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Highlights of 2012

Global Sensor Network Program

2012 marked the completion of the system design, and algorithms research and simulation, for ITR’s Global Sensor Network. This low earth orbit satellite system will provide highly efficient and cost effective communications from large numbers of remotely located ground-based sensors. ITR successfully demonstrated the system using space hardware in the laboratory, and also decoded overlapping transmissions using ITR-patented waveform designs. Real world trials using aircraft and satellites will be carried out in 2013.

Free Space Optical

During the year ITR-developed research was applied to greatly improve the reliability of Free Space Optical (FSO) communications. FSO is a type of high-speed broadband communications which does not require a radio frequency (RF) spectrum. Experimental transmissions over a 12km test range at ITR’s Mawson Lakes campus showed marked increases in the reliability of the optical channel links, thanks to ITR’s advanced coding and synchronization methods. The trials demonstrate that these links are a viable alternative to spectrum-limited RF communications.

Satellite Celebrations

ITR hosted a major celebration to mark the ten-year anniversary of the launch of FedSat, Australia’s 58kg microsatellite. FedSat established Australia as an international presence in space research and development. ITR played a key role in the project, developing the communications system for the satellite and providing ground station services.
First NHMRC Grant

ITR was awarded its first National Health and Medical Research Council (NHMRC) grant, demonstrating the Institute’s outstanding capacity for multi-disciplinary research. The $500,000 grant went jointly to ITR’s Dr Mark McDonnell and Associate Professor John Bekkers from the John Curtin School of Medical Research at the Australian National University. The project, called ‘Persistent firing in cortical interneurons: mechanisms and potential anticonvulsant role’ will investigate brain function and epilepsy.

International Space Station

In March, ITR successfully monitored the flight path of an Ariane 5 rocket, launched from French Guiana carrying a payload to the International Space Station. The mission delivered fuel, water, oxygen, food and research equipment. ITR was one of only six stations worldwide to track the rocket’s progress, recording its speed, location and status.

Intelligent Transport appointment

ITR Director Professor Alex Grant was elected in December to the Intelligent Transport Systems (ITS Australia) Board of Directors. ITS Australia promotes technology that enables safer, more efficient and more sustainable transport across the public and private sectors.
Vision
Advancing human knowledge in the transmission, processing and use of information, enabling high impact technologies that deliver economic, social, cultural, environmental and health benefits.

Mission
To conduct world class fundamental research, partnered with industry, to deliver leading edge technologies in a vibrant research and education environment.
Institute for Telecommunications Research

What We Value

**TECHNOLOGY TRANSFER**
Leveraging fundamental research outcomes, we value the applied and experimental development of new technologies and delivery to market in partnership with industry.

**INTERNATIONAL VISION**
We value researchers and research outcomes that are internationally renowned and we conduct our business on the international stage.

**ENGAGEMENT**
We engage internationally and locally with end users, industry, government agencies, and like-minded research and engineering organisations.

**COLLABORATION**
We value multidisciplinary collaborative research leading to outcomes far beyond what we can achieve on our own.

**HIGH QUALITY RESEARCH**
We value internationally competitive research undertaken by active researchers at the forefront of their fields.

**EDUCATION**
We believe our high values and long lasting achievements are delivered through high quality, industry-relevant education and training of higher degree students and staff.

**IMPACT AND BENEFIT**
We expect our research outcomes to have high impact and to deliver benefit to society.

**END USER CONTEXT**
We value breakthrough fundamental research that enables new technologies, applications and commercialisation opportunities.
It is always rewarding at the end of the year to reflect on the outstanding achievements by the staff and students at the Institute for Telecommunications Research.

Exciting developments continue apace for our major Australian Space Research Program funded project, the Global Sensor Network. The Global Sensor Network is being developed as a low earth orbit satellite system to provide inexpensive, efficient communication for remote sensing. This year marked the completion of system design, algorithms research and initial performance evaluation. We successfully demonstrated the system using space hardware in the laboratory, further demonstrating the performance of our new, patented waveforms. Aircraft and satellite system trials are planned for the first half of 2013.

During 2012, ITR attracted a number of high quality research grants and made some significant new appointments, reflecting the ever-strengthening profile of our research work and industry collaborations.

A first for ITR was the awarding of our first ever National Health and Medical Research Council (NHMRC) grant. This $500,000 grant went jointly to ITR's Dr Mark McDonnell and Associate Professor John Bekkers from the John Curtin School of Medical Research at the Australian National University. Our involvement demonstrates ITR's outstanding capacity for multi-disciplinary research. In this instance, computational neuroscience will be harnessed to investigate brain function and epilepsy.

This year also saw the establishment of an Institute Manager position. This senior leadership position is part of our strategy to improve internal processes, supporting our vision for research excellence, engineering innovation, postgraduate education delivery and responsiveness to commercial opportunity. The new manager, Mr Larry Pereira, brings with him extensive experience in the telecommunications industry, plus an MBA and a Master's degree in Electrical Engineering.

In other significant staff developments, Dr Terence Chan was promoted to Associate Professor. Dr Siu-Wai Ho and Dr Gottfried Lechner were also promoted to Senior Research Fellows, recognizing their outstanding contributions to the Institute and to the University.

Our research on wireless communications received a boost with the awarding of $352,000 under the ARC Discovery Project scheme. This ‘Foundations for Future Wireless Networks’ project, to commence 2013, will focus on the delivery of more reliable and higher speed wireless broadband, even to highly mobile users. Senior Research Fellow Dr Mark McDonnell was awarded a six-month research fellowship as part of the Australian Government’s Endeavour Awards. This international travel award enables Dr McDonnell to strengthen collaborations, focussing on how the structure of our brain may provide a model for information processing.

Senior Research Fellow Dr Ingmar Land’s outstanding research was recognised with an international scholarship to further his work in distributed source coding. The visiting professor scholarship, awarded by the Ecole Nationale Superieure de l’Electronique et de ses Application (ENSEA) enables Dr Land to spend 10 weeks at the University of Cergy-Pontoise, Paris, to collaborate on research leading to advances in wireless applications that can be implemented in Australia, in the area of public safety and emergency communications.

