create future products and services here in the UK.

As well as producing innovative solutions to key emerging research challenges, the Centre provides a coherent advanced training network for the national communications community, and entrepreneurial engineers to underpin the future of the industry.

The CDT was established with financial support from EPSRC and some 25 UK companies and trade associations to address this demand. Bristol has a long-standing reputation for outstanding research in communications and in the training of high calibre postgraduate students who have gone on to become leaders of industry.

Through its Centre for Communications Research (CCR), Bristol has worked for many years on cross-disciplinary research. In particular with the School of Mathematics, Departments of Electrical & Electronic Engineering, Computer Science and the Faculty of Medicine. The Centre strengthens these relationships by combining the CCR expertise with Bristol's world-leading capabilities in statistics and interactivity to address emerging challenges.

Successful research partnerships worldwide have demonstrated that mathematicians can make contributions to characterising the performance of real-life communication networks. In Bristol, long-established links between Mathematics and the CCR have led to a number of jointly supervised PhDs, generating patents and papers.

Industrial Advisory Board

The IAB provides continuous guidance to ensure alignment of the taught programme content, specialist training activities and research topics that are key to the sector. Membership is drawn from the companies and trade organisations that have given direct support for the Centre. The IAB meets twice a year. Current membership includes:

CDT Management Team
BAE Systems
BBC
EPSRC
NEC
Thales
Toshiba
u-blox

The CDT in Communications grant application was supported by over 25 organisations, including:

Research Projects

In September 2012 project sponsors were invited to Bristol to view the work undertaken by the 2011 entry cohort. This formed the basis for the 1st annual CDT in Communications research event.

Project Allocation

Our industrial partners are invited to submit state-of-the-art research project suggestions aligned with the remit of our Centre. These are complemented by proposals from the academic team to ensure that the full breadth of the Centre and cohort is embraced. The first batch of proposals were showcased during a CDT open project fair, where our students had the opportunity to meet and discuss projects with the proposers. Subsequent individual interviews were

> *"The Bristol CDTs focus on enterprise training provides studnents with an insight into the real world, combining business skills with technology. It is of huge value for the future of UK* plc.*"*
>
> - *Graeme Hobbs FREng*
> *Chairman, Motorola Solutions UK Ltd.*

Research Projects Commenced October 2012

Project: Video Compression Techniques for Difficult Terrain
Student: Brett Hosking
Sponsor: EPSRC, BAE Systems

Video compression and coding is essential when transmitting visual data for both military and civil applications. Without compression, a standard definition (SD) video would require roughly 248 Mbits/sec bandwidth. Therefore a DVD would hold less than twenty seconds of uncompressed video. The frequency spectrum, particularly for wireless applications, has a finite capacity and so this is highly inefficient. Additionally, the signal strength of a wireless channel varies over frequency and time - during a deep fade the video bitstream may be subjected to high levels of error. For this reason, intelligent error resilient coding algorithms are required to maintain the intended visual quality output by the encoder.

This project aims to investigate the challenges of video transmission over wireless channels within military environments and devise methods for more efficient and robust video communications. This is a particular problem for air-ground simulation video networks fror land-based operations.

Project: Adaptive Broadcast Transmission with End-User Metrics
Student: Peter Bagot
Sponsors: EPSRC, BBC

The current broadcasting system still relies on many installation and operation principles established well before the days of digital transmmission. Broadcast antennas are installed and run on a 'one-off' basis, with little change in operation unless maintenance is required. This is a legacy of the outgoing analogue system, where received picture quality is directly linked to signal quality. This differs to a digital system, where if you operate above a certain threshold of power the signal can be accurately decoded and any extra power above this threshold may be unnecessary. Now that the UK has gone digital, new opportunities exist for improving the broadcast model. If you were able to engineer the system so that the power received in most users' aerials was just sufficient to decode the signal, and if this could be altered in real time, then the entire system could become very energy efficient, as well as provide important feedback on the system to help maintenance.

The purpose of this work is to investigate how the spectrum and energy efficiency of the current digital broadcast system can be improved using adative techniques. It will design a way for signal information can be fed back from users' televisions, and how to integrate this data into a real-time database and control algorithm.

Project: Blind Source Separation
Student: Richard Porter
Sponsor: EPSRC

Traditional methods of source separation focus on the case of at least as many mixtures as sources. This research project focuses on novel ways of exploiting the underlying structure of sources in digital communications, in order to improve the separation in the underdetermined case. This involves the use of Hidden Markov Models, and investigating methods that have been applied to signals in various other application domains.