I look forward to 2013 with the knowledge that ITR’s research will continue to make a real difference to the speed, efficiency and reliability of communications technology, in an era where this is needed more than ever before.

Alex Grant
The ITR Advisory Board convened twice in 2012 – on 23 April and 9 October.

During the Advisory Board meeting of the 9th of October 2012, the Board Members congratulated Prof Alex Grant on his leadership of ITR and another year of strong performance across the range of research, education and development initiatives.

Prof Grant presented some key achievements in 2012:

- Research publications reached a 4 year high with 80% of publications in A and A* journals.
- As a result of research activities on the Australian Space Research Project (ASRP), staff have prepared six Provisional Patent applications with several more on the way.
- HDR student load has doubled over the last 4 years and actively seeks to increase HDR numbers in the coming years.
- Several ITR researchers received ARC Discovery grants.

The ASRP has been an intensive research project that utilised most of the staff in 2012. Activities ranged from fundamental and highly innovative research in waveform design and protocols, to developing system architectures, software and firmware for systems and terminals ahead of field trials in early 2013.

Members of the Board with links to space and satellite industry leaders have recommended several actions for ITR to pursue in relation to taking the ASRP project to its next phase of commercialisation.

The Board was also presented with the status of plans for the transition of ITR to the Division of ITEE, which was expected to be completed by January 2013. While operationally, ITR would continue with its existing management structure, its reporting and external interfaces will be with the ITEE rather than the office of the DVC-R.

In view of this, ITR has made some structural changes to its Business and Administration, by creating an Institute Manager position thus liberating the Business Manager from the day to day operations of the centre. ITR has also recruited an IT Administrator and a Marketing and Communications Coordinator to complement its existing professional staff profile.

Further, ITR is rigorously searching for a strategic professorial appointment to boost its research capacity in wireless communications with the intent of achieving its ERA objectives.

The transition of ITR to the ITEE was seen as a positive from an undergrad teaching perspective and it was expected that ITR would be more integrated with the School of Engineering in courses related to communications.

The Board meetings in 2012 concluded that ITR’s strategies and objectives were aligned with its Vision of, ‘Advancing human knowledge in the transmission, processing and use of information, enabling high impact technologies that deliver economic, social, cultural, environmental and health benefits’.

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ITR Advisory Board Membership for 2012

Mr Neil Bryans, Chair
DSTO
Edinburgh, SA

Prof Sakkie Pretorius
Deputy Vice Chancellor & Vice President
University of South Australia

Prof Alex Grant
Director
Institute for Telecommunications Research
University of South Australia

Mr Brett Biddington
Principal
Biddington Research Pty Ltd

Prof Reg Coutts
Managing Director
Cou tts Communications, SA

Dr Peter Shoubridge
Research Leader
Military Communications Branch
DSTO
Edinburgh, SA

Dr Ian Oppermann
Director
CSIRO ICT Centre, NSW

Mr Jeff Kasparian
Business Manager
Institute for Telecommunications Research
University of South Australia

Dr Gregory Clark
Chairman
KaComm
Flexible Radios and Networks

Why we’re doing this

The Flexible Radios and Networks sector focuses on advanced technologies and implementations to deliver flexible and adaptable networks with improved user experience.

Flexibility can mean any number of things for a communications system. Some examples include networks that can be used for different purposes by different people; and networks that are scalable, self-organising or self-healing. We can also now make radios and networks more flexible by making it possible to reconfigure or update new applications without costly hardware or redeployments.

Where we’ll go next

2013 will kick off with ITR playing host to the Australian Communication Theory Workshop (AusCTW) in Adelaide. This IEEE conference attracts more than 120 researchers from Australia, New Zealand and beyond. Dr Gottfried Lechner is the 2013 AusCTW Conference Chair.

Continuing the research journey, and drawing on the back-to-back success of research projects in the Flexible Radios and Networks sector, Prof Alex Grant has been awarded funding commencing in 2013 for research on Foundations for Future Wireless Networks. This $352 000 ARC Discovery Project will deliver new technologies that enable lower costs through more efficient use of radio spectrum. It will develop more reliable and higher speed wireless broadband with better coverage, even to highly mobile users.

2013 will also see the continuation of several large ARC Discovery Projects and the harvesting of publications, ideas and opportunities from the fertile and fruitful Global Sensor Network project. ITR researchers will again be energetically pursuing research funding from competitive grants and industry collaborations for 2013 and beyond.

We have seen some fabulous developments emerge from research projects over the last twelve months. Wireless data is an exciting field to be involved in at the moment.
Flexible Radios and Networks | Key Research Areas

Up Close

Software Defined Radio Laboratory
Flexible Radios and Networks research, experimentation and technology development is supported and enhanced by ITR’s software defined radio (SDR) laboratory facilities, refurbished in 2012. A range of state-of-the-art SDR platforms (Spectrum, Lyrtech, Ettus USRP) and associated development, verification and testing tools and equipment are available. A particular focus is rapid model-based design and development for software defined radios and field programmable gate arrays (FPGAs).

Global Sensor Network Project
In 2012, many of ITR’s researchers were enthusiastically engaged with the Global Sensor Network (GSN) project. Several key advances for the GSN were underpinned by Flexible Radio and Network expertise. See page 16 for more on the GSN project.

Vehicular Communications
The interest of governments and industry investors in dedicated short-range communications (DSRC) for vehicle communications expanded exponentially in 2012. This technology has the potential to significantly reduce the road toll. Using wireless links, vehicles are able to communicate with each other and key infrastructure.

ITR’s spin-off company Cohda Wireless continued its success, announcing investments by Cisco and NXP as well as contracts for pilot road safety trials in Europe. ITR maintains a strong relationship and active collaboration with Cohda Wireless on communications technology research for intelligent transport systems.

High-Speed Implementations
In work spanning 2011 and 2012, ITR assisted the Commonwealth Scientific and Industrial Research Organisation (CSIRO) with development of firmware components for the technology transfer stage of their Ngara very high-speed wireless backhaul project. This work exemplifies both ITR’s ability to deliver high-speed signal processing systems and collaboration with other research institutes. ITR used a model-based design approach for FPGA implementation that complements ITR’s own software defined radio research and development. Achieving data rates above 5 Gbps, this is strong validation of the model-based design approach.