Title: The Dynamics of Relay Networks
Student: David Simmons
Sponsor: EPSRC

Multi-hop, cooperative relay networks have received a lot of attention in recent years due to their ability to improve coverage and, thus, capacity. Such networks have found applications in low-complexity systems, such as emerging energy and utility management applications (e.g., “smart grid” and water metering communication networks) as well as industrial wireless sensor networks. Simple relay networks (e.g., two-hop networks) have received a considerable amount of attention and have been standardised for use in future cellular systems (e.g., LTE Rel-10). However, societal requirements and changes will force engineers to develop methods of scaling relay networks to support tens or hundreds of hops. Although this scenario can be seen every time one browses the World Wide Web, it is a relatively new concept in the field of wireless communications.This project will explore the characteristics of large-scale relay networks through the mathematical formalism of dynamical systems. This formalism describes physical phenomena such as flows, fractals, and even the evolution of a particle trajectory in a geometrically bounded (or partially bounded) system. In brief, a dynamical system is one in which a (potentially nondeterministic) principle governs the temporal progression of a point in space. By adopting a loose definition of ‘space’ in the preceding definition, one can easily identify an application of this concept to large relay networks. A question that might arise is: under what system conditions (e.g., relay transmit power, coding strategy, propagation environment, etc) is such a network stable? This project will aim to answer such questions, and to use this information to devise transmission and reception strategies that improve stability.

Project: Non-Deterministic Finite Automata
Student: Jorge Sved
Sponsor: EPSRC

High speed packet filtering based on regular expressions has many applications, particularly in the area of NIDS (network intrusion defence systems). Regular expression processing at very high speeds (100 Gbps+) is extremely challenging when large numbers of complex regular expressions are combined with traditional fixed keyword searches. The use of standard Deterministic Finite Automata (DFA) to support this type of application has two major limitations due to computational complexity. When multiple regular expressions contain wildcard repetitions, the state count of the DFA increases exponentially and so does the memory footprint. Non-Deterministic Finite Automata (NFA) offer possible solutions but still suffer from algorithmic complexity.

The objective of this research is to find new or improved algorithms that provide a good trade-off between complexity, memory usage, lookup rate and bandwidth and to propose corresponding target hardware and software architectures to implement them.

Project: Target Designation and Surveillance Presentation for Live Aerial Imagery
Student: Chris Morris

As Unmanned Aerial Vehicle (UAV) technology improves, and the regulations for their use in civilian airspace are relaxed, far greater levels of automation are likely to be employed that will remove the need for direct piloting by human beings. Users will be able to send instructions from the ground using off-the-shelf mobile devices such as tablets, with the aerial imagery returned directly to the user that requires it.

This will lead to the wider adoption of UAVs for civilian applications but will also create a need for new modes of interaction, to leave behind sensor-centric views intended for pilots and replace them with interfaces designed around the users needs. This project wil gather requirements from potential users and optimal designs determined and evaluated to allow the user to express their intent in requesting imagery and in presenting that imagery in a contextualised manner that maximises situational awareness.

Project: Optimization of Machine to Machine Communication in Large Scale Opportunistic Networks
Student: Divya Mohan
Sponsors: EPSRC, Toshiba

Opportunistic networks are characterised by frequently moving nodes with erratic and unstable contacts, and there is no guarantee that a complete path exist between source and destination nodes. Many such networks are delay tolerant, and employ a store, carry and forward approach to transmit messages.

Research on opportunistic networks has mostly focused on higher layers and many of the physical layer challenges are still unsolved. The key research challenge we focus on is that of dynamic spectrum allocation. Spectrum is a scarce resource, and if it is to be shared efficiently between multiple devices, then collisions and conflicts need to be minimised. It is also desirable to minimise interference caused by spectrum reuse in order to maximise throughput. Our research challenge is to develop and investigate decentralised algorithms to achieve these goals. Later, we shall also seek to develop routing and forwarding algorithms.

Project: A More Cognitive Approach to Wireless Access
Student: Vaia Kaladiou
Sponsors: EPSRC, NEC

As wireless networks become more and more popular, the demand on higher data rates is increasing, leading to the need for the development of faster and more efficient and reliable systems. Furthermore, as the number of wireless links is getting higher, it is essential to find new ways to wirelessly access environments where the presence of interference is significant due to the large number of users in the network. Therefore, a more cognitive approach to wireless access is required to deal with interference under any circumstances. One of the key aspects relates to the amount of collaboration between the nodes.