Passive Radar Signal Processing
FPGA development is also central to ITR’s contribution to field trial equipment for DSTO’s passive radar research program in 2012 and 2013. Passive radars use broadcast communication signals, for example digital TV, to detect targets such as aircraft, cars and trucks at distances of up to 150km. Researchers from ITR and DSTO are also collaborating on system design and advanced receiver signal processing methods for passive radar. Complementing this, a small amount of funding from the Government of South Australian enabled visits by passive radar researchers from the University of Queensland.

Software Defined Radio
ITR maintained a high profile with the software defined radio industry through participation in the Wireless Innovation Forum (WinnF). A/Prof. Linda Davis was the Technical Program Chair for the WinnF Communications Technologies and SDR Conference in Brussels in June 2012.

On the research front, the SDR team focused in on analog-to-digital conversion and its interaction with subsequent signal processing in software defined radios. Also, network coding and SDR technology was brought together to demonstrate physical layer network coding using software defined radios in the laboratory. Parts of these research projects supported internships for students from ANU, University of Adelaide and UniSA.

Coding, Information Theory and Security
In 2012, the ARC Discovery Project, ‘Efficient Data Transport Using Network Coding’ successfully concluded with graduating ITR students Satyajit Thakor and Daniel Salmon receiving accolades for their PhD theses.

Dr Roy Timo spent much of 2012 abroad in his role on the ARC Discovery Project ‘Compression of Distributed Data: Bridging the Gap between Theory and Practice’. Roy spent almost seven months at Princeton University (ranked 7th in Shanghai Top-150 World Universities) working with information theory guru Prof. Sergio Verdú. Roy also spent three months at the Technical University of Munich (ranked 53rd) collaborating with Prof. Gerhard Kramer. Roy’s research expertise is in the emerging field of non-asymptotic information theory.

International Interactions
ITR’s researchers undertook a range of visiting professorships: Dr Ingmar Land (Dr Claudio Weidmann, University of Cergy-Pontoise, Paris), Dr Ying Chen (Chinese University of Hong Kong), Dr Gottfried Lechner (Prof. Stephan ten Brink, Alcatel-Lucent Germany and University of Stuttgart), Dr Roy Timo (Prof. Sergio Verdú, Princeton University and Prof. Gerhard Kramer, Technical University of Munich), Dr Su-Wai Ho (Prof. Francois Baccelli, INRIA, France and Dr Calvin Chen, Alcatel-Lucent).
High Speed Data Communications

Professor Bill Cowley
Professor of Communications Signal Processing

Why we’re doing this

Given society’s ever-increasing demand for data, our research in High Speed Data Communications aims to develop communications systems which are wireless, yet can carry large amounts of information quickly. This requires Gbit communication rates. Since the bandwidth used is proportional to the bit rate, it is difficult to provide mobile broadband using the crowded radio-frequency (RF) spectrum.

Much of our attention has therefore been directed to broadband optical transmission, since this requires no RF spectrum. Free Space Optical (FSO) links use optical transmission through the atmosphere, or through space, to provide mobile broadband communication.

Where we’ll go next

In future we will continue research into both theoretical and practical aspects of FSO and hybrid RF/FSO communications. For example, adaptive transmission methods have been widely used in RF communications but not in FSO links. ITR sees excellent potential to combine advanced coding and synchronisation methods, with adaptive transmission techniques, to give significant gains in average bit rate and reliability.

Free Space Optical offers extremely high (GBit) data rates for terrestrial and satellite communications.
Free Space Optical

In 2012, ITR continued its research into broadband communications that require no radio frequency spectrum. In particular, we have been carrying out research on Free Space Optical (FSO) communications. These FSO links, which operate at 1550 nm, are ‘eye-safe’ and offer the possibility of extremely high speed (Gbit) data rates for both terrestrial and satellite communications. Over the past 12 months ITR has continued a number of R&D projects in both FSO links and also hybrid RF-FSO schemes. These projects have been carried out in collaboration with DSTO in Australia and the German Aerospace Agency, DLR.

While FSO links offer high-speed secure communications, there is the problem of rapid variations in amplitude, due to small changes in the atmosphere’s refractive index. These scintillation effects (which cause variations in a similar way to stars twinkling), combined with attenuation signal loss due to fog and clouds, have previously limited the terrestrial applications of FSO to short distances of several kilometers. ITR is using advanced channel coding methods that can greatly improve the reliability of FSO communications.

A particular challenge is that both FSO and RF links can be adversely affected by the weather: fog in the optical case and rain in the high frequency RF case. We are exploring methods of adapting to varying weather conditions, by coding across hybrid RF/FSO channels to adjust both the total number of information bits, and the fraction carried on each channel.

FSO and RF/FSO Channel Characterisation

ITR has continued to expand the use of its 12 km RF/FSO test range between the RAA Repeater at Houghton and ITR at the University of South Australia’s Mawson Lakes campus, both in Adelaide.

This test range records channel propagation statistics at both 37 GHz and 1550nm. These joint channel statistics are required to optimise the design of hybrid RF/FSO links, since almost no existing measurement data is available. ITR post graduate students have been using the data to generate Markov models of the hybrid RF/FSO channel and derive new algorithms for estimating channel parameters.

During 2012 a new measurement campaign was started in collaboration with DSTO to measure the angle of arrival (AoA) statistics of the optical signal over the 12 km link. These AoA measurements allow models of the physical parameters of the atmosphere, such as the refractive index structure constant, to be determined. These measurements help us model how to transmit the signal in different atmospheric conditions.

In addition, we recently completed an analysis of the reciprocal-channel measurements carried out with the German Aerospace Agency (DLR). We have found that high levels of correlation exist in FSO channel fading for bidirectional coaxially-aligned links. This is important since traditionally, the use of adaptive transmission methods requires a feedback route from the receiver to the transmitter. This can now be avoided, if reciprocal fading is assumed. The results of these investigations have been published in leading international journals (see Publications Page 26 – 30).

FSO Transceivers

ITR is also very interested in the practical application of novel coding and adaptive transmission methods in optical communications. To date we have designed and tested a fully-functional real-time FSO transceiver operating at medium data rates (close to 10 Mbit/s), plus selected portions of a Gbit transceiver.

During 2012, trials of the medium data rate transceiver were carried out over our 12 km test range, plus other FSO links. In addition to field tests, considerable effort has been devoted to realistic testing in the laboratory. We have used a variable optical attenuator, controlled by a suitably synthesized signal to achieve a fading optical channel.

This has the advantage that any link distance or fading parameters can be selected, thereby providing a test facility that can model a wide range of optical equipment parameters and/ or weather conditions. The transceiver was successfully demonstrated at ITR to senior Australian Defence personnel in 2012. The trials clearly demonstrated the benefits of powerful channel coding and synchronisation to mitigate FSO fading, by streaming real-time video through ITR’s transceiver.
Machine-to-machine (M2M) communications is one of the most dynamic sectors today.

Why we’re doing this

2012 marked a significant shift in ITR’s research focus on Satellite Communications. Most of our effort went into a greenfield design for one of the most dynamic sectors today: machine-to-machine communications (M2M). This sector provides connectivity to light terminals that can be used for fleet management, fixed-asset monitoring, asset tracking, resource management, scientific data monitoring, and personal tracking devices on land, at sea and in the air.

While most services available today are a modification/extension of conventional one-to-one links in order to increase the number of users, ITR decided to go with a revolutionary approach that can directly enable millions-to-one satellite communications.

From a few hundred million dedicated M2M devices today, market research estimates that in less than 20 years there will be between 25 and 50 billion M2M devices, most of them needing zero human interaction for continuous communication. Most of the major satellite market participants are active in this field and report large annual growth in M2M. For some, such services represent over one third of their customer base.

Through this effort, ITR has positioned itself at the front of this new wave of services which allow low-cost connectivity anytime, anywhere for millions of terminals.

Where we’ll go next

ITR is investigating how to enable remote users to communicate random large bursts of data. Such a service-on-demand would make available an agile satellite pencil radio frequency (RF) and/or laser beam (pico beam) to a particular user for a very short time. A satellite could provide a large number of these simultaneous RF/optical pico beams to individual users within its footprint. The energy in such a pico beam would allow the receiver to operate at extremely low power and at the same time receive a large amount of data. This beam could also be steered with milliradians to sub-micro-radian accuracy.

Optical (laser) beams can transport very large amounts of data in very short bursts, weather permitting. Phased array antennas (PAA) are less sensitive to weather conditions and allow the beam to jump from one target to the next in a few microseconds. The communication could be a multifunction operation by using both RF and optical beams simultaneously.

The increased use of software defined radio (SDR) platforms will enable ITR to move quickly from MATLAB simulations to proof-of-concept demonstrations for these kinds of technologies. A shorter development cycle will allow a faster project implementation phase and reduced cost. The reuse of knowledge libraries will increase the efficiency and reliability of our products.
Turbo Coding Technology

In the field of telecommunications there are theoretical limits for the speed at which information can be transmitted error-free. Reaching them became theoretically possible only with the discovery of turbo codes in the early 1990s. Thanks to a recent increase in computational complexity, turbo codes can now allow the recovery of data which has been transmitted in a very ‘noisy’ environment.

The challenge of implementing such powerful error control codes was increased further by the need for the receiver to be more complex in the areas of acquisition and synchronisation. ITR directly addressed these past shortcomings in telecommunications capacity with the development of Turbo Coding Technology (TCT), an enabling technology crucial for the development of mobile, satellite-based communications.

Today, TCT is applied to numerous maritime, aeronautical and land-vehicular services, multimedia services capabilities and faster rates for mobile services.

While many companies have benefited from ITR’s TCT research breakthroughs, the technology’s highest commercial impact has been on satellite communications company Inmarsat. Inmarsat’s R&D Director and Head of New Programs Eyal Trachtman describes how TCT contributed to their business:

‘UniSA had a significant contribution in the development of our new standard air interface, performing a study phase followed by a proof of concept phase (building a physical model). This has led to IAI1 (Inmarsat air interface 1) which was based on 64kbps fitting into a 40kHz channel and was implemented in our GAN (Global Area Network) system. The same technology was extended and implemented in our IAI2 which is the BGAN (Broadband Global Area Network) air interface, where we scaled IAI1 up and down to create the family of BGAN physical bearers. The BGAN service was introduced in 2005 and is currently our mainstream product.’

X-Band Satellite Reception Facility

The 10th anniversary of the X-Band Tracking Facility was marked by very high standard quality images acquired from SPOT-4 and SPOT-5 satellites by our 3rd generation satellite receiver, ERSDEM-3.

S-band Reception Facility

In March 2012, ITR engineers provided a tracking service for a supply mission launched to the International Space Station (ISS). The mission saw the Autonomous Transfer Vehicle (ATV) Edoardo Amaldi filled with a payload of supplies launched into space aboard an Ariane rocket.

During launch and orbit, ITR engineers collected and monitored essential flight data on the position and status of the rocket.

Since the first ATV launch in 2008, ITR has been involved in tracking three ATV missions. During this period there has been a dramatic reduction in travel time. In 2008, ATV1 took almost one month to reach the ISS. In 2011, ATV2 took eight days and this year ATV3 took only five days to reach the ISS.

The antenna used to track the launch mission was ITR’s own S-band 3m dish, located at Mawson Lakes, Adelaide.

Industry exchange links France – Australia

The ATV3 tracking was performed as part of an agreement between ITR and Centre National d’Études Spatiales (CNES), France. This relationship became even stronger when ITR senior engineer Marc Lavenant spent eight weeks at the Toulouse CNES division Direction Des Lanceurs, Sous-Direction Developpement Sol (DLA/SDS/AS), where he worked on antenna tracking software.
Why we’re doing this

ITR’s Computational and Theoretical Neuroscience Laboratory brings together researchers, students and interdisciplinary collaborators to answer fundamental scientific questions about how electrical signals are used in the brain to represent and process information.

A particular emphasis is on reverse engineering the biophysical mechanisms exploited by networks of neurons to reliably communicate with each other, despite high levels of stochastic noise. Increased understanding in this area will suggest new bio-inspired methods for designing engineered electronic systems.