Interference Alignment is a cooperative interference management technique that exploits the availability of multiple signaling dimensions, which are provided by multiple antennas. According to current research, theoretically and under the assumption that perfect Channel State Information (CSI) exists, this approach of can provide wireless networks with extremely high capacity and quality of service allowing the network's capacity to increase linearly with the size of the network.

This PhD will develop signal processing algorithms for high capacity small cell wireless networks, so as to enhance the energy and spectrum efficiency. The work will exploit the statistical nature of the interference resulting in novel methodologies on interference mitigation.

Project: Alternative Methods for Frequency Duplexing
Student: Leo Laughlin
Sponsors: EPSRC, u-blox

Many wireless systems achieve two way communication by using separate carrier frequencies for simultaneous transmission and reception. In this configuration the received signal contains strong self-interference due to the transmission. If too large, this interference will overload the RF front-end and/or desensitise the receiver. The current solution to this problem is to use highly selective filters in the antenna coupling network to attenuate the self-interference to an acceptable level – a "Diplexer". Current Diplexers typically achieve this using SAW (Surface Acoustic Wave) devices, which are extremely difficult to tune and are therefore fixed for a particular frequency band. This significantly limits the frequency flexibility of the system, and requires multiband devices to contain a separate diplexer for each band. Due to this, the many operating bands defined in LTE (28 in LTE-Advanced) would mean a significant increase in the cost and size of an LTE "world phone", thus making an alternative frequency duplexing method attractive.

This research project investigates alternatives to fixed frequency diplexers, with the goal of eliminating conventional diplexers altogether. Specifically this project is focussed on actively cancelling the transmit energy entering the receiver, and the potential for combining signal cancellation, digital signal processing, and reconfigurable/tunable RF circuits to achieve isolation between transmitter and receiver without the need for fixed frequency components.

Looking Ahead...

Cohort 2012-2013

October 2012 saw the arrival of our 2nd cohort of 10 postgraduate students recruited from a wide range of subject backgrounds including Computer Science, Electrical & Electronic Engineering and Physics.

Changes to Programme Structure

We are continually adapting our course content to suit the changing research landscape and the requirements of industry. For example in 2012-2013 we have reviewed our syllabus and will be reducing the number of core units in future year. This will increase flexibility for students joining from different backgrounds. We also plan to enhance our content to include more optional material on high performance networks and software engineering. We are also increasing the time available for the first year project to create a more natural transition to their PhD phase of the programme.

Opportunities to Become Involved

Prospective Students

We welcome applications from highly motivated and academically well-qualified graduates in the fields of Computer Science, Electrical & Electronic Engineering, Mathematics and Physics who wish to embark on state of the art training and research in the board field of Communications. Our training is also well aligned to graduates who wish to return from industry to education.

Industry

Industrial engagement either as a research project sponsors, mentors or providers of specialist training to enrich our curriculum is most welcome. Sponsoring arrangements include full sponsorship, assignment of iCASE to the centre and industrial CASE conversion. Details of intellectual property ownership are available on request.

For further information please contact:

Email: cdt-communications@bristol.ac.uk
Phone: +44 (0)117 954 5395
Website: www.bris.ac.uk/cdt-communications

CDT in Communications
University of Bristol
Merchant Venturers Building
Woodland Road
Bristol, BS8 1UB

Management Team

Professor Joe McGeehan
Chairman
Professor of Communications Engineering
J.P.McGeehan@bristol.ac.uk

Professor Dave Bull
Director
Professor of Signal Processing
Dave.Bull@bristol.ac.uk

Professor Mark Beach
Centre Manager & Tutor, Year 1
Professor of Radio Systems Engineering
M.A.Beach@bristol.ac.uk

Dr Simon Armour
Admissions Tutor
Senior Lecturer in Software Radio
Simon.Armour@bristol.ac.uk

Dr Olly Johnson
Tutor, Years 2-4
Reader in Information Theory
O.Johnson@bristol.ac.uk

Dr Kevin Morris
Director of Studies, Year 1
Senior Lecturer in RF Engineering
Kevin.Morris@bristol.ac.uk

CDT in Communications
University of Bristol
Merchant Venturers Building
Woodland Road
Bristol, BS8 1UB

www.bris.ac.uk/cdt-communications