Where we’ll go next

Future research will investigate why repetitive oscillations are often observed in measurements of brain signals, potentially leading to the development of biomedical prosthetics and brain-inspired machine-learning applications. This five-year project, titled ‘Communication and information storage mechanisms in complex dynamical brain networks’, is funded by an ARC Discovery grant.

Overall, our research is leading to new mathematical and computational models of neurobiological systems; new hypotheses regarding computation and communication in biological neurons and brains; new methods and tools for neuroscience research; and new approaches in biomedical engineering and biologically inspired technology.

The ultimate aim of the research is to develop new methods for biologically inspired artificial intelligence.
Research at the Computational and Theoretical Neuroscience Laboratory focuses on three key areas:
Computational Modeling of Neurobiology, Reverse-engineering of the brain, and Biomedical Engineering.

**Computational Modelling of Neurobiology**

**Networks Neuroscience**

During 2012 Dr Mark McDonnell collaborated with Professor Lawrence Ward at the University of British Columbia, to investigate how different parts of the brain are connected by nerve cell contacts. The visit was funded by an Endeavour Research Fellowship, awarded by the Australian Federal Government Department of Education, Employment and Workplace Relations.

Dr McDonnell also visited Northwestern University in Chicago, and gave seminars at the University of Washington at Seattle; Brandeis University, Boston; University of British Columbia, Vancouver; and University of Melbourne. Research results were presented at conferences in the USA and Germany.

PhD student Brenton Prettejohn completed his PhD thesis, but tragically passed away as a result of an accident within days of submission of his thesis. However his thesis examination went ahead on the wishes of his family.

PhD student, Brett Schmerl and Associate Professor John Bekkers collaborated on a project modeling the olfactory cortex. The aim of the research is to predict how network connectivity within the olfactory cortical region influences its electrical activity, and ultimately its function.

**Stochastic noise in the brain**

Following publication of a review paper on stochastic noise in the nervous system in Nature Reviews Neuroscience in 2011, Dr McDonnell was invited to give a Bernstein Lecture at the Bernstein Center for Computational Neuroscience in Munich, and a presentation at the Australian Neuroscience Society annual conference.

In collaboration with Associate Professor Christian Stricker, of John Curtin School of Medical Research, Australian National University, PhD student Ashutosh Mohan presented research at the Australian Neuroscience Society conference. This included modeling work on synapses in the somatosensory (touch) cortical area, and the development of new methods for simulating stochastic synapse activity in software.

Preliminary work on stochastic modeling of neural ion channels was presented in poster form at the Conference on the 60th Anniversary of the Hodgkin-Huxley Model, Trinity College, Cambridge, UK; Bernstein Conference on Computational Neuroscience, Munich; Neural Coding Conference, Prague; and at the International Joint Congress on Neural Networks, Brisbane.

**Reverse-engineering the brain**

**Oscillatory neuronal communication**

A visit by ITR this year to the University of British Columbia facilitated new research in modeling the possible role of oscillatory brain activity in communication between brain regions. During this visit, Dr Mark McDonnell worked with Professors Lawrence Ward and Priscilla Greenwood, on fundamental mathematical modeling about how bandpass filtering effects can emerge in noisy neurobiological networks.

Papers on this topic were presented at two international conferences: the International Conference on Applications of Nonlinear Dynamics (ICAND), Seattle; and the Neural Coding Conference, Prague.

**Brain-inspired Machine Learning**

Dr McDonnell and ITR’s Dr Russell Brittkworth continue to work with PhD student, Daniel Padilla, on research that aims to mimic how the mammalian cortex learns to identify and predict sequences from data. Preliminary results from this project were presented at the Neural Coding Conference in Prague.

**Biomedical engineering**

This year we welcomed PhD student, Gao (Demi) Xiao from China. Demi is interested in improving the performance of cochlear implants and bionic eyes, with her research aiming to apply information theoretic methods to make predictions for the optimal number of electrodes in such biomedical electronic prosthetics. This project is a collaboration with Associate Professor David Grayden, of the University of Melbourne. Previous work in this area was presented at the International Engineering in Medicine and Biology Congress, in San Diego.

**Other highlights**

The Laboratory has had an exciting year in other areas. Dr Mark McDonnell, jointly with Associate Professor John Bekkers (John Curtin School of Medical Research, Australian National University) were awarded a National Health and Medical Research Council (NHMRC) Project Grant entitled “Persistent firing in cortical interneurons: mechanisms and potential anticonvulsant role.” This grant will provide $500K total funding for 2013-2015.

New staff member Dr Tony Vladusich joined the Laboratory, along with PhD students Demi Gao and Brett Schmerl. Dr Bingchang Zhou, from the Northwestern Polytechnical University, Xi’an, PR. China, arrived for a 12 month visit.

In 2012, Dr McDonnell co-founded the Australian Association of Computational Neuroscientists and Neuroengineers, to advance Australian computational neuroscience.
The Global Sensor Network is a new low earth orbit satellite system, with innovative architecture and waveform design, that enables highly cost effective communications for diverse and large remote sensor applications.

2012 marked the second year of the Space-Based National Wireless Sensor Network Project, now known as the Global Sensor Network (GSN). The project was born out of the Commonwealth Government’s Australian Space Research Program (ASRP) initiative in which ITR was awarded $5 million in November 2010. Matched with investment from project partners COM DEV (Canada), SAGE Automation, DSTO, CSIRO and AMS, the total value of the project is in excess of $12.5 million.

The project aims to demonstrate a proof-of-concept system that is capable of filling the market gap in the area of cost-effective data gathering for remote, low data rate applications. The program looks at the overall system development and design, as well as the ground and space segment aspects, including the demonstration of new algorithms, enabling very cost effective services for large numbers of sensor terminals.

A Consortium Workshop was held in February to define the key test case scenarios for aircraft trials. This laid the foundation for further detailed planning around the operations and logistics of the trials, in which an experimentation aircraft will be provided by DSTO in 2013 to act as a satellite surrogate. A number of ground terminals will be distributed around Adelaide and the greater South Australian area, including the Gulf of St Vincent, where a terminal will be mounted on a buoy supplied by DSTO.

**Big Info, Small Bandwidth**

Fundamental research outcomes of 2011 were used to finalise the design and simulate the GSN communications system. A low earth orbit satellite channel simulation model was developed in order to verify and optimise the waveforms and algorithms. A key capability of the GSN system is its ability to simultaneously receive messages from a very large number of terminals using only a small amount of bandwidth. Simulation performance showed a significant improvement over existing systems. Intellectual Property developed during 2012 resulted in six provisional patent filings, with drafting of several more in progress.

The use of Software Defined Radio (SDR) tools and techniques remains a key strategic objective of the GSN project. Commercially available SDR platforms were procured for use as experimental satellite payload and ground terminals. Implementation of the GSN waveforms onto these platforms is ongoing, in preparation for the aircraft trials.

The transfer of research outcomes onto the field trial system has been streamlined through an efficient development methodology that tightly couples the simulation model to the final implementation. A common set of software routines has been shared across the simulation model and programs that will run on the field trial hardware. This approach has reduced both technical risk and implementation time.

**Flight Ready**

A key achievement in July 2012 was the integration of prototype GSN ground terminal equipment with the flight-ready satellite payload. Using ITR’s multuser receiver, the full end-to-end functionality of the system was verified. The integrated system included the same space-ready payload hardware that will be used during the aircraft trials. Two terminals transmitted simultaneously, effectively talking over the top of each other, so that their signals overlapped in time and frequency. The multuser receiver successfully decoded both signals. During the aircraft trials this capability will be demonstrated on a much larger scale by recreating satellite pass scenarios during which the payload will ‘see’ tens of thousands of terminals.

Further progress was made on the Phase A Mission Study to derive the requirements and design of a deployable satellite mission for the GSN communications system. A review of the mission requirements derived under this study was undertaken during the workshop held in February. During September COM DEV visited ITR and a review of system requirements was carried out. The final revision of the Phase A Study documents is in progress. Planning also commenced for satellite trials to take place after the aircraft trials in 2013. During these trials an existing satellite in low earth orbit will be used to receive GSN signals and downlink them to the ground for processing and performance analysis at ITR.

The extensive research program at the core of the GSN project has resulted in publications being submitted to top tier academic journals and presented at international conferences. Further publications will be submitted throughout 2013.
2012 was a strong year for the GSN program. Fundamental research outputs were transferred into system implementation, and performance was verified using both simulation and space hardware testing.
Our work is intended to be of relevance and value to industry, with industry being broadly defined to include commercial companies, not for profit organisations and various government entities nationally and internationally.

Our contributions range from consulting, fundamental research, through to system and device prototype and product development, and commercialisation. We engage with organisations in a way that provides the best outcomes, both technically and contractually. We pride ourselves on ensuring that we understand the needs of our customers, deliver what is expected, when it is expected, and within the right contractual framework to ensure success, addressing appropriate project and intellectual property rights management.

This section provides a snapshot of programs and projects undertaken with external organisations during 2012.

**Coding for Hybrid Free Space Optical (FSO) / RF Channels**

Funded by the Sir Ross and Sir Keith Smith Fund, this project targeted FSO communication links as a broadband link alternative for both terrestrial and satellite broadband communications where radio frequency spectrum is limited. Unfortunately FSO links are affected by atmospheric scintillation and poor weather, such as clouds and fog. ITR is applying advanced coding methods to dramatically improve the performance of FSO communications, including the use of multiple optical channels and hybrid approaches using both RF and FSO channels so that as the quality of individual channels varies, the best overall performance can be obtained.

**Ngara Backhaul Project**

Funded by CSIRO, this project involved implementing an outer transceiver using high speed FPGAs as part of a larger development program being undertaken by CSIRO. The project demonstrated a 5Gbit/s wireless backhaul.

**ATV3 Satellite Tracking Services**

ITR provided tracking services from its S-band steerable tracking facility at Mawson Lakes, South Australia, for the third Autonomous Transfer Vehicle (Eduardo Amaldi) launch to the International Space Station.

**Industry Projects**

Mr Jeff Kasparian  
*Business Manager*
SPOT Satellite Tracking
ITR continued to provide daily tracking services from its 6.8m steerable antenna tracking facility, receiving data from the SPOT-4 and SPOT-5 satellites. This is now the tenth year of providing such a service.

High Performance Algorithms for Next Generation Quantum (HiPANQ) Key Distribution
Quantum Key Distribution (QKD) is a new technology for long term security of exchanged keys. It is an invaluable component to secure future communication infrastructure but its applicability is hampered by its low key rates. QKD post-processing – transforming the correlated and partly secret results of quantum measurements into a secure key – is a computationally intensive task and well elaborated for kbit/s key rates. Handling higher rates in real-time faces completely new methodological and algorithmic challenges. HiPANQ addresses these challenges and aims to develop effective methods for rates in the 100 Mbit/s regimes.

International Space University
ITR has provided lectures and workshops in satellite communications for the very successful Southern Hemisphere Space Studies Program (SH-SSP). UniSA and the International Space University ran this five-week multi-disciplinary live-in program in January this year.

ATN/DAAD Energy-Efficient Multicarrier Transmission
A joint project between ITR and Hamburg University of Technology focused on two aspects of orthogonal frequency-division multiplexing (OFDM). The first was differential modulation with incoherent detection; and the second included principles for reducing the high dynamic signal range. For both aspects the team will apply the concept of signal processing in finite fields.

Free Space Optical Trials
Building on previous sponsored work that resulted in trials of a functional, real-time, free-space-optical transceiver, the current project extends the design to double the data rate and then undertake performance measurements under realistic fading channels. Evaluation includes the demonstration of reliable video transmission over optical channels with significant scintillation. The results show significant increases in performance and reliability of the coded systems developed when compared to uncoded FSO.

Current and Future SAR Missions and Sensors
The government has placed a priority on space situational awareness. As part of a larger team, ITR conducted an independent survey to assess the status of unclassified space-based Synthetic Aperture Radar (SAR) systems, capabilities and associated technologies in order to support the definition of a favoured acquisition strategy for a SAR satellite.

Mathematical Analysis of Health Data
During 2012, ITR undertook mathematical analysis and recommended statistical algorithms for providing increased confidence and reliability when detecting potential defects in health related microarray data.

FPGA and Communications Algorithm Development for Flexible Data Capture
This project involved the development of a digital, Field Programmable Gate Array (FPGA) based system to implement a high-speed data landing card using 8-channel off the shelf hardware. This system was required to record analogue signals in real-time at 250 MSPS/channel and provide control to decimate the sample rates at run-time. A highly-programmable digital down conversion (DDC) design was developed to decimate the incoming data stream, before being streamed and displayed.
Investing in scientific research and technologies is critical to long-term and sustainable growth in Australia. Research contributes to technological innovations and advances, improves the economy, and increases productivity and prosperity. Other spinoffs from research include the creation of new innovative Intellectual Property, the commercialisation of bright ideas, and the education of future innovators and leaders in universities and industries.

Most fundamental research programs are funded through the Australian Government. Competition for research funding is fierce, with only the highest quality and most impactful research programs being successful.

The following research grants awarded to ITR indicate our significant success in attracting national and international research funding.

ARC Discovery: Robust Transmission, Identification and Key Agreement in Communications Networks
Dr Terence Chan and Professor Alex Grant
2010–2013
Australian Post Doctoral Fellowship
Dr Siu Wai Ho
2010–2013

Networks rely heavily on efficient and robust communications. This project aims to determine the fundamental limits and costs of robust transmission, identification and key agreement in unreliable or compromised networks. The research will propose a new approach based on network coding to embed reliability in the core of the network. Expected outcomes of the research, which will impact the information and communication technology industry, are contributions to the theory of provably robust networks and efficient and robust data transmission, and identification and key agreement schemes in networks.

These research grants indicate our significant success in attracting national and international research funding.
to deliver the required quality of service. These balance the available resources and new network designs, schemes, and deep understanding of performance, networks. Targeted outcomes include in wired and wireless multimedia to reduce management overhead and coding to increase throughput and distribution and multimedia streaming. Performance increases are predicted for distributed storage, content distribution and multimedia streaming. The project focuses on network coding to increase throughput and to reduce management overhead in wired and wireless multimedia networks. Targeted outcomes include contributions to network coding theory, deeper understanding of performance, complexity and resource trade-offs, practical network coded data transport schemes, and new network designs. These balance the available resources to deliver the required quality of service.

ARC Discovery: Communication and Information Storage Mechanisms in Complex Dynamical Brain Networks
Australian Research Fellowship Dr Mark McDonnell 2010–2014
Repetitive oscillations are often observed in measurements of brain signals. While mathematical approaches have discovered how these oscillations arise in brain networks from complex interactions between large numbers of neurons, their role in brain function remains a largely unresolved and fundamentally important question. A novel approach will assess the hypothesis that oscillations allow communication of information between separate brain regions. Mathematical and computational models of modulation, and memory storage and retrieval, in oscillatory brain networks will be produced, and assessed, using communications-engineering metrics. Findings will potentially lead to innovative ideas for future medical bionics and brain-machine interfaces.

ARC Discovery: Efficient Data Transport Using Network Coding
Professor Alex Grant and Dr Terence Chan 2008–2012
This research aims to understand the relation between resource allocation and service quality in communication networks. Network coding changes the way we think about networks by allowing network nodes to perform coding, rather than just routing. Performance increases are predicted for distributed storage, content distribution and multimedia streaming. The project focuses on network coding to increase throughput and to reduce management overhead in wired and wireless multimedia networks. Targeted outcomes include contributions to network coding theory, deeper understanding of performance, complexity and resource trade-offs, practical network coded data transport schemes, and new network designs. These balance the available resources to deliver the required quality of service.

ARC Linkage: Satellite Data Communications for Remote Sensing and Broadband Connectivity
Associate Professor Linda Davis, Professor Alex Grant, Dr Nick Letzepts and Dr Ingmar Land 2009–2012 (extended to 2013)
The remote, distributed location of many of Australia’s primary industries precludes the use of consumer oriented terrestrial wireless broadband services. In many instances, satellite communications provides the only feasible means of connectivity for telemetry, supervisory control and data acquisition, tracking and fleet management. Meteorology, remote sensing, irrigation, mining, oil and gas exploration, and fisheries are just a few examples of high value applications of particular significance to Australia. This project will develop bandwidth efficient satellite communications technologies that greatly reduce cost and pave the way toward new market opportunities for broadband access and telemetry applications.

ARC Discovery: Early Career Researcher Award – Reliable Transmission for Wireless Control
Dr Khoa Nguyen 2012–2014
The application of wireless communications in automation and control brings substantial benefits to industry, including low installation and maintenance cost, low failure rate and flexibility. However, current wireless communication technologies are not designed for control applications. This project aims at developing novel communication technologies for control systems. These technologies will revolutionise wireless control systems in terms of efficiency, reliability and applicability. The expected outcomes are: Information-theoretic limits of communications in control applications, which provides guidelines and benchmarks for system designs; and practical and efficient communication technologies for control applications.

ARC Discovery: Physical Layer Security Techniques for Multiuser Wireless Networks
Dr Ingmar Land: 2012–2014 (Joint Project with University of New South Wales)
In this project we will develop novel physical layer security theories and techniques that will dramatically increase the secrecy and robustness of wireless communications. More specifically, our new designs will exploit the variability of wireless channels as a means of ensuring the secrecy of wireless communications. Our solutions accommodate threat models that are more realistic and far beyond those previously studied. It is expected that the innovative security techniques we propose will be used to substantially improve existing network security measures and open up a new frontier of opportunities for future wireless networks.

ARC Discovery: Compression of distributed data: Bridging the gap between theory and practice
Dr Ingmar Land, Dr Roy Timo 2012–2014 (Joint Project with University of Newcastle)
Modern digital communication and storage relies on the compression of data, and the ideal data compression approach is different for each application. While excellent data compression techniques exist for applications such as image compression, those for correlated sources, for instance sensor networks, are far from ideal. This project aims to develop optimal data compression techniques for these systems, by exploiting a recently-discovered link between compression and error correction codes. The new compression algorithms developed by this work will significantly increase the efficiency and lifetime of a wide range of communications systems.
OUR PEOPLE

Staff

Director
Prof Alex Grant

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Mr Jeff Kasparian

Institute Manager
Mr Larry Pereira

Professor of Communications
Signal Processing
Prof William Cowley

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Associate Research Professor of Wireless Communications Technologies
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Dr Steven Pietrobon
Dr Sylvie Perreau
Dr Weimin Zhang

Research Fellows
Dr Benny Johnson
Dr Nicolangelo Iannella
Dr John Tsimbinos
Absent from photograph are: Sarah Armour, Colin Biggs, Terence Chan, Wendy Clark, Bill Cowley, Linda Davis, Amanda Johnston, Trevene Leonard, Lin Luo, Khoa Nguyen, Rees Quilford, Penny Reidy, Thomas Schneider and Hidayat Soetiyono.

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**Visitors**

Dr Konstanty Biakowski  
University of Queensland  
Assoc. Prof Linda Davis*  

Assoc Prof  
Vaughan Clarkson  
University of Queensland  
Assoc. Prof Linda Davis*  

Pierre Letapissier  
CNES French Guiana  

Ashutosh Mohan  
Australian National University  
Dr Mark McDonnell*  

Andrew Harms  
Princeton University  
Assoc. Prof Linda Davis*  

Andrew Zhang  
CSIRO  
Dr Lin Luo*  

Dr Sarah Johnston  
University of Newcastle  
Dr Gottfried Lechner, Dr Ingmar Land, Dr Roy Timo*  

Sean (Xiangyun) Zhou  
Dr Ingmar Land*  

Dr Sean Manning  
DSTO  
Prof Bill Cowley*  

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Prof Bill Cowley*  

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Prof Terence Chan*  

Prof Gerhard Kramer  
Institute for Communications Engineering, Technical University of Munich  
Dr Roy Timo and Dr Ingmar Land*  

Dr Scott Madry  
International Space University  
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Assoc. Prof Linda Davis*  

Assist Prof Tracey Ho  
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The Chinese University of Hong Kong  
Dr Terence Chan*  

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PhD student at the Hamburg University of Technology  
Dr Lin Luo*  

Assoc Prof Ryutaroh Matsumoto  
Department of Communications and Integrated Systems, Tokyo Institute of Technology  
Dr Terence Chan and Prof Alex Grant*  

*Supervisor/Host
Why do students choose to study at ITR? As Australia’s largest university-based research organisation in telecommunications, ITR offers students outstanding supervisors, excellent facilities, and a great study and research environment.

The number of students at ITR grew to reach 33 in 2012, representing an eight-year high. Since its inception more than 25 years ago, 113 PhD and Masters students have graduated from ITR. Many have launched successful careers across the globe in industry and academia. Several have won prestigious awards including the SA Young Tall Poppy, Young Entrepreneur of the Year, and Engineer of the Year. Not surprisingly ITR graduates are highly sought after by employers in both academia and industry.

ITR prides itself on having a collaborative working environment among students and research staff. There are many opportunities for Theory-to-Industry collaborations and overseas exchange programs. ITR strongly supports students to access scholarships and top ups, as well as presenting their research at national and international conferences.

Students at ITR have access to world class facilities. For example, with a focus on Software Defined Radio, ITR’s Advanced Prototyping Laboratory enables research which transitions from theoretical and algorithmic outcomes to proof-of-concept demonstrations. For students interested in pursuing research in satellite communications, ITR has advanced laboratory facilities as well as two ground stations on site.

Research Degree students can choose to do either a PhD in Telecommunications (three years), or a Master of Engineering (Telecommunications) (two years). ITR also offers undergraduate students the opportunity to do up to 12 weeks of Work Experience; and an Internship Program for international undergraduate and postgraduate students.

An award for the most outstanding PhD completed by an ITR student is offered each year. Named in honour of ITR’s founding director, Emeritus Professor Michael Miller, the Medal recognises research that is creative, original, contributes to new knowledge, and has an impact through the number and level of international publications and presentations.

For more information on studying at ITR, please phone 08 8302 3769, or email itrstudent@unisa.edu.au or visit www.itr.unisa.edu.au/study
PhD in Telecommunications

Assad Akhlaq
PhD in Telecommunications

Md Noor-A-Rahim
Channel Coding for Delay-Universal Transmission

Daniel Padilla
Biometric machine learning for auditory information processing based on the hierarchical temporal memory model of the mammalian neocortex

Brenton James Prettejohn
Understanding the underlying similarities shared by complex systems: A study of consensus formation, and neuronal network dynamics, through the application of complex network simulations

Yinyue (Ivy) Qiu
Next Generation Software Defined Radio Architectures

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MIMO Satellite Communication

Nayyema Sadeque
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Modelling the Impact of Complex Synaptic Connectivity Topologies on Cortical Neuronal Dynamics

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Ontology-based conceptual Payload Design

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Tradeoffs in Energy Efficient Wireless Sensor Networks

Yaguang Zhang
UniSA exchange student from China

Th omas Schneider
UniSA
Ingmar Lard*

Fangxing Wu
ANU

Xiaoke Yang
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Robby McKilliam*

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Jun Li
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ITR undertakes a number of research and development activities, with outputs in many cases published in relevant journals and conference publications – subject in some cases to commercial restrictions and agreements. We pride ourselves on targeting very highly ranked, and relevant refereed publications to publish our work, and rank very highly in this regard.

### Refereed Journal Articles


Revenue

$5.827 MILLION

57.7% Industry and Government Projects

16.3% UniSA Internal Funding

15.3% Teaching
  Postgraduate: 12.6%
  Undergraduate: 2.7%

10.7% ARC Research Grants
Our Story

Left to right: Ricky Luppino, Dave Haley, Jeff Kasparian, Hidayat Soetiyono, Marc Lavenant (all from ITR), Trevor Johnston, Jesse Eyer (both from COM DEV)
ITR was founded in 1994 and, at that time, was one of only two key research concentrations at UniSA. ITR originated from the Digital Communications Group that commenced in the mid-1980s within the School of Electronic Engineering where its research foci were mainly in the areas of modulation and coding, and satellite and mobile communications. Today, as Australia’s largest university based group specialising in wireless communications, fundamental and applied research, proof of concept development and commercialisation activities all play an important part in ITR’s success. Strong national and international relationships and collaborations with the telecommunications business community ensures our work has a high degree of relevance to the problems facing the wireless communications industry